CHAPTER 5
DENSITY AND DISTRIBUTION

Where are the horses? Where are they dense?
Up in the hills and over the fence?
Eating oat grasses, while ruminants rest
Walking and looking for forage that's best

Climbing the hills to remove what remains.
Back to the flats to graze when it rains.
Plenty of forage and water to drink
Lets horses and cattle cohabit I think

5.1 Introduction

In North America and Australia a variety of interest groups in the community wish to manipulate the density and distribution of feral horses. Pastoralists believe that horses compete with cattle for food and water and generally wish to remove them from areas where they have cattle. Those associated with the horse-meat industry in Australia wish to harvest feral horses on a sustained-yield basis and run them in combination with cattle or separately in areas unsuitable for cattle production. The CCNT recognised the need to test whether feral horses have the potential to compete significantly with cattle or whether there is separation caused by their selection of habitat or diet. One of the objectives in the contract that initiated this study was to identify significant components of habitat of feral horses and the degree of their common usage with cattle. Work conducted to achieve this objective forms the basis of this chapter.

McKnight (1976) described the Australia-wide distribution of feral horses and more recently aerial surveys conducted by the CCNT (1981/1984) determined the distribution and density of feral horses in the Northern Territory. Deserts (lack of surface water), poisonous plants that cause Walkabout or Kimberley disease, and intensive pastoral management appear to limit the Australia-wide distribution of feral horses (McKnight, 1976). Likewise deserts and the more intense management practices on the Barkly Tablelands appear to limit the distribution of feral horses in the Northern Territory (Berman & Jarman, 1987).

Bowman (1985) analysed data from aerial survey of the Alice Springs region (Graham et al., 1986) and found numbers of horses to be generally high in areas of spinifex hills and scrubby hills and low in areas of grassy plains where the majority of cattle occurred. Bowman found high numbers of horses where there are many natural water-holes or dams, whereas cattle appeared to be most common in areas which have artificial watering points (bores and dams). Possible explanations are that horses are more easily trapped or mustered in the absence of natural water-holes; that artificial watering points have been provided in habitats favoured by cattle; cattle displace horses; or that types of watering point vary with another factor which independently correlates with distribution of horses and cattle.

Although horses throughout the world occupy a broad range of habitats from oceanic islands to alpine mountains (Berger, 1986) they are generally considered to be most suited to open grassy plains because they are large, mobile grazers. Do feral horses in the Alice Springs District truly tend to inhabit scrubby or spinifex hills and avoid areas of grassy plains as suggested by Bowman (1985)? The data analysed by Bowman (1985) for the relatively coarse-grained aerial survey of the Alice Springs District were collected over a large area (388,000 km^2), and may not be confidently used to draw conclusions on factors that control distribution and density at the level of the property or paddock where most managers act.

This chapter describes the results of 3 years intensive ground-based data collection on the Hale Plain to determine, and monitor changes in, the distribution and density of feral horses and cattle with respect to water, landform, soil and vegetation. The second section of this chapter describes the property-wide distribution of feral horses on The Garden station in relation to the distribution of cattle, donkeys and rabbits, habitat and distance from water using data from three aerial surveys (March 1986, March 1988 and October 1988). These sections together test the hypothesis that the distribution and density of horses at the property level is affected by one or a combination of the following factors;

a) vegetation, soil and landform,

b) rainfall or grass productivity, and standing crop,

c) availability of surface water,

d) the activity of other herbivores such as cattle, rabbits, donkeys,

e) poisonous plants (*Indigofera linnaei* and *Swainsona* spp.), and

f) mustering or control activities.

Is there potential for competition between horses and cattle in central Australia? Under what conditions might such competition be greatest or least?

5.2 Ground survey of the Hale Plain

5.2.1 Methods

The results presented here refer to transect work done on a 200 km^2 section of The Garden station called the Hale Plain. The distributions of horses and cattle were monitored through regular patrolling of transects, by vehicle along existing roads and fencelines, and on horse-back over rough terrain. Land types (units A to G) based on vegetation, soil and landform were derived from the detailed land-unit classification of Grant (1986). Methods are explained in detail in Chapter 2.

Data were analysed to determine the distributions of horses and cattle with respect to habitat type (land unit) and distance from watering point at different times since rain. The 1984, 1985 and 1986 sample periods had different pasture condition (see Chapter 4). I merged data from the following months to form three sample periods.

Period 1: 1984 (July, August, September and October).

Period 2: 1985 (July, August, October and November).

Period 3: 1986 (September and October).

In period 1 there was sparse, dry pasture containing high quality species (mainly *Enneapogon*) throughout most land units. Very few areas other than the hills of unit B provided stock with high quality pasture species during period 2. In period 3 there was abundant, green perennial grass species (Moderate to Good palatability) and non-grass species resulting from the good 1986 winter rainfall.

5.2.2 Results

a) Density of horses and cattle

Horses: It is important to note here that horses tended to have a clumped distribution. It was common to find the majority of horses along certain transects while other transects were always horseless. Suddenly, or apparently so, herds moved to new locations and were no longer found where they had spent periods up to six months. These moves coincided with and were probably in response to drying or filling of water-holes or dams, depletion or growth of forage, or rainfall.

This clumping of and drastic changes in distribution not surprisingly resulted in large standard deviations, and therefore low precision, of density estimates. The coefficients of variation about estimated density were 270%, 276% and 258% in 1984, 1985 and 1986 respectively. The density data were skewed so normality could not be assumed. For this reason nonparametric statistical methods were employed for comparison of yearly estimates of densities and the densities determined for different land types (units A to G).

For the purposes of analysing data from ground-based transects separate sections of land units visible along transects were defined as sample areas. Combining all sample areas that were searched during the three years work on the Hale Plain, a total of 305 sample areas were searched during transects giving a mean density of 2.89 ±1.10 horses/km^2 (±95% confidence limits). Large numbers of horses and particularly cattle often congregate within 500 m of water, drinking or resting in the shade after drinking. These areas were excluded from calculations of densities when comparing land units.

The overall density of horses on the Hale Plain decreased from 3.54 ±1.99 in 1984 to 1.82 ±1.24 horses/km^2 in 1985, then increased to 3.10 ±2.31 horses/km^2 after the rainfall of winter 1986. Although the differences in density estimates were not statistically significant, other factors (tracks and dung) indicated that there was a real change in overall density during the three years mirroring the changes in mean sample density. Tracks and dung counts indicated that the majority of horses moved to the hills of unit

B outside the area covered by transects during the very dry conditions of 1985.

Cattle: Some cattle were removed from the Hale Plain by the pastoralist on two occasions during the study. The first was early in 1985 and the second early in 1986, explaining the decreases in cattle densities during the study from 8.99 ±3.21 cattle/km^2 in 1984 and 7.88 ±4.06 in 1985 to 4.41 ±4.46 cattle/km^2 in 1986. This change in density was statistically significant (Kruskal-Wallis test; $H=9$, $df=2$, $P<0.01$).

Cattle and horses: The density of horses in 1984 (3.54) and 1985 (1.82) differed significantly from the density of cattle (Mann-Whitney test; $Z=2.36$, $N=184$, $P<0.02$ and $Z=2.66$, $N=130$, $P<0.01$ respectively), but in 1986 there was no significant difference (cattle 4.41, horses 3.10, Mann-Whitney test; $Z=0.41$, $N=98$, $P<0.69$).

b) Association between horses and cattle

Period 1: There were 132 areas sampled during the 1984 period. Both horses and cattle were present in 16 sample areas, horses were present and cattle absent from 18, cattle present and horses absent from 33 and both species absent from the remaining 65 sample areas. Chi-squared analysis indicated that there was no significant association between the species ($\chi^2=1.94$, $df=1$, NS). The C_7 coefficient of association (Cole, 1949) was 0.16 ±0.11 meaning that 16% of the possible positive association was realised but the association between horses and cattle was not statistically significant ($t=1.39$).

Period 2: There were 96 areas sampled during the 1985 period. Both horses and cattle were present in 9 sample areas, horses were present and cattle absent from 9, cattle present and horses absent in 28 and both species absent from the remaining 50 sample areas. Chi-squared analysis indicated that there was no significant association between the species ($\chi^2=1.11$, $df=1$, NS). The C_7 coefficient of association was 0.19 ±0.17 meaning that 19% of the possible positive association was realised, which is not statistically significantly ($t=1.11$) different from random expectation.

Period 3: There were 77 areas sampled during the 1986 period. Both horses and cattle were present in 8 sample areas, horses were present and cattle absent from 13, cattle present and horses absent in 8 and both species absent from the remaining 48

Table 5.1: Densities of horses and cattle (/km^2), population estimates and overlap in distribution (1984, 1985 and 1986 periods combined) for areas at different distance from water.

Distance Category (d)	Area of Hale Plain (km^2)	HORSES Mean density	HORSES SD	CATTLE Mean density	CATTLE SD	Number of sample areas (N)
1) $0<d<=0.5$ km	3.5	7.6	10.8	42.0	53.5	27
2) $0.5<d<=3$ km	98.9	3.9	10.2	10.6	19.3	100
3) $3<d<=6$ km	93.5	2.2	5.9	5.4	11.5	88
4) $d>6$ km	4.1	0.8	3.1	1.3	5.2	18
	% area	number	%	number	%	Overlap
1) $0<d<=0.5$km	2	27	4	147	9	4
2) $0.5<d<=3$km	50	386	62	1048	61	61
3) $3<d<=6$km	47	206	33	505	30	30
4) $d>6$km	2	3	1	5	0	0
		619		1705		95

sample areas. Chi-squared analysis indicated that there was a significant association between the species (χ^2=5.26, df=1, P<0.05). The C_7 coefficient of association was 0.22 ±0.10 meaning that 22% of the possible positive association was realised and is statistically significantly (t=2.29, P<0.05) different from random expectation.

c) Distance from water & overlap with cattle

Combining data from all three sampling periods there was a decline in mean density of horses and cattle as distance from water increased (Table 5.1).

Period 1: In 1984 56% of the cattle population and 74% of the horse population were 3 kilometres or less from permanent water and the percentage overlap in distribution with respect to distance from water was 77% (see Table 5.2).

Period 2: In 1985 the total overlap with respect to distance from water was 60%. Sixty seven percent of horses were using areas further than 3 km from water whereas

Table 5.2: Densities of horses and cattle, population estimates and overlap in distribution (Period 1: 1984) for areas of different distance from water.

1984					
Distance Category (*d*)	HORSES		CATTLE		Sample areas (n)
	Mean density	SD	Mean density	SD	
1) 0<*d*<=0.5 km	4.7	8.4	42.0	49.9	11
2) 0.5<*d*<=3 km	5.0	11.8	9.8	15.6	51
3) 3<*d*<=6 km	2.0	5.2	9.2	15.8	36
4) *d*>6 km	0.0	0.0	0.0	0.0	5
	number	%	number	%	Overlap
1) 0<*d*<=0.5 km	16	2	147	7	2
2) 0.5<*d*<=3 km	496	72	964	49	49
3) 3<*d*<=6 km	182	26	856	44	26
4) *d*>6 km	0	0	0	0	0
	694		1967		77

only 20% of the cattle were in areas further than 3 km (see Table 5.3). It should be noted that signs (dung tracks and grazed pasture) indicated that horses were grazing well outside (greater than 6 km from water) the area covered by transects in land unit B. Most horses seen within 3km of water were moving to or from a watering point on pads (stock trails). The data therefore perhaps underestimate the separation of horse and cattle distribution during this period.

Period 3: During the 1986 sampling period there was 68% overlap. All cattle were found 3 km or less from permanent water (see Table 5.4).

Table 5.3: Densities of horses and cattle, population estimates and overlap in distribution (Period 2: 1985) for areas of different distance from water.

1985					
Distance Category (*d*)	HORSES		CATTLE		Sample areas (n)
	Mean density	SD	Mean density	SD	
1) 0<*d*<=0.5 km	5.8	8.3	46.0	63.8	11
2) 0.5<*d*<=3 km	1.2	4.5	15.6	24.6	22
3) 3<*d*<=6 km	2.4	5.6	4.6	7.0	32
4) *d*>6 km	1.2	3.9	2.1	6.5	11
	number	%	number	%	Overlap (%)
1) 0<*d*<=0.5 km	16	5	124	6	5
2) 0.5<*d*<=3 km	118	35	1505	74	35
3) 3<*d*<=6 km	202	60	380	19	19
4) *d*>6 km	22	7	37	1	1
	336		2046		60

Table 5.4: Densities of horses and cattle, population estimates and overlap in distribution (Period 3: 1986) for areas of different distance from water.

1986					
Distance Category (*d*)	HORSES		CATTLE		Sample areas (n)
	Mean density	SD	Mean density	SD	
1) 0<*d*<=0.5 km	17.9	13.8	33.2	29.9	5
2) 0.5<*d*<=3 km	3.9	9.8	8.0	20.1	27
3) <*d*<=6 km	2.3	5.0	0.0	0.0	20
4) *d*>6 km	0.0	0.0	0.0	0.0	2
	number	%	number	%	Overlap (%)
1) 0<*d*<=0.5 km	63	9	116	13	9
2) 0.5<*d*<=3 km	390	59	791	87	59
3) <*d*<=6 km	212	32	0	0	0
4) *d*>6 km	0	0	0	0	0
	665		907		68

Table 5.5: Densities of horses and cattle (/km^2), population estimates and overlap in distribution (Period 1: 1984) for land units of the Hale Plain.

1984		HORSES		CATTLE		Sample areas (n)
Land Unit	Area (km^2)	Mean density	SD	Mean density	SD	
B	54.4	0.7	1.4	0.0	0.0	5
C	31.0	4.2	7.7	10.5	17.5	27
D	57.0	1.7	3.8	15.2	19.4	24
E	36.4	0.0	0.0	6.9	8.5	9
F	11.4	0.0	0.0	5.4	9.5	16
G	6.2	15.4	20.0	2.8	5.8	11
	Area (%)	number	%	number	%	Overlap (%)
B	27	38	11	0	0	0
C	16	130	36	326	21	21
D	29	97	27	866	57	27
E	18	0	0	251	17	0
F	6	0	0	62	4	0
G	3	96	27	17	1	1
	99	694		1967		49

Table 5.6: Densities (/km^2) of horses and cattle, population estimates and overlap in distribution (Period 2: 1985) for land units of the Hale Plain.

1985	HORSES		CATTLE		Sample areas (n)
Land units	Mean density	SD	Mean density	SD	
B	5.6	9.1	2.5	4.2	4
C	2.6	6.4	10.4	19.5	25
D	0.3	1.4	11.8	19.3	17
E	0.0	0.0	0.0	0.0	3
F	1.3	3.4	1.0	1.9	8
G	1.8	2.4	4.4	5.5	8
	number	%	number	%	Overlap (%)
B	305	71	136	12	12
C	81	19	322	28	19
D	17	4	673	58	4
E	0	0	0	0	0
F	15	4	11	1	1
G	11	3	27	2	2
	428		2046		38

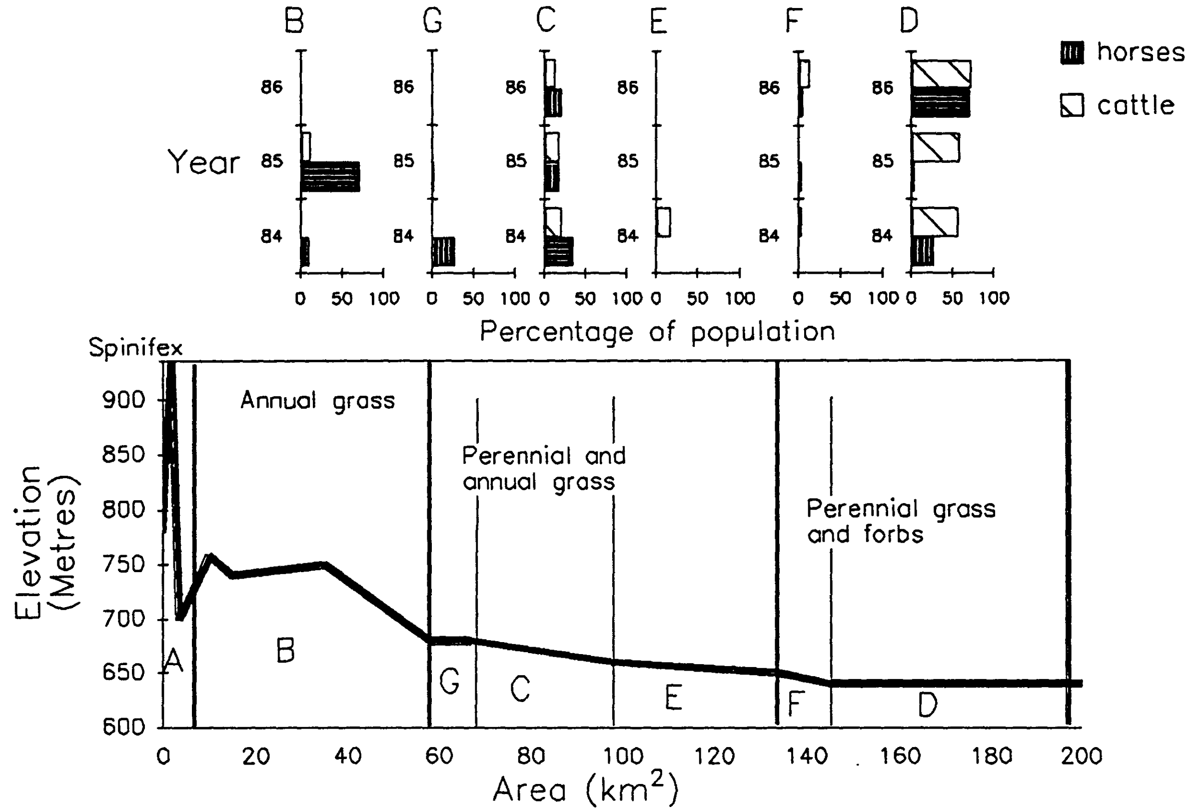

Figure 5.1: Simplified cross section of the Hale Plain showing the cumulative area of each land unit and the density of horses and cattle calculated for each land unit 1984, 1985 and 1986 (Figure 4.3 & Figure 2.9).

d) Land units

Period 1: Sixty three percent of the horse population occupied units C and G, and 57% of cattle used unit D. The total overlap was 49% most of which occurred in units C (21%) and D (27%). Horses but not cattle were using unit G (1% overlap) and cattle were using unit E (0% overlap) (Table 5.5 & Figure 5.1).

Period 2: Seventy one percent and 19% of the horse population occupied unit B and unit C respectively (Table 5.6). Fifty eight percent and 28% of the cattle occupied units D and C respectively. The total overlap was 38% most of which occurred in units

C (19%) and B (12%). All the horses seen in unit B were moving towards or away from water along pads (horse tracks); the majority appeared to be grazing outside the range of transect coverage in unit B (greater than 6 km from water). The data perhaps underestimate the separation between distributions of horses and cattle in 1985.

Period 3: Twenty one percent and 71% of the horse population occupied units C and D respectively. Thirteen percent and 73% of cattle occupied units C and D respectively. The total overlap was 90% most of which occurred in units C (13%) and D (71%) (Table 5.7).

Table 5.7: Densities (/km^2) of horses and cattle, population estimates and overlap in distribution (Period 3: 1986) for land units of the Hale Plain.

1986	HORSES		CATTLE		Sample areas (n)
Land unit	Mean density	SD	Mean density	SD	
B	0.0	0.0	0.0	0.0	4
C	3.7	10.0	1.7	5.4	18
D	6.8	7.7	5.0	12.2	7
E	0.0	0.0	33.3	47.1	3
F	3.0	8.2	4.3	7.7	10
G	1.1	2.7	1.0	2.5	7
	number	%	number	%	Overlap (%)
B	0	0	0	0	0
C	115	21	53	13	13
D	388	71	285	73	71
E	0	0	0	0	0
F	34	6	49	13	6
G	7	1	6	0	0
	665		393		90

Table 5.8: Densities of stock for strata determined for three sampling periods 1984, 1985 and 1986. Presented are mean densities (animals/km^2) for sample areas visible along transect.

Stratum	SAMPLING PERIOD					
	1984 density /km^2		1985 density /km^2		1986 density /km^2	
	CATTLE	HORSES	CATTLE	HORSES	CATTLE	HORSES
B2	0	1	6	21	0	0
B3	0	0	0	1	0	0
B4	0	0	0	0	0	0
C1	74	3	0	0	0	0
C2	9	21	21	0	8	10
C3	12	4	7	4	0	2
C4	0	0	3	2	0	0
D1	30	6	51	10	38	19
D2	15	1	17	1	5	7
D3	16	3	3	0	0	0
D4	0	0	0	0	0	0
E2	6	0	0	0	14	6
E3	9	0	0	0	0	0
E4	0	0	0	0	0	0
F2	8	0	3	0	7	5
F3	0	0	0	3	0	1
G2	3	19	0	0	1	2
G3	2	18	5	2	3	0

Data pooled for transects run in:
Period 1: 1984 July, August, September and October
Period 2: 1985 July, August, October and November
Period 3: 1986 September and October

Distance from water categories:
1) $0<d<=0.5$km, 2) $0.5<d<=3$km, 3) $3<d<=6$km, 4) $d>6$km

e) Land unit and distance from water

Stratification was conducted using both land unit classification and categories of distance from water to produce 18 strata (Table 5.8). The density of stock in these strata determined from transect counts varied from 0 to 74 cattle/km^2 and 0 to 21 horses/km^2 during the three sampling periods. The highest densities of cattle were calculated for areas within 0.5 km of permanent water and for horses from 0.5 to 3 km from water. Density of cattle for strata further than 0.5 km from water varied from 0 to 21 cattle/km^2. The highest density for horses within 0.5 km of water was 19 horses/km^2.

For areas further than 0.5 km from water, strata that carried the highest densities of cattle were C2, D2, and E2 (i.e. Land units C, D and E, 0.5 to 3 km from water). High densities of cattle were also determined for C3 and D3 (i.e. Strata C and D, 3 km to 6 km from water). Areas which carried the highest densities of horses were B2, C2 and G3.

i) Overlap accounting for both water and land unit

Period 1: In 1984 the total overlap was 33%; horses were found mainly in stratum C2 and cattle in stratum D2. The total overlap in 1985 was 29% due to small amounts of common usage of strata D1, B2, D2 and C3.

Period 2: In 1985 69% of the horses were distributed in B2, and 49% of the cattle were in stratum E2 (Table 5.9).

Period 3: The estimated percentage overlap in the distributions of horses and cattle on the Hale Plain was greatest (73%) soon after the winter rain of 1986 (Table 5.9). At this time the majority of horses and cattle were found in strata C, D, and E more than 0.5 km and less than 3 km from permanent water (C2, D2 and E2).

Table 5.9: Estimated percent of populations and overlap in the distributions of cattle (C) and horses (H) in strata (land unit and distance from water[a]) for periods[b] of each year from 1984 to 1986.

	1984			1985			1986		
Stratum	C	H	O'LAP	C	H	O'LAP	C	H	O'LAP
B2	0	1	0	8	69	8	0	0	0
B3	0	0	0	0	1	0	0	0	0
C1	3	0	0	0	0	0	0	0	0
C2	12	64	12	25	0	0	24	31	24
C3	8	6	6	6	13	6	0	4	0
C4	0	0	0	0	1	0	0	0	0
D1	4	2	2	8	14	8	11	6	6
D2	40	7	7	49	6	6	24	41	24
D3	15	5	5	3	0	0	0	0	0
E2	7	0	0	0	0	0	34	14	14
E3	7	0	0	0	0	0	0	0	0
F2	3	0	0	0	0	0	5	3	3
F3	0	0	0	0	5	0	0	1	0
G2	1	9	1	0	0	0	1	1	1
G3	0	6	0	1	1	1	1	0	1
TOTAL OVERLAP			33			29			73

[a] Distance from water categories
1) 0<*d*<=0.5 km, 2) 0.5<*d*<=3 km, 3) 3 <*d*<=6 km, 4) *d*>6 km

[b] Periods of data collection
Period 1: 1984 July, August, September and October
Period 2: 1985 July, August, October and November
Period 3: 1986 September and October

ii) Temporal overlap

The distribution of cattle in 1984 overlapped the 1985 cattle distribution by 66% and the 1985 horse distribution by 18%. This indicates that 66% of cattle used areas previously used by cattle. Sixteen percent of horses and 45% of cattle in 1985 used areas occupied by horses in 1984 (Table 5.10). Table 5.10 shows the overlap of 1984 and 1985 distributions with respect to strata (land unit and distance from water). Table 5.11 shows the overlap of 1984 and 1985 distributions with respect to land unit and distance from water separately.

f) Distribution and overlap: Caution in interpretation

Extreme caution must be used when interpreting the distribution and overlap data. Horses and cattle occupy areas for reasons other than feeding. Transects sampled distributions of horses and cattle only during daylight; both move and feed actively at night. Cattle spend much of the daylight hours resting and ruminating in areas where there is shade, usually near to a watering point. Horses seen in one area may be moving through that area from water to the area of feeding. Both the above situations probably occurred during the study. The occasional high percentage occupancy of unit E by cattle may be a result of their shading under mulga trees which grow there. The cattle may have been using the neighbouring relatively treeless strata (C and G) as feeding areas, possibly at night. Horses were recorded moving through stratum B2 obviously moving between water and stratum B4. Apart from the above examples, the distribution data probably well indicate the relative use of areas by stock for feeding and are a good indication of the degree of overlap between horses and cattle in feeding areas.

Horses and cattle probably influence the distribution of each other; their distributions might have been different if members of the other species were never present during the study. For example 70% of the horse population used unit C during the 1984 period. There was a reduction in the biomass of pasture in unit C from 40 g/m^2 to 16 g/m^2 between the 1984 and 1985 periods probably due mainly to grazing by horses. Only 32% of the population of cattle used unit C during the 1985 period, perhaps many less than if the pasture had been untouched by horses.

Table 5.10: Estimated percent of horse and cattle population in strata (land unit & water[a]) for 1984 and 1985[a]. Overlap in the distributions of horses (H) and cattle (C) in 1985 with 1984.

Stratum	1984		1985		overlap			
	C	H	C	H	CC	CH	HH	HC
B2	0	1	8	69	0	0	1	1
B3	0	0	0	1	0	0	0	0
C1	3	0	0	0	0	0	0	0
C2	12	64	25	0	12	0	0	25
C3	8	6	6	13	6	8	6	6
C4	0	0	0	1	0	0	0	0
D1	4	2	8	14	4	4	2	2
D2	40	7	49	6	40	6	6	7
D3	15	5	3	0	3	0	0	3
E2	7	0	0	0	0	0	0	0
E3	7	0	0	0	0	0	0	0
F2	3	0	0	0	0	0	0	0
F3	0	0	0	5	0	0	0	0
G2	1	9	0	0	1	0	0	0
G3	0	6	1	1	0	0	1	1
TOTAL OVERLAP					66	18	16	45

[a] Distance from water categories
1) 0<d<=0.5 km, 2) 0.5<d<=3 km, 3) 3 <d<=6 km, 4) d>6 km

[b] Periods of data collection
Period 1: 1984 July, August, September and October
Period 2: 1985 July, August, October and November

CC is the percent overlap in the distributions of cattle in 1984 with cattle in 1985
CH is the percent overlap in the distributions of cattle in 1984 with horses in 1985

Table 5.11: The percent of horses (H) and cattle (C) populations in land units and areas of different distance from water for 1984 and 1985, and overlap in the 1984 and 1985 distributions of horses and cattle.

Stratum	1984		1985		OVERLAP			
	C	H	C	H	CC	CH	HH	HC
B	0	1	5	54	0	0	1	1
C	23	70	32	21	23	21	21	32
D	59	14	63	16	59	16	14	14
E	14	0	0	0	0	0	0	0
F	3	0	0	7	0	3	0	0
G	1	15	0	2	0	1	2	0
TOTAL					82	41	38	47
Distance from water Category (d)	1984		1985		OVERLAP			
	C	H	C	H	CC	CH	HH	HC
1 $0<d<=0.5$ km	8	2	8	6	8	6	2	2
2 $0.5<d<=3$ km	62	80	81	63	62	62	63	80
3 $3<d<=6$ km	31	18	10	30	10	30	18	10
4 $d>6$ km	0	0	0	1	0	0	0	0
TOTAL					80	98	83	92

[a] Periods of data collection
1984 July, August, September and October
1985 July, August, October and November

5.3 Aerial surveys of The Garden station

5.3.1 Methods

To determine the distribution and density of horses and cattle and relationships between these and other environmental factors aerial surveys of The Garden station were conducted in March 1986, March 1988 and again in October 1988. The methods are described in detail in Chapter 2. Horses, cattle and donkeys were counted. Each transect segment (25 km^2 map grid cell) was rated (0-3) for 9 habitat types. Cells were classified into 6 habitat groups using the PATN pattern analysis package (Belbin, 1987). Cells were also rated (0-3) on the occurrence of rabbit warrens. The survey area was stratified into 2 areas based on the availability of long-lasting natural watering points. Long-lasting natural watering points are defined as those that provide water for at least 9 months after sufficient rain has fallen to cause rivers to flow (Figure 5.2). Stratum 1 (42 grid cells) had 1, while Stratum 2 (39 grid cells) had 19 long-lasting natural watering points. Figure 4.1 shows that the aerial surveys were conducted during dry periods after rainfall had been consistently below the mean and with no effective summer rain since January 1984. The conditions could probably be best described as drought.

5.3.2 Results

a) Horse abundance and density

Population estimates were generated from counts of groups rather than individuals because they were more precise. The estimated number of horses and mean densities in the survey area (2025 km^2) are shown in Table 5.12. Overall group densities were 0.23, 0.25 and 0.19 groups per km^2, in March 1986, March 1988 and October 1988 respectively. In March 1986 the density of groups in map grid cells (5x5km) ranged from less than 1 to 9.5 groups per km^2 which was greater than in March 1988 (<1 to 6.5 groups/km^2) and in October 1988 (<1 to 4.3 groups/km^2).

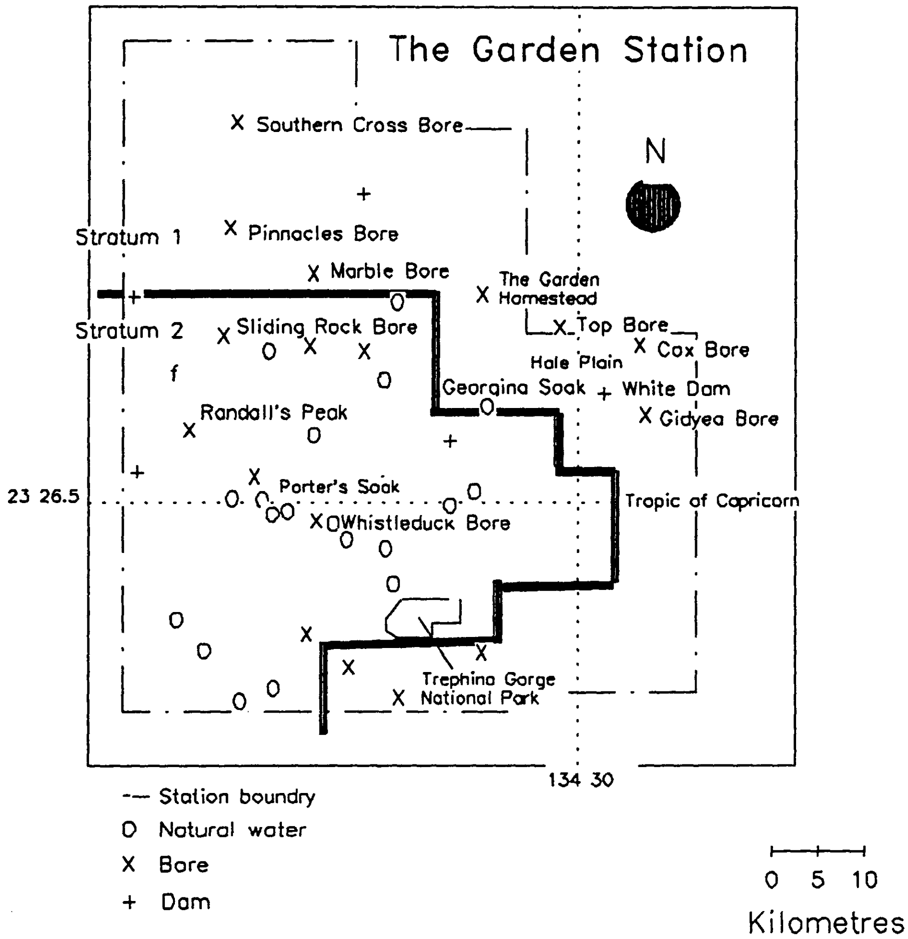

Figure 5.2: Watering points (artificial and long-lasting natural) on The Garden station and the strata for the aerial surveys (Stratum 1: few natural waters & Stratum 2: many natural waters) defined by the thick line.

Table 5.12: Estimates from aerial survey of horse densities and numbers for The Garden station.

Survey	Group Count	Estimated population of groups	Group size Mean±95%CL	Density horses/ km^2	Number of horses ±95%CI
1986 Mar	53	474	5.08±1.0	1.17	2497±892
1988 Mar	52	500	3.47±0.6	0.87	1732±330
1988 Oct	39	385	3.52±0.8	0.67	1355±206*
* very windy and uncomfortable for observers					

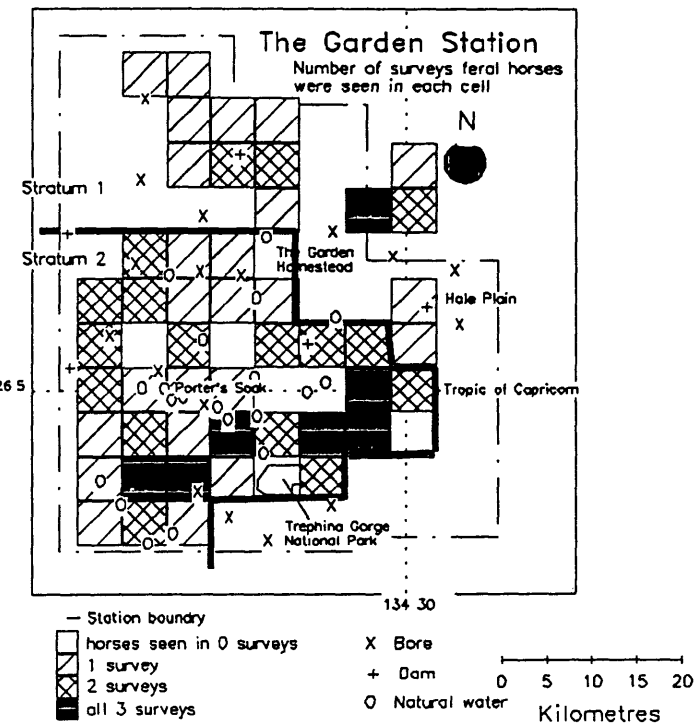

Figure 5.3 The number of surveys that horses were seen in each grid cell for 3 surveys of The Garden (Mar 86, 88 & Oct 88). The stratum boundary is indicated by the thick lines.

b) Horse distribution

Generally the highest numbers of horses occurred in the south western to middle areas of the property. Stratum 2 contained the majority of horses. Horses were recorded in 71% of cells in Stratum 2 although it is 52% of the area surveyed. Some horses occurred in Stratum 1 just (5 to 15 km) north-east, north-west and south-east of the Garden Homestead. Horses were not observed near Pinnacles Bore, in the vicinity of the homestead, nor within and south to south-east of the Trephina Gorge National Park (Figure 5.3).

In only 7 (9%) of the 81 cells were horses observed during all three surveys (Figure 5.3). For 24 (30%) cells horses were observed during one survey only and in 17 (21%) cells horses were observed twice leaving 33 (41%) cells with no observations of horses recorded during the three surveys.

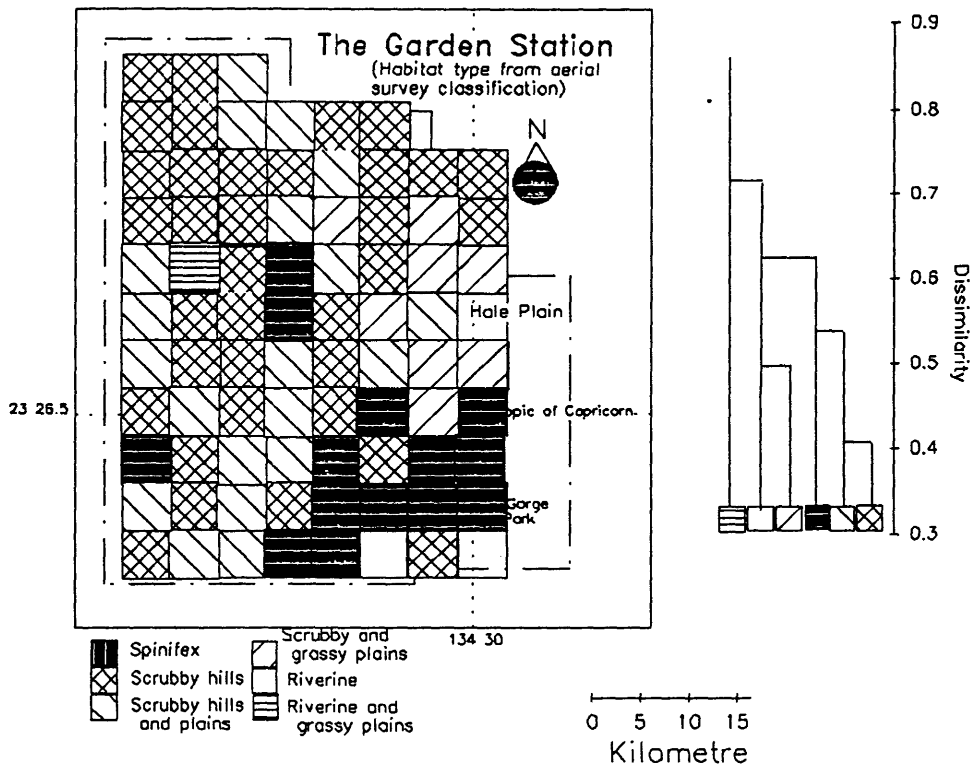

Figure 5.4 Cluster analysis grouped cells into 7 habitat classes based on rating for amount of hills, trees or shrubs, and spinifex during the aerial survey of 1986.

c) Habitat and Water

During the survey each transect segment (map grid cell) was rated for 9 habitat types. There was considerable cross-correlation between the habitat types. Grassy plains were negatively correlated with scrubby hills and positively correlated with riverine. Scrubby hills were negatively correlated with grassy plains, spinifex hills, scrubby plains, riverine and gibber while scrubby plains were positively correlated with gibber. Cells were classified into 6 habitat classes (see Figure 5.4) using PATN pattern analysis package (Belbin, 1987) in an attempt to increase the efficiency of analyses by reducing the number of habitat attributes. Due to a lack of relationship between horses and the habitat classes, raw habitat data were used in correlation analyses.

Table 5.13: Characteristics of strata for aerial surveys of The Garden station and results of comparison using Chi-square analysis.

Habitat Class in cell	Number of cells in		Results of statistical comparison
	Stratum 1	Stratum 2	
Spinifex	4	10	Chi-square = 9.4 df = 3 P=0.03, Significant
Scrubby hills	20	15	
Scrubby hills and plains	6	14	
*Scrubby and grassy plains	6	2	
*Riverine	3	0	
*Riverine and grassy plains	0	1	
Totals	39	42	
Water type in cell			
Bores	9	7	Chi-square = 12.1 df = 2 P<0.002, Significant
Dams	3	3	
Natural waterholes	1	19	
Totals	13	29	
* lumped for analyses due to low occurrence			

The strata differed significantly in the proportion of cells of the major habitat classes and watering-point type (see Table 5.13).

d) Factors associated with horse distribution

i) All three surveys combined

Presence or absence of horses in cells: Table 5.14 shows that the presence or absence of horses within cells appears to be independent of habitat group but dependent on the type of watering-point. Stratum 1, in which there are no important natural watering-points, differed from stratum 2 in the number of cells with horses present (34/42 to 14/39).

Table 5.14: Characteristics of cells where horses were observed at least once or not at all during the three aerial surveys of The Garden station.

Habitat Class in cell	Frequency of observation of horses in cells		Results of statistical comparison
	Never	More than once	
Spinifex	7	7	Chi-square=2.9 df=3 P=0.41, NS
Scrubby hills	16	19	
Scrubby hills and plains	5	15	
*Scrubby and grassy plains	3	5	
*Riverine	2	1	
*Riverine and grassy plains	0	1	
Totals	33	48	
Water type in cell	Never	More than once	
Bores	7	7	Chi-square=8.1 df=2 P=0.02, Significant
*Dams	0	3	
*Natural waterholes	3	12	
Trap, no natural waterhole	4	1	
Totals	14	23	
* lumped for analyses due to low occurrence			

Correlations: There was a negative correlation between the number of horse groups counted per cell and the distance from trap yards (Table 5.15). The number of horse groups per cell was not correlated with donkeys, cattle, rabbits, distance from drinking water nor any of the unclassified habitat ratings (Table 5.15). Trap yards were negatively associated with grassy plains and gibber but possitively associated with scrubby hills (Table 5.15). Rabbits were positively associated with grassy and scrubby plains but negatively associated with spinifex hills (Table 5.15).

Table 5.15: Linear correlation results for environmental variables and horses, cattle, donkeys and rabbit warrens recorded during 3 aerial surveys (Mar 86, Mar & Oct 88) of The Garden station.

Environment Variables	Distance to trap	Distance to water	Horses (number of groups per cell)	Cattle	Donkeys	Rabbit warrens (per cell)
Distance to trap	-	-0.14	**0.34*** **	-0.09	0.14	-0.05
Distance to water	-	-	-0.04	-0.07	0.05	-0.09
Horses	-	-	-	-0.04	0.09	-0.02
Cattle	-	-	-	-	-0.02	0.09
Donkeys	-	-	-	-	-	-0.11
Grassy plains	**-0.19** **	-0.05	0.01	0.03	-0.06	**0.21** **
Spinifex hills	0.04	0.08	-0.05	-0.12	0.10	**-0.20** **
Scrubby plains	0.02	-0.04	0.14	-0.01	**0.17* **	**0.24*** **
Scrubby hills	**0.22** **	-0.05	0.06	0.04	**-0.15* **	0.04
Riverine	0.05	-0.13	-0.10	-0.02	-0.10	0.07
Gibber	**-0.19** **	-0.08	-0.11	0.13	0.03	0.09
*P<0.05, **P<0.01, ***P<0.001, n=243 (the number of 25 km^2 cells)						

Multiple regression: Fourteen percent of the variability in the number of horse groups per cell (i.e. R^2=0.14) can be attributed to a correlation with the rating for scrubby plains, riverine, and the distance from a trap (F=13.78, df_{reg}=3, df_{res}=239, P<0.001). All other habitat types, cattle, donkeys, and distance from water had very little relationship with the number of horse groups per cell.

ii) March 1986

Rainfall: Little significant rain had fallen since January 1984, 26 months before this survey, and the property had been declared drought-affected by the DPP (DPI&F).

Correlations: Horses were not correlated with any of the habitat ratings nor was there any significant association between horses and cattle, donkeys or rabbits (Table 5.16). There was, however, a positive correlation between horses and distance

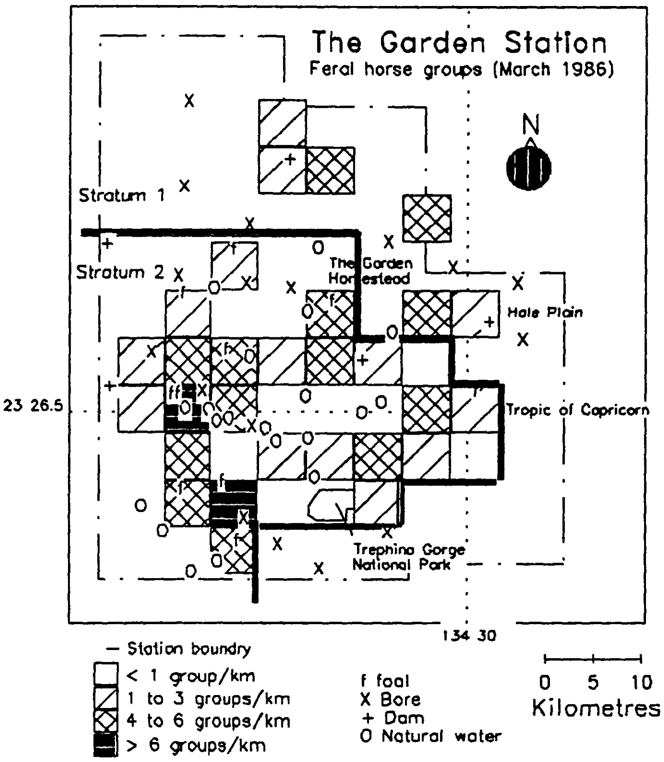

Figure 5.5 Distribution of group density determined by aerial survey of The Garden station March 1986. The location of groups with foals, watering-points and the stratum boundary are indicated.

from traps. Donkeys, too, were positively correlated with distance from traps (Table 5.16).

Multiple regression: Fifteen percent of the variability in the number of horse groups per cell can be attributed to a correlation with the rating for scrubby plains and the distance from traps ($F=6.9$, $df_{reg}=2$, $df_{res}=78$, $P<0.01$). All other habitat types, cattle, donkeys, and distance from water had very little relationship with the number of horse groups per cell.

Trapping: Horses were trapped in 1985 at Marble, Pinnacles and Southern Cross Bores (Stratum 1) and Sliding Rock Bore (Stratum 2) (Figure 5.2).

Group density: Figure 5.5 shows the distribution of horse group density determined

Table 5.16: Linear correlation results for environmental variables and horses, cattle, donkeys and rabbit warrens recorded during the aerial survey of The Garden station in March 1986.

Environment Variables	Horses	Cattle	Donkeys	Rabbit warrens (per cell)
	(number of groups per cell)			
Distance to trap	**0.35****	0.15	**0.26***	-0.05
Distance to water	-0.16	-0.05	0.08	-0.09
Horses	-	-0.10	0.06	-0.05
Cattle	-	-	-0.05	0.01
Donkeys	-	-	-	-0.14
Grassy plains	-0.03	-0.03	-0.06	0.21
Spinifex hills	-0.09	-0.08	0.11	-0.18
Scrubby plains	0.18	-0.04	0.17	**0.23***
Scrubby hills	0.16	0.05	-0.18	0.02
Riverine	-0.10	0.11	-0.07	0.07
Gibber	-0.11	0.08	-0.05	0.09

*P<0.05, **P<0.01, ***P<0.001, n=81 (the number of 25 km² cells)

by aerial survey in March 1986. The highest densities and the greatest number of groups with foals were in the south-western part of the property in the Porter's Well area.

iii) March 1988

Rainfall: Apart from some early summer rain (most of the value of which had disappeared during the hot and dry January and February) little rain had fallen since July 1986, 19 months before. Drought conditions prevailed up until 3 weeks prior to the survey when 40 mm of rain fell, filling all ephemeral water-holes.

Correlations: As for the survey of 1986 (2 years previously) horse groups were positively correlated with distance from traps and there was no correlation between horses, habitat, cattle or rabbits (Table 5.17). Unlike 1986 donkeys and horses were

Table 5.17: Linear correlation results for environmental variables and horses, cattle, donkeys and rabbit warrens recorded during the aerial survey of The Garden station in March 1988.

Environment Variables	Horses	Cattle	Donkeys	Rabbit warrens (per cell)
	(number of groups per cell)			
Distance to trap	**0.34****	-0.20	0.08	-0.05
Distance to water	-0.02	-0.13	0.07	-0.09
Horses	-	-0.19	**0.32****	-0.10
Cattle	-	-	-0.09	**0.32****
Donkeys	-	-	-	-0.14
Grassy plains	-0.01	-0.05	-0.05	0.21
Spinifex hills	-0.03	-0.16	0.19	-0.21
Scrubby plains	0.12	-0.04	0.21	**0.24***
Scrubby hills	-0.04	0.12	-0.04	0.05
Riverine	-0.12	-0.09	-0.11	0.08
Gibber	-0.11	0.12	-0.04	0.09

*P<0.05, **P<0.01, ***P<0.001, n=81 (the number of 25 km^2 cells)

positively correlated (Table 5.16 & Table 5.17) . Cattle and rabbits were positively associated (Table 5.17).

Multiple regression: Nineteen percent of the variability in the number of horse groups per cell can be attributed to a correlation with the number of donkey groups (7%) in a cell and the distance from a trap ($F=9.7$, $df_{reg}=2$, $df_{res}=78$, $P<0.001$). All other habitat types, cattle, and distance from water had very little relationship with the number of horse groups per cell.

Mustering or trapping: Horses were trapped in 1986 at Marble, Pinnacles and Southern Cross, Top, Cox and Gidyea Bores and White Dam, in stratum 1. Trapping also occurred at Sliding Rock, Randalls Peak and Whistleduck Bores in stratum 2, although there were alternative watering points available.

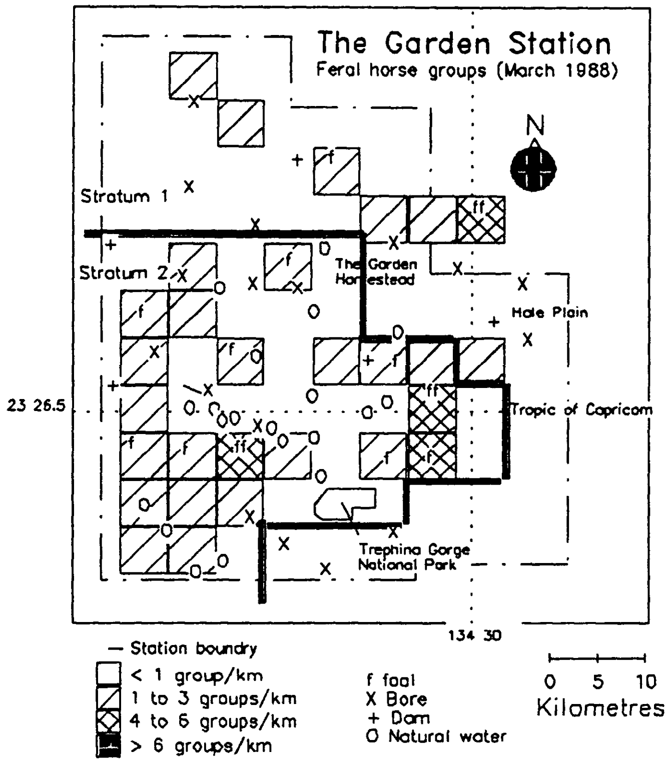

Figure 5.6 Distribution of group density determined by aerial survey of The Garden station in March 1988. The location of groups with foals, watering-points and the stratum boundary are indicated.

Group density: Figure 5.6 shows the distribution of horse group density determined by aerial survey in March 1988. Unlike March 1986 there were no cells with densities greater than 6 groups per km^2. There appears to have been a reduction in group density in the Randall's Peak and Porter's Well areas. Trapping at Randall's Peak may have accounted for the reduction in that area. The groups appear to have spread out, particularly in the south-western corner of the property (Figure 5.6 cf. Figure 5.5). Rain just prior to the survey may have allowed horses to spread out into areas which are normally too far from drinking water.

iv) October 1988

Rainfall: As for the two previous surveys drought conditions prevailed with 27 months having elapsed since the last significant above-average rainfall event and almost 5 years since the last substantial summer rainfall event.

Table 5.18: Linear correlation results for environmental variables and horses, cattle, donkeys and rabbit warrens recorded during the aerial survey of The Garden station in October 1988.

Environment Variables	Horses	Cattle	Donkeys	Rabbit warrens (per cell)
	(number of groups per cell)			
Distance to trap	**0.32****	-0.20	0.11	-0.05
Distance to water	0.10	-0.01	0.02	-0.09
Horses	-	**0.28****	0.12	0.11
Cattle	-	-	0.08	0.13
Donkeys	-	-	-	-0.15
Grassy plains	0.08	0.19	-0.07	0.21
Spinifex hills	-0.01	-0.11	0.01	-0.21
Scrubby plains	0.10	0.05	0.13	**0.24***
Scrubby hills	0.08	-0.06	**-0.22***	0.05
Riverine	-0.07	-0.08	-0.12	0.08
Gibber	-0.10	0.19	0.16	0.09

*P<0.05, **P<0.01, ***P<0.001, n=81 (the number of 25 km^2 cells)

Correlations: Again, for the third survey in succession horses were positively correlated with distance from a trap (Table 5.16, Table 5.17 & Table 5.18). Introduction of cattle to the Porter's Well area by the pastoralist caused a positive correlation between horses and cattle.

Multiple regression: Twenty two percent of the variability in the number of horse groups per cell can be attributed to a correlation with the number of cattle groups per cell and the distance from a trap ($F=11.4$, $df_{reg}=2$, $df_{res}=78$, $P<0.001$). Habitat types, donkeys, and distance from water had very little relationship with the number of horse groups per cell.

Trapping: No trapping occurred between March 1988 and October 1988.

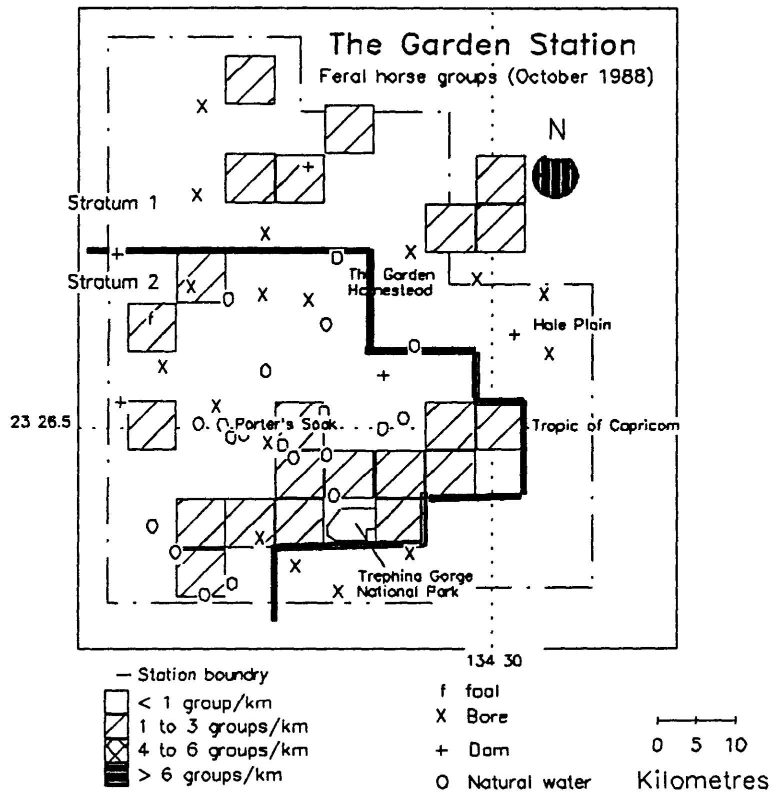

Figure 5.7 Distribution of group density determined by aerial survey of The Garden station October 1988. The location of groups with foals, watering-points and the stratum boundary are indicated.

Group density: Figure 5.7 shows the distribution of horse group density determined by aerial survey of The Garden station in October 1988. Unlike the surveys in 1986 and March 1988 no cells had greater than 4 groups per km^2. There appears to have been an overall reduction in group density and a population shift from the west and south-western areas to the south or south-eastern part of Stratum 2 from 1986 to October 1988 (Figure 5.7 cf. Figure 5.5 & Figure 5.6). There were a low number of groups with foals recorded in October 1988 probably because the foaling season had just commenced. Surveys conducted in March are more likely to detect foals since the foaling season usually runs from September to January and foals would still be small enough to identify.

5.4 Discussion

5.4.1 Survey from the Ground

a) Changes in Distribution: Rainfall and Pasture

During the study the distributions of horses and cattle on the Hale Plain changed in a way that appears to be explicable in terms of rainfall, pasture growth and grazing. Rainfall in the summer of 1983/84 (see Figure 4.1) produced most of the pasture growth used by stock during the ground-based study period (see Chapter 4). When systematic ground-based transects were started in June 1984 there was still apparently abundant pasture everywhere for horses and cattle, and both species were found on the gilgaied plains (unit G) and terraces (unit C) within 3 km of permanent water. During the period from August to September 1984 the mean distance from water for horses was 2.9 km and for cattle 2.7 km. By December 1984 most of the palatable grasses had been grazed down on the terraces and gilgaied plains, and cattle used the river flats (unit D) more intensively while horses moved into the rugged hills (unit B). Both were still using pasture within 3 km of permanent water (70% of cattle and 82% of horses).

The cooler weather of winter months of 1985 allowed both horses and cattle to graze further from water. Horses were seen up to 6.9 km from water in the hills (unit B) and cattle 7.2 km on the flats (unit D) and terraces (unit C). The mean distances were for cattle 2.4 km and horses 5.5 km. As temperatures rose at the end of winter 1985 the distance travelled from water was restricted by the need to drink more frequently, and cattle began to use the hills (unit B) within 3 km of water. Horses grazed further and further into the hills (unit B) walking more than 8 km from water. Both species declined in condition.

Spring rains allowed germination and growth of many palatable grasses on the river flats (unit D), and gilgaied plains (units G and F) (Chapter 4). Horses and cattle quickly took advantage of puddles for drinking water, and grazed in areas normally out of reach of water. As the puddles dried, stock returned to the pasture close to permanent water to graze on the new growth of grasses. By autumn 1986 most of the useful pasture close to water had been removed and stock were forced once again to graze in the hills. Horses were observed up to 15 km and cattle up to 10 km from permanent water.

Germination of forbs and vigorous growth of perennial grasses occurred after the rainfall of winter 1986 (Chapter 4). Horses and cattle responded by returning from the distant hills to the flats close to permanent water (mean distances from water were 1.4 km for horses and 1.1 km for cattle). The overlap with respect to distance from water was 95 percent.

The ranges of horses and cattle overlapped almost completely if the whole cycle was considered, although for much of the time the two species were largely separated by their choices of habitat. When pasture is growing, or at least still green, both species seem to prefer to feed on flat country close to water (stratal overlap was 73%). Once growth has ceased, and as food becomes scarce close to water, the horses move back into the rugged hills (stratal overlap was 33%). With further drying off of pasture cattle, too, are forced back into the hills following the horses. Since horses withdraw from the flat country and the vicinity of permanent water before cattle, the latter are moving into areas already grazed by horses as they are forced to seek pasture away from water. It has yet to be shown that the previous grazing and trampling by horses has a detrimental effect on food availability for cattle. However, considering that cattle have a broader diet than horses and that they eat similar species (see Chapter 4), it is probably safe to assume that horses remove forage which would otherwise have been valuable to cattle. In Chapter 10 I discuss further the possibility of ecological competition.

b) Overlap and Components of Habitat

The degree of overlap in the distributions of horses and cattle changed considerably during the study from 73 percent soon after good rainfall to 29 percent after 22 months with very little rain. Where there had been no recent trapping or mustering the components of habitat that appeared to determine significant components of habitat which determined the distributions of horses and cattle were:

. distance from drinking water,

. relative abundance of annual and palatable perennial grasses,

. topography or relief, and

. perhaps the previous distribution of other stock.

The level of association between horses and cattle was not significant for much of the study period because horses used the annual pasture of the hills and terraces more distant from water while the cattle used the river flats and other perennial pasture close to water. The degree of influence of horse and cattle distributions on each other is not known but it is likely that the horses would have spent a longer period close to water had there been no cattle and cattle might have used the annual pasture of the terraces to a greater extent if horses had not already been there. The removal of pasture from the hills by horses reduced the drought reserve of cattle which they sought after exhausting the pasture on the flat land. Cattle might have used the hills earlier had there been no horses present.

5.4.2 From the Air

It took 4 hours flying for each of three surveys of feral horses, cattle, and donkeys on The Garden station. The three surveys provided valuable information about the density and distribution of feral horses at the level of the central Australian property and indicated that the absence of feral horses was associated with the presence of trap yards where there are no alternative natural watering points. In these areas horses can be trapped as they come to drink. In areas that have many natural watering points horses can avoid being trapped and occur in high densities. This pattern appears to be true for the Alice Springs District as a whole, according to Bowman's (1985) finding that horses were in highest numbers where there are natural water-holes or dams.

Analyses of the aerial survey data failed to show any relationship between horse distribution and habitat type. The predominance of hilly country may have clouded any relationship or the coarseness of sampling of habitat types may have not allowed accurate enough pairing of horses and habitat. The cells were 25 km^2; within these areas there are many vegetation types and landforms.

5.5 Conclusion

For the 3 years prior to mustering and trapping the density and distribution of horses on the Hale Plane was influenced by a combination of distance from drinking water, vegetation, soil and landform, rainfall, and perhaps the previous distribution of cattle. When forage was abundant close to drinking water highest densities of horses and cattle were found there. During dry times horses moved to the hills, distant from water, sooner than cattle.

Horses were generally absent from areas near trap yards at the time of the aerial surveys indicating that human activity influences horse distribution and density at the property-wide level.

Horses and cattle can both tolerate a broad range of habitats. Both show preferences for particular habitat types but in time virtually all habitats are used by both species. Horses and cattle can separate from each other in the short term by choice of habitat but in the long term must inevitably use habitat that has been or is being used by the other species. Areas having the greatest diversity of vegetation, landform and distance from water (relatively few watering points) would permit the greatest separation of horses and cattle and perhaps the least competition. Flat areas with many watering points may support the greatest ovelap (in diet and distribution) between horses and cattle.

In the absence of substantial human determination of the species' distributions, flat areas with predominantly perennial pasture and frequent watering points appear more suited to cattle than horses, whereas hilly areas growing predominantly annual pasture appear better suited to horses than cattle. Both horses and cattle can inhabit flat or hilly country but would probably do better in all habitats without the presence of the other species.

CHAPTER 6
SOCIAL ORGANISATION

The stallion stood still between me and his harem.
He put his ears back and his head down to scare 'em,
To keep'm together, away from a threat.
One mare is pregnant the other's not yet.

The stallion was poor, a bachelor (fatter),
A squeal and a clatter, attempted to scatter,
The harem, he stole a mare and a foal.
Two years of drought had taken their toll.

6.1 Introduction

Klingel (1972) described two basic patterns of social organisation for equids (see section 1.3 for details). Consequently a "solid line" has been drawn between territorial equids with stable breeding-group structures (e.g. horses) and non-territorial equids with unstable groups (e.g. asses). More recently studies of feral horses and asses have indicated the "solid line" between the two types of equids should not be so solid. Feral horse breeding-groups show varying degrees of stability. Also some feral horses defend territories (Rubenstein, 1981). In one case asses were observed to form stable breeding-groups (McCort, 1979) and in another they rarely defended territories (Woodward, 1979). Are territorial equids really so different to non-territorial equids? Are these two factors, territoriality and the permanence of bonding between adults, important enough to draw a "solid line" through the equids?

Hoffmann (1983) conducted a 2-month study of feral horses in central Australia and concluded that their social organisation differs from the generally accepted "normal" pattern of wild horse social organisation. The "social organisation....shows more similarities to the adjacent ass population and other ass populations than to the social organisation of any other horse population" (Hoffmann, 1983). Hoffmann believed the breeding-group composition to be generally unstable and reported the occurrence of more than one adult male in breeding-groups. Given the great variation displayed by equids elsewhere in the world Hoffman's findings are not surprising, but just how different are central Australian feral horses? Does unpredictable amount and timing of rainfall

rainfall cause horses in central Australia to abandon their "normal" system of stable social groups? Can they be placed on the other side of Klingel's "solid line" as Hoffmann (1983) implied?

In this chapter I attempt to answer some of the above questions by first describing the social organisation of feral horses on The Garden station. Secondly, I try to identify factors that influence distribution, composition and size of feral horse social groups in central Australia.

6.2 Methods

Information from ground-based transects provides the basis for this chapter. Limited data were also collected from radio tracking and identification of individual horses on the Hale Plain. Further information was derived from more intensive radio-tracking and water-hole observations conducted in the Porter's Well area (Dobbie & Berman, 1990). Methods are described in detail in Chapter 2 and the report by Dobbie and Berman (1990).

The group was defined as 1 or more horses feeding or moving together in a coordinated fashion. Members of groups were usually within 20 m of each other when grazing and came closer together (<2 m) when disturbed. Individuals approaching members of other groups too closely were either rounded up and retrieved by their dominant stallion or were driven away by the dominant stallion of the other group. Horses were nearly always seen in clearly separated groups. Only occasional temporary difficulties in defining a group arose when adult males closely followed groups to which they did not belong. That was resolved when the dominant stallion was seen to act aggressively towards them trying to keep them away from the group.

a) Radio-tracking

Upon determining the radio-location of the study animals, the horses were periodically located on foot and directly observed for varying lengths of time. Chapter 3 and Dobbie and Berman (1990) give details. A receiver and hand-held yagi antenna enabled the observer to locate collared horses and record their behaviour and social group structures. Features of individual members in each group were recorded to aid identification. Characteristics recorded were: age class, sex, colour, facial and leg markings.

b) Transects and observations at water-holes

The method used to immobilise horses involved waiting in ambush at watering points for horses to come to drink. Observations made by me at different water-holes while waiting to dart horses and while conducting transects on the Hale Plain indicated differences in the use of different watering points by different types of social groups. In this chapter I have analysed the Hale Plain transect data and presented data collected by Dobbie in the Porter's Well study area (Dobbie & Berman, 1990). To compare the social structures of horse groups using different watering points.

I compared 4 watering points (3 permanent and 1 almost permanent) with different land units available to horses drinking at them and Dobbie (Dobbie & Berman, 1990) made observations at three water-holes in succession to enable comparisons between permanent and temporary water-sources. Each water-hole was observed by Dobbie for a continuous 36 hour period (two nights and one day). Horse groups were recorded as they came in to water. Group size, plus sex and age structures were of particular interest for this Chapter. The work was performed in mid-September, 1989.

Dobbie collected water samples from 10 watering points in the Porter's Well study area. Chemical and microbiological analyses were performed to investigate the influence of water quality upon horse distribution and watering preferences (Dobbie & Berman 1990). Chemical analyses were performed by Amdel Ltd., Berrimah, and microbiological analyses by Power and Water Authority, Alice Springs. Both agencies conduct analyses in accordance with "Standard Methods for the Examination of Water and Wastewater - 14th Ed." (Rand et al., 1975).

Chemical parameters examined were: pH, electrical conductivity, total dissolved solids, total suspended solids, hardness (calculated as $CaCo_3$), Ca, Mg, Na, K, Cl, Total alkalinity, CO_3, HCO_3, NO_3, SO_4, turbidity, fluoride, silica, and total iron (with calculated cation/anion balance).

Microbiological analyses of water samples were conducted to assess the degree of contamination from animal sources and its influence upon horse distribution. Indicator organisms rather than pathogens were examined, as is common practice. The coliform group of bacteria are the principal indicators. Microbiological parameters examined were: total coliform concentration, *E. coli* concentration, faecal *streptococci* concentration, and plate count organisms (37°C).

6.3 Results

6.3.1 Social goups

Feral horses on The Garden station were observed in 2 main types of structured social group. There were groups containing 1 or more adult females which have in other parts of the world been called **harem** groups, bands, family or breeding groups. There were also "non-breeding" groups called **bachelor groups** consisting of all males.

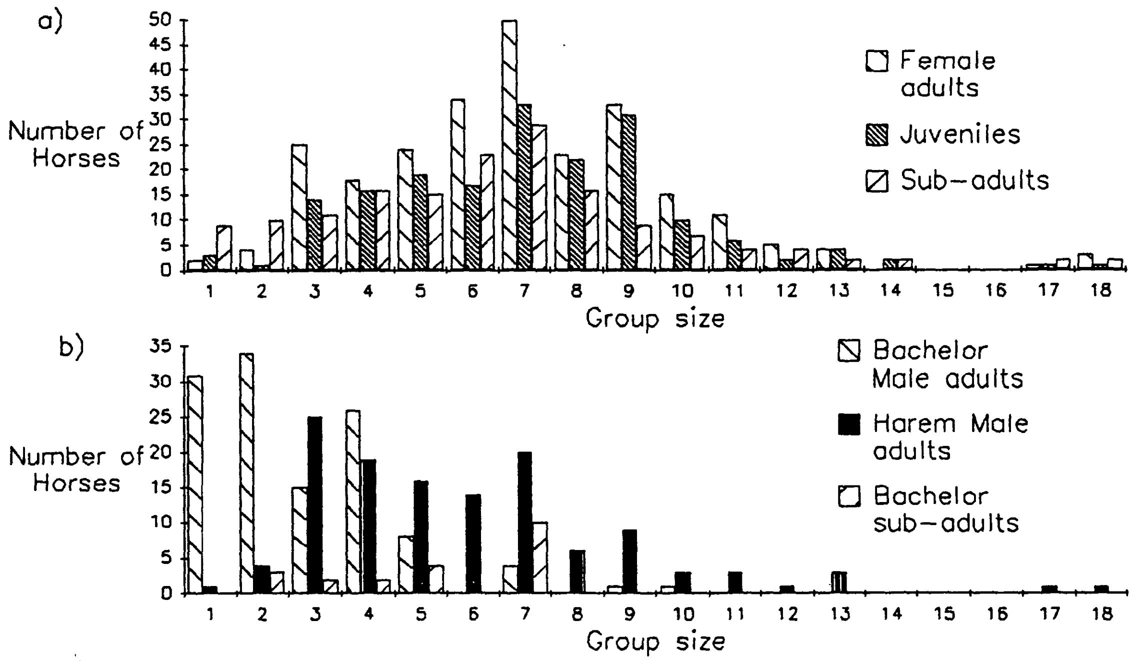

Figure 6.1: a) Number of female adult, sub-adult, juvenile and b) male adult horses recorded in bachelor and harem groups of various sizes. All transect data collected from 1984 to 1986 on the Hale Plain were pooled.

Figure 6.1 shows the numbers of individuals of different age and sex classes seen in harem and bachelor groups of different sizes. The frequency distributions for female adults and harem male adults differed significantly (Kolmogorov-Smirnov test; D=0.21, $N_♀$ =259, $N_♂$ =124, P=0.0009) and so did that for harem male adults and bachelor male adults (Kolmogorov-Smirnov test; D=0.49, $N_{Bach.}$=122, N_{Harem}=124, P<0.00001). Female adults were, more likely to experience a greater number of horses in their groups than were male adults, particularly bachelor male adults.

a) Harem groups

Harem groups are defined here as groups with 1 or more adult female. The harem group usually (94% out of n=96 harems) consisted of one adult male, mares and their offspring. Occasionally 2 or 3 adult males were present in a harem (4 and 2% of 96 harems respectively). The mean (±SD) size of 90 harems with only 1 male adult was 5.8±2.4. For harems with only one stallion the mean number of individuals ranged from 6.6±2.2 in autumn 1985 to 4.3±1.5 in spring 1986. However, there was no significant change in size of these groups according to Kruskal-Wallis non-parametric one-way AOV (P=0.14). The Mann-Whitney test indicated that there was a decrease in size from spring 1985 to spring 1986 (P=0.01).

Jarman (1974) believed the typical group size to be a better measure of the average animal's experience within its group than is the mean. The typical group size (single stallion harems) calculated for each 3 month season decreased in a linear fashion (Figure 6.2) from spring 1984 to spring 1986 (r=-0.95, df=5, P<0.002). The typical number of female adults in single stallion harems also decreased significantly (Figure 6.3) (r=-0.80, df=5, P<0.05) from spring 1984 to spring 1986 but typical numbers of sub-adult and juveniles did not (r=-0.59 and r=-0.53 respectively) (Figure 6.4 & Figure 6.5). This suggests that decrease in typical harem group size during the study resulted from a reduction in the number of female adults per group. There may have been a corresponding reduction in sub-adults and juveniles per group but this was clouded by seasonal fluctuation.

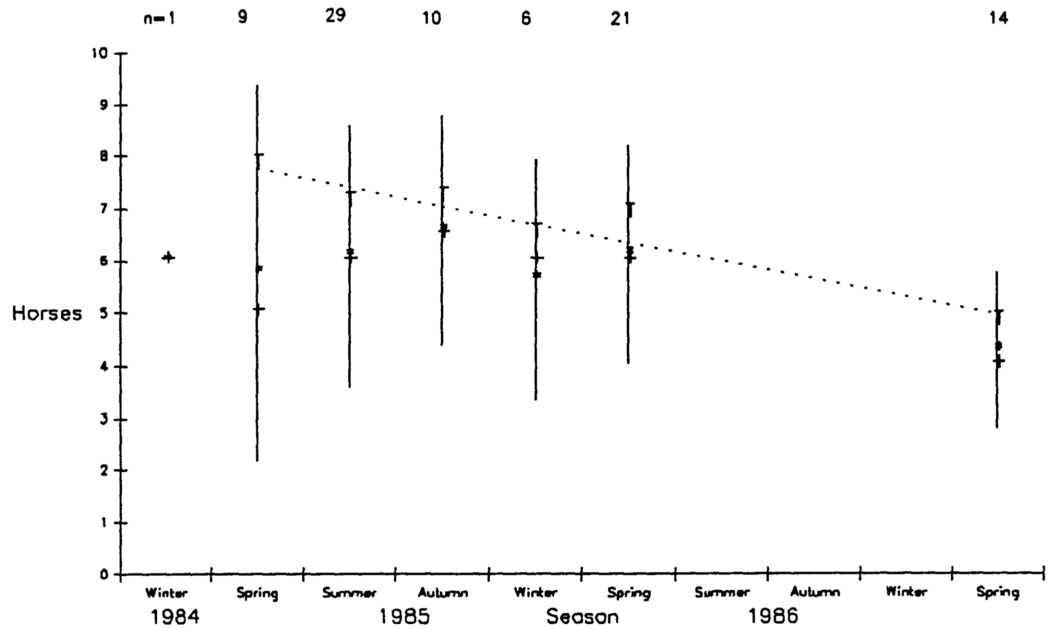

Figure 6.2: Typical (T), mean (*), ±SD (vertical lines) and median (+) size for harem groups with only one adult male seen along transects on the Hale Plain. The line of best fit is drawn through the typical group sizes.

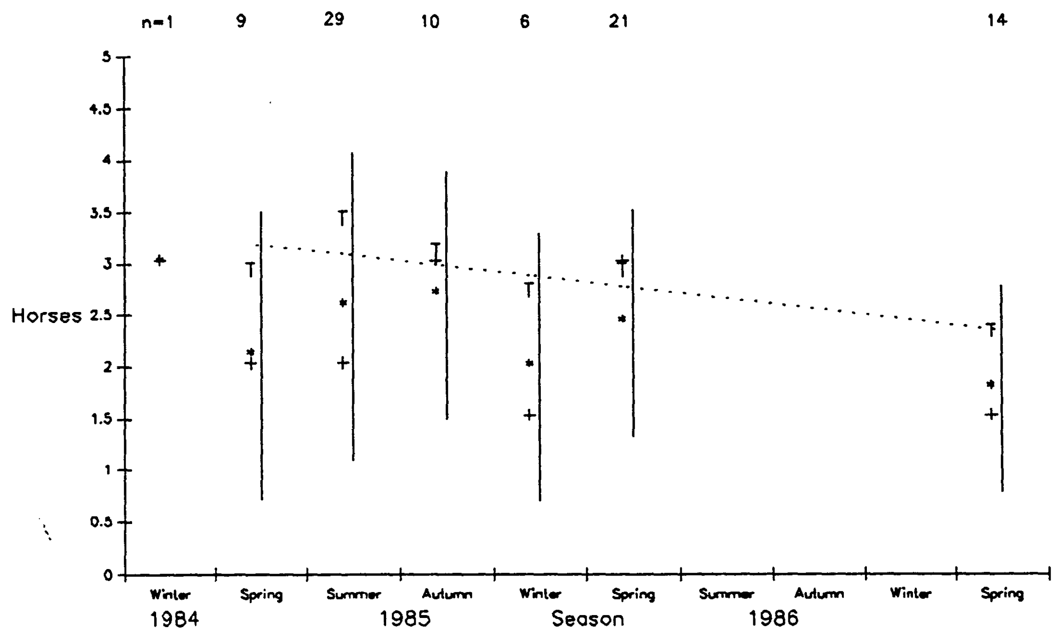

Figure 6.3: Typical (T), mean (*), ±SD (vertical lines) and median (+) size for harems (female adults) in groups with only one adult male (along Hale Plain transects). The line of best fit is drawn through typical harem size.

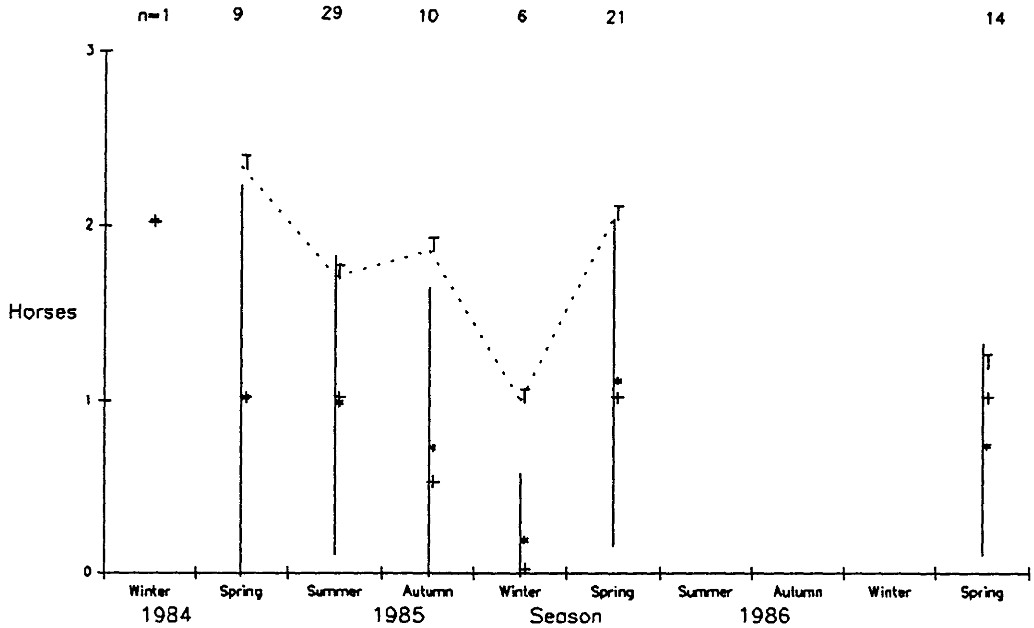

Figure 6.4: Typical (T), mean (*), ±SD (vertical lines) and median (+) number of sub-adults, in harem groups with only one adult male, seen along transects on the Hale Plain.

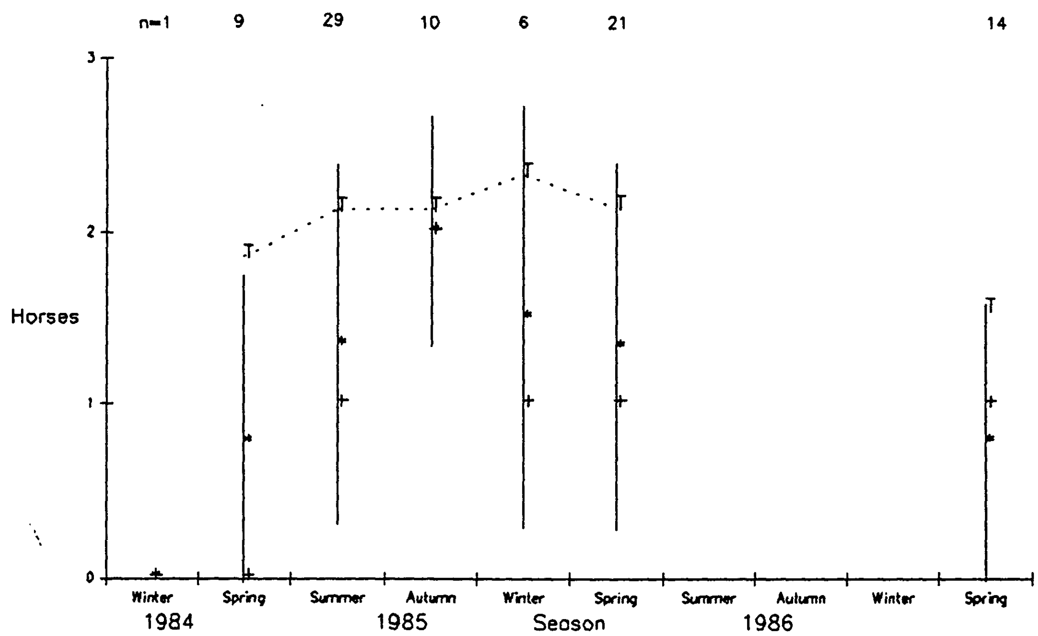

Figure 6.5: Typical (T), mean (*), ±SD (vertical lines), median (+) number of juveniles in harem groups, with only one adult male, seen along transects on the Hale Plain.

b) Bachelor groups

Distinct from harem groups were found males, singly or in groups (typically numbering 3 to 5, but up to 10). The mean number of males in non-breeding groups ranged from 1.1±0.3 in autumn 1985 to 2.8±2.1 in spring 1985. Although there appears to have been an overall decline in typical group size during the study similar to harem groups, there is evidence of seasonal fluctuation which was not apparent for harem groups (Figure 6.6 & Figure 6.7). The largest mean bachelor group sizes were observed during spring and summer of 1984 and spring of 1985 corresponding with the seasons of birth and perhaps an influx of young males forced from harems. This was not apparent during spring 1986, when values were approximately equal to autumn and winter 1985.

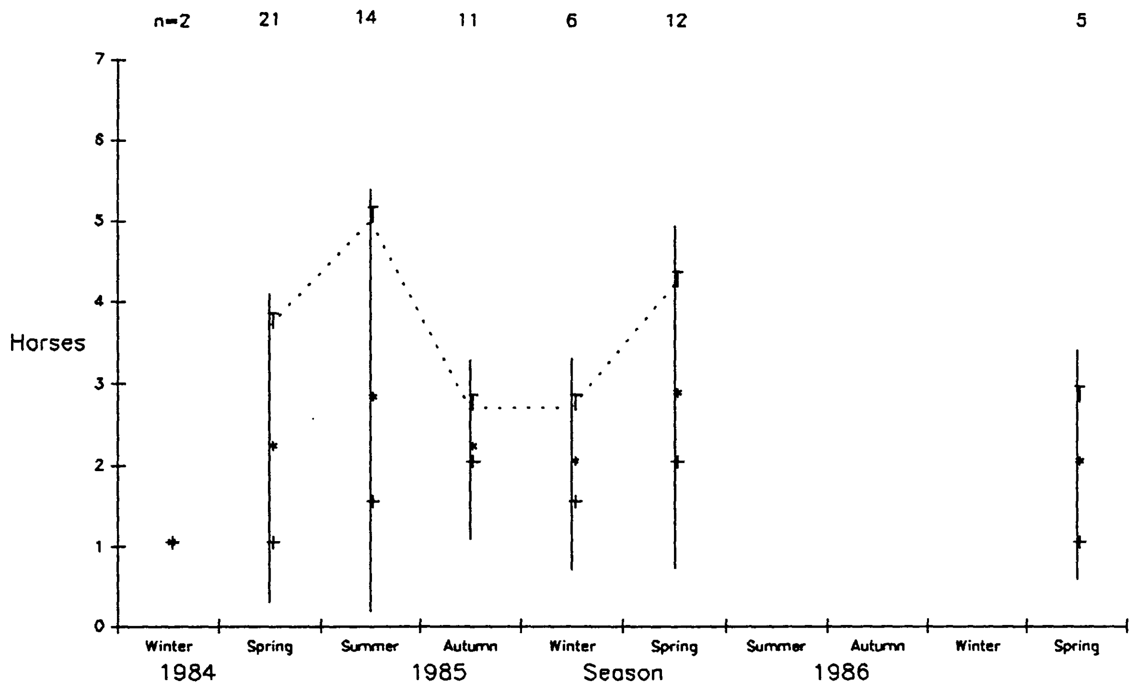

Figure 6.6: Typical (T), mean (*), ±SD (vertical lines) and median (+) size for bachelor groups seen along transects on the Hale Plain.

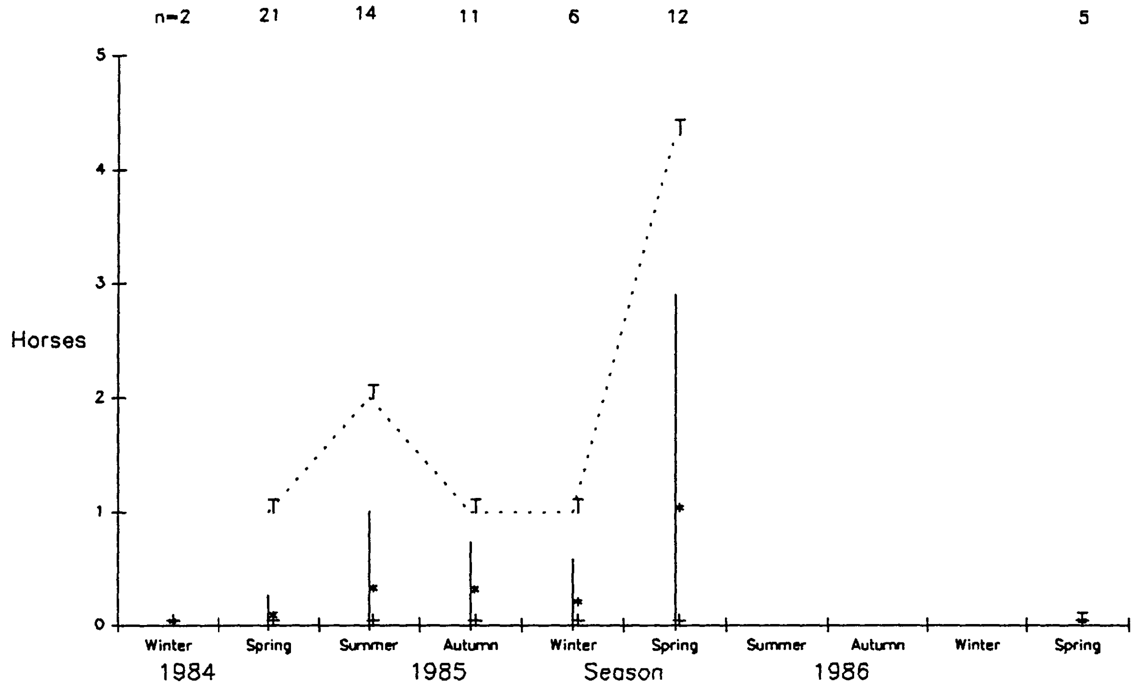

Figure 6.7: Typical (T), mean (*), ±SD (vertical lines) and median (+) number of subadults in bachelor groups seen along transects on the Hale Plain.

d) Other Groups

On four occasions mares were seen without any adult male escort (5% of a sample of 75 groups containing female adults). These groups each consisted of one female adult and a foal and were recorded near watering points.

Large aggregations of feral horses (50 to 300) that I have called herds were also observed during the study. Herds were described as structured social units by Miller and Denniston (1979) for feral horses in the Wyoming's Red Desert. I have not quantified in detail the properties of the large aggregations of horses that I observed for this thesis and therefore cannot confirmed that they are truly structured. However, I present a general description of my observations referring to the large aggregations as herds based on Miller and Denniston's work.

During the period from March to July 1984 most horses were seen in herds grazing on the open grassy plains. When I disturbed the horses in these herds they promptly sorted themselves into smaller distinct harem and bachelor groups. Members of these groups moved closer together while the dominant males positioned themselves between their group and the "danger" (me or other stallions). For much of the study period (late 1984 to September 1986) the bachelor and harem groups were relatively more dispersed and there were few notable aggregations. After the rainfall and pasture growth of winter 1986 large herds of horses were seen within 1 km of watering points on the Hale Plain. About 100 individuals were recorded grazing near White Dam and over 70 horses were seen together near Top Bore. At that time another large herd of about 100 horses was recorded near Bond Dam on the western boundary of The Garden station. In March 1988 approximately 300 horses were seen at Porter's Soak in the Porter's Well study area. Of these, 100 or so members of harem and bachelor groups were all within a 20 by 100 metre area of the river bed digging in the sand for water.

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

Plate 7: Large aggregations of horses (a & c) were made up of smaller groups called harem (d) and bachelor (e & f) groups. In (a) some of over 100 horses seen near Bond Dam in December 1986 are shown. Stallions fight for mares and maintain harem group cohesion (b). There were over 50 horses photographed grazing in a large aggregation on the Hale Plain in March 1984 (c). The bachelor in (f) may have broken his leg in a fight. Horses like (f) in very poor condition were rarely seen. Pregnant mares were often in good condition (g) but while lactating they were usually poor. During transects horses were classified according to condition, sex and age. Photo (h) shows a Juvenile and 2 sub-adults.

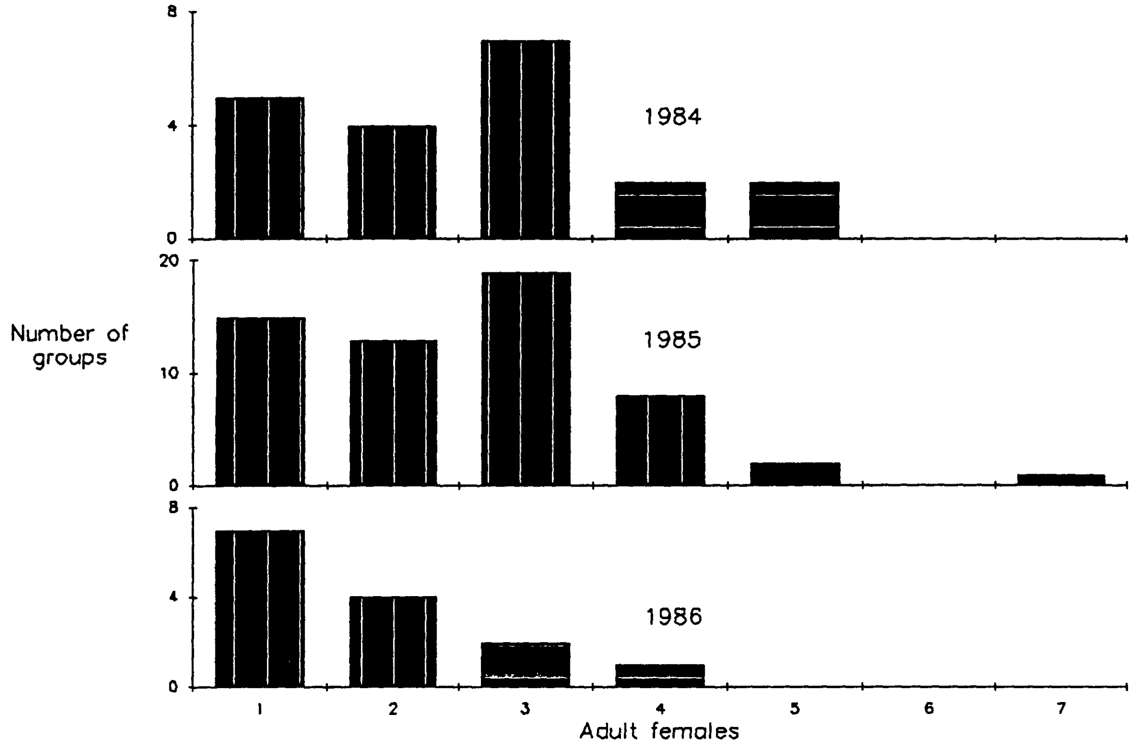

Figure 6.8: Frequency of harems (i.e. number of female adults per group) of different sizes for 1984-86. Only groups with 1 male adult, and where all adults were classified according to age and sex, are included.

6.3.2 Changes in size of social groups

Figure 6.8 indicates that the distribution of harem size changed between 1985 and 1986. There was an increase in the proportion of single mare harems and a decrease in multiple-mare harems, particularly those with three mares. The difference was not quite significant (P=0.07) using the Kolmogorov-Smirnov test for goodness of fit. However, the sample size in 1986 was small. If there was a real change in the frequency distribution of harem size due to an increase in single-female harems at the expense of multiple-female harems, then there should have been a decrease in the proportion of male adults in bachelor groups. Unless this resulted from deaths of mares in multiple female harems, Figure 6.9 indicates that bachelors did indeed take mares from stallions with more than 1 mare to form single mare harems. In 1984 67% of the 54 male adults recorded were in bachelor groups compared to 42% of 24 in 1986 (χ^2=4.29, df=1, P=0.038). This is evidence to suggest that there was considerable harem group instability in 1985 or early 1986 and bachelor males benefited by picking up mares from the larger harems.

The mean number of adult females per adult male in harem groups ranged from 2.7±1.1(SD) in autumn 1985 to 1.7±1.0(SD) in spring 1986. The decrease in harem size during the study was associated with a decrease in pasture biomass of land unit C (r=0.96, P<0.001) and a decrease in the mean quality of the "diet" (faeces) of horses (r=0.85, P<0.001). Harem stallions with 3 mares appeared consistently lower in body condition than stallions with 2 or 1 mares (Figure 6.10). This was not statistically significant; however, the low minimum for condition recorded for harem stallions with 3 mares in March 1985 is, I believe, biologically significant, since that is when these stallions appear to have lost mares to better conditioned bachelor stallions or stallions with fewer mares.

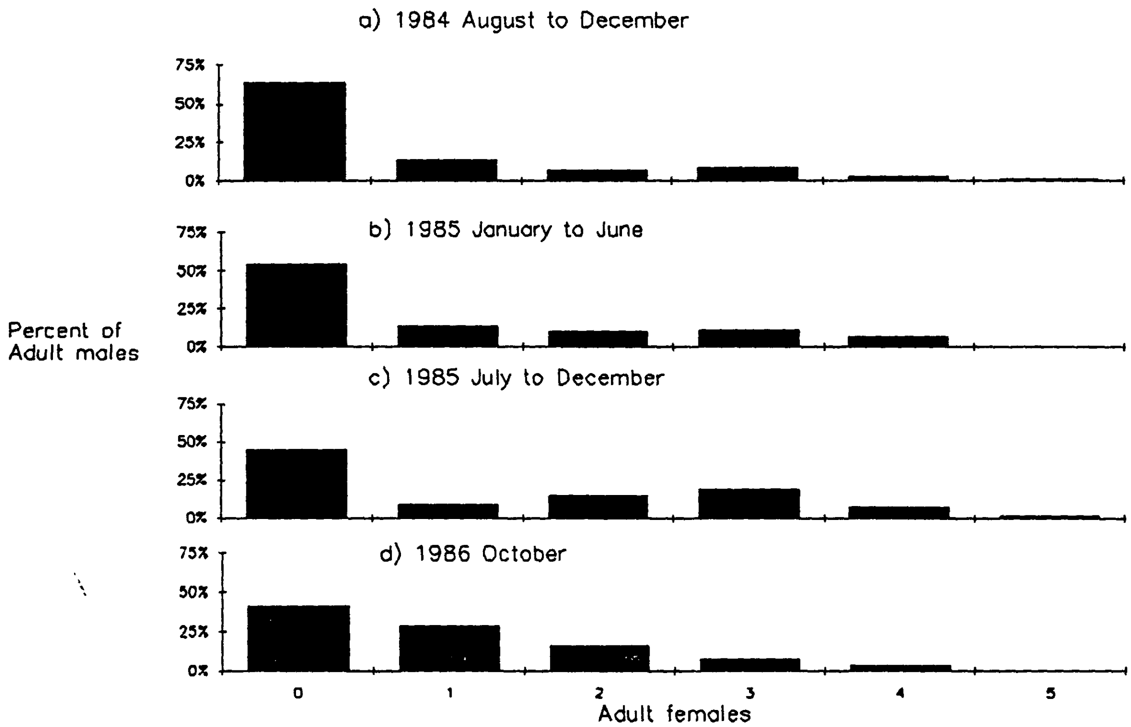

Figure 6.9: Frequency distribution of male adult horses in groups with 0 to 6 female adults seen along transects on the Hale Plain.

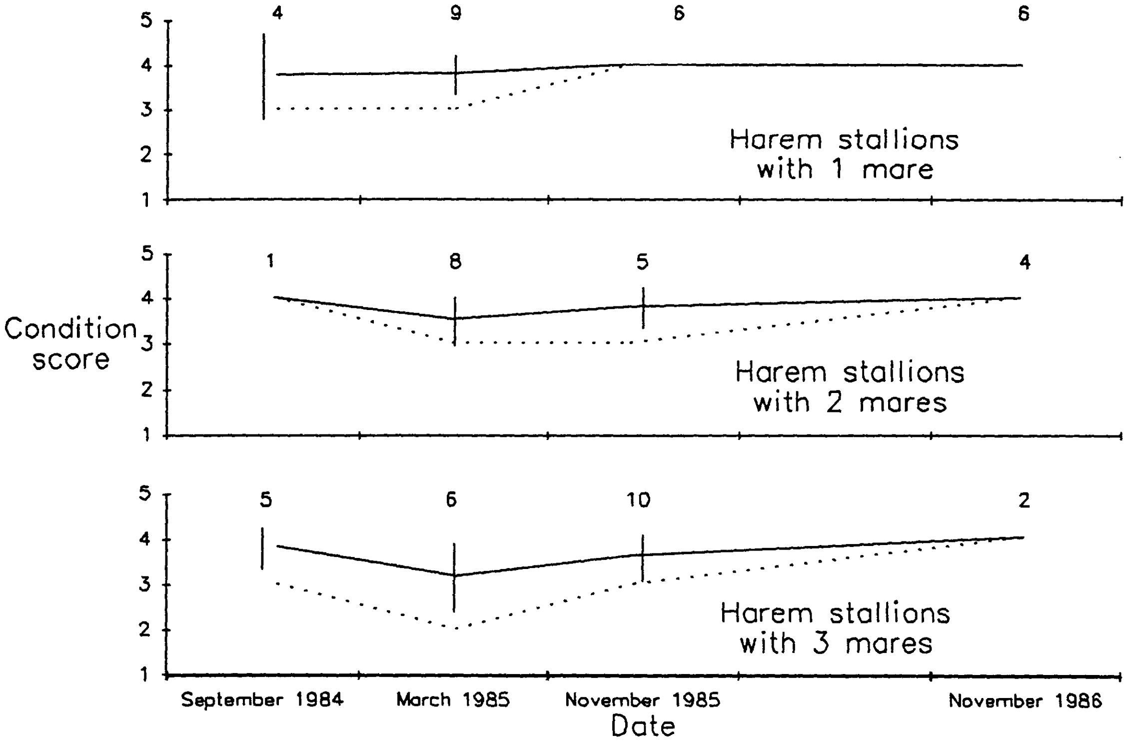

Figure 6.10: Condition of harem stallions with 1, 2 or 3 mares recorded along transects on the Hale Plain. The standard deviation (vertical lines), number of horses sampled, means (__) and minimum scores (...) are shown.

6.3.3 Social stability of radio-marked groups

Of the 4 harem groups radio-marked on the Hale Plain (1985 to 1986) there was 0.54 adult changes/group/year. The total number of times that composition was recorded for radio-marked groups on the Hale Plain was 14 for a combined total of 2.3 years (Table 6.1). On 5 (36%) of these occasions I found the groups to have lost or gained an adult mare. "Brumby One" maintained a 3-mare harem until he lost a mare in September 1985. "Black Brumby" who was a member of a multiple-male harem group originally containing 3 mares lost one mare in November 1985. In March 1986 "Bay Brumby" who had maintained a 2-mare harem lost both mares then picked up a different

Table 6.1: Changes in adult composition of 4 radio-marked social groups in the Hale Plain study area (1985 to 1986). They were all harem groups. The number of records does not include the initial record.

Radio-marked stallion	Months	No. of records	No. of changes in adults	Group Size	Group mares
"Brumby 1"	13	4	2	7-5	3
"Black"	3	3	1	8-6	3
"Bay"	8	4	2	3	1
"Bruce"	4	3	0	3	1

mare in March 1986. The other stallion "Bruce" did not lose his mare during the study. These changes in group composition are from a very small sample of groups. However, they are consistent with the results from transects that indicated there was considerable group instability during 1985 and early 1986, when large harems became smaller.

In the Porter's Well area between 1988 and 1990 the composition of social units were recorded for 8 radio-marked groups of horses (Dobbie & Berman, 1990). For the 6 harem groups studied there was 0.11 adult changes/group/year. Of the 3 bachelor groups studied there was 0.74 adult changes/group/year (Table 6.2). The total number of times that composition was recorded (excluding the initial 8 records) for radio-marked groups in the Porter's Well area was 42 for a combined total of 7.7 years. On 11 (26%) of these occasions Dobbie or myself found the groups to have lost or gained adult(s). "Lucky Six" maintained his group of one mare, one sub-adult male and one juvenile male throughout the study period without change. The only disruption to another harem group ("Pirate's") resulted from a helicopter muster when some of his mares were yarded, though "Pirate" escaped. Results indicate that harem groups were more stable than bachelor groups but records were too irregular to enable detailed analysis.

Statistical analyses indicated that helicopter muster did not significantly affect the overall stability of the social groups nor were the four groups, within the area mustered, more unstable after the muster than before (2 x 2 contingency table). Pooling all groups, prior to the muster, out of 19 observations there were 5 changes in composition recorded. After the muster 24 observations were made with 10 changes (χ^2=0.18, NS). For groups within the muster area, prior to the muster, out of 9 observations there was 1 change in composition recorded. After the muster 13 observations were made with 5 changes (χ^2=0.38, NS).

Table 6.2: Changes in adult composition of 9 radio-marked social groups in the Porter's Well study area (1988 to 1990). H stands for harem and B for bachelor group. The number of records does not include the initial record.

Radio-marked stallion	Months	No. of records	No. of changes in adults	Group		
				Type	Size	mares
"Killer"	14	1	1	B	7-2	0
"Killer"	8	3	0	H	3	1
"Harry"	21	7	0	H	3	2
"Pirate"	21	4	1*	H	4	3
"Lucky six"	14	3	0	H	4	1
"Hobbles"	9	4	4	B	6-2	0
"Wobbly"	21	8	2	H	3-4	2
"Bronson"	18	7	1	B	3-1	0
"Tawriffic"	7	5	2	H	5-9	3-4

* his mares were captured during a helicopter muster

6.3.4 Distribution of Social Groups

a) The influence of land unit

Soon after rainfall when pasture was plentiful and green, horses were seen in large aggregations, up to 100 individuals, feeding within 1 km of White Dam and Top Bore.

Large aggregations were not seen near Cox Bore, Gidyea Bore or Georgina Soak. All these waters were on transects that were regularly patrolled during the study. For all periods during the study on the Hale Plain, of 106 groups seen, 72% were near 2 of the 5 permanent watering points (White Dam or Top Bore). Harem groups were more often seen near White Dam or Top Bore and bachelors were more often seen near Cox or Gidyea Bores (Table 6.3) (χ^2=4.5, df=1 ,P=0.03).

Table 6.3: Proportion of horse groups using 4 watering points on the Hale Plain (1984 to 1986) and the area of land units within 3 km dominated by annual and perennial grasses.

Water	Land units (km^2)		% of all horse groups			Social groups		
	Ann.	Per.	1984	1985	1986	Bach.	Harem	n
White	20	6	54%	30%	45%	42%	58%	37
Gidyea	13	14	13%	25%	8%	58%	42%	19
Top	10	7	33%	31%	39%	28%	72%	35
Cox	7	17	8%	15%	8%	58%	42%	12
			n=24	n=61	n=18			

b) Permanent versus temporary water-sources

In September 1989 Dobbie (Dobbie & Berman, 1990) observed more horses using Porter's Soak than either Whistleduck or Dead Horse Waterholes. The importance of Porter's Soak was probably more pronounced than results indicate because conditions were coolest whilst observing the activity at Porter's Soak (23°C, versus up to 33°C during observations at the other water-holes). The greater number of groups, the larger group size and the higher proportion of family groups typified Porter's Soak. There was a statistically significant difference in the proportions of harem and bachelor groups recorded at the 3 waters (χ^2=8.28, df=2, P<0.02) (see Table 6.4).

Table 6.4: Horse group characteristics recorded (mean ± SD are presented) during 36 hours of observation at 3 different water-holes. Taken from Dobbie and Berman (1990).

	Porters Soak	Whistleduck WH	Dead Horse WH
Date of observations	13-14/9/89	15-16/9/89	17-18/9/89
No. of Groups	21	9	15
Mean Group size ± SD	3.8 ± 1.6	2.9 ± 1.4	2.5 ± 1.6
Mean harem group size ± SD	4.1 ± 1.9	3.7 ± 0.7	3.6 ± 2.3
Mean bachelor group size ± SD	1.0 ± 0	1.3 ± 0.3	1.6 ± 0.9
% Bachelor groups	9.5	33.3	53.3
% Harem groups	90.5	66.7	46.7
Mares/stallion in harem group ± SD	2.2 ± 0.9	1.8 ± 0.8	1.9 ± 0.7
% Juveniles	18	4	8
% of Mares with foals	31	10	20
% Horses in good condition	94	96	100
Mean Time on Water (mins) ± SD	5.3 ± 2.0	12.7 ± 5.7	13.5 ± 12.3(soak) 3.3 ± 1.2(w'hole)
No.Donkey groups and (Individuals)	1(8)	0	6(14)
No.Cattle	0	0	0
Bird Species (waterbirds)	26 (2)	14 (0)	12 (0)
Rate of drop in water level	7 mm/day	?	14 mm/day

Both Whistleduck and Dead Horse Waterholes were temporary waters. Their capacity is variable, depending upon the nature of, and time since the last creek flow. Whistleduck Waterhole is 6.3 km south-east of Porter's Soak. Dead Horse Waterhole is 12.8 km east of Porter's Soak. Permanent springs are located about 6 km by track from Dead Horse Waterhole on the other side of the Georgina Range. However, access around the end of the range is rugged and the route did not appear to be favoured by horses. Porter's Soak is essentially the nearest permanent watering point to Dead Horse Waterhole.

The number of bachelor groups were high at Dead Horse Waterhole (53%), low at Porter's Soak (10%), and intermediate at Whistleduck (33%) (Table 6.4). General observations throughout the project supported indications that the proportion of bachelor groups was high in the vicinity of Dead Horse Waterhole whereas harem groups appeared to predominate around the permanent water of Porter's Soak.

Tests of water indicated that the microbiological quality of water has little influence upon where horses prefer to water (Dobbie & Berman, 1990) at least in the Porter's Well study area. Concentrations of chemical constituents may increase in ephemeral water-holes as they dry up (Hart,1974) and therefore chemical quality is probably correlated to the permanence of a water-hole. Dead Horse Waterhole did have high fluoride, bicarbonate and iron levels which may influence its use by horses. However, none of the chemical parameters measured for the other 2 watering points were outside limits acceptable for stock (Dobbie & Berman, 1990). Water was not tested chemically or microbiologically on the Hale Plain but it tasted good and there is no reason to suspect that the bores differ significantly in quality.

6.4 Discussion

Generally, the social organisation of feral horses on The Garden station conforms with the basic pattern described for horses by Klingel (1972). Most harem groups (bands) consisted of one male adult, 1 to 3 mares and their offspring. A large proportion of male adults were seen in bachelor groups. Harem groups appeared more stable than bachelor groups. Each group occupies a non-exclusive home range that overlaps with many other groups (Dobbie & Berman, 1990). Stallions are not territorial in that they do not mark out and defend an area. They do, however, keep other stallions away from their mares. The composition of harem groups remained relatively stable during the study indicating there are strong bonds between adult horses. All these characteristics are consistent with the basic pattern set out by Klingel (1972). However, there were variations. Bonds between adults were occasionally broken; there were a small proportion of multiple male and female groups (multiple-male bands); and some adult females were not accompanied by an adult male. These inconsistencies with the basic social pattern have previously been revealed by numerous other studies (see reviews by Miller, 1979; Waring, 1983; Berger, 1986) and probably should be considered part of the overall feral horse social system, not just as aberrant variations (see Chapter 10).

A decline in the stability of bands and the proportion of multiple-male bands in Wyoming's Red Desert was associated with a severe winter when deep and persistent snow limited forage availability. Miller believed increased fragmentation of preferred habitat may have caused the social groups to split as has been reported for African buffalo by Sinclair (1977). Feral horse harem groups on the Hale Plain in central Australia decreased in size during the very dry period from 1985 and early 1986 when pasture quantity and quality was low (Chapter 4). This decrease in harem size was not in my opinion due to fragmentation of preferred habitat. The harem groups decreased in typical size as pasture disappeared. This decrease was a combined result of decreased proportion (to stallions) of foals, mares and sub-adults in harem groups. The proportion of foals decreased because foaling rate or foal survival decreased combined with mares leaving or being coerced out of larger harems to form new harem groups with bachelors. Sub-adults left or were forced to leave harems and join bachelor groups earlier when food was scarce. To seek out the fewer patches of suitable feeding habitat, or increasing differences between lactating and dry mares in their resource needs may have caused horses to split into smaller groups. However, the harem stallion's inability to obtain sufficient energy from forage to continue to fight off the better conditioned bachelor males was in my opinion the main cause of decreased harem group size.

The energy cost of maintaining a harem of 3 mares is considerably more than having no mares at all. The more mares a stallion has the greater energy must be expended in their defence (Berger, 1986 page 145). So when pasture resources are limiting, harem stallions lose condition relative to bachelors (section 6.3.2). Furthermore, mares in poor condition are less likely to be pregnant (Chapter 7). Whether this is due to abortion, or failure to conceive or ovulate is not known. I suspect failure to conceive is an important factor (Chapter 7) but I have no real evidence to support this belief. Mares in unstable groups tend to produce fewer foals (Berger, 1986 page 64; Rubenstein, 1986; Miller, 1979). Mares from unstable Mountain zebra groups were thought to have aborted (Penzhorn, 1985) and Berger (1986 page 165) showed that 82% of females procured by new males when less than six months pregnant aborted their foetuses. In my study lactation appears the major cause of poor condition in mares (Chapter 7) and poor condition is associated with failure to be pregnant. Instability of the group or stallion take-over therefore in my opinion was not the major cause of infertility. Further, these lactating mares had previously been members of groups that allowed them to successfully produced offspring which are presumably more likely to be stable groups. If failure to conceive is common for mares that are in poor condition and if they then continue to come into estrus once a month, the effort required by the stallion to defend that mare would be exaggerated. If a stallion has three poor mares that continue to come into estrus alternatively he will have no rest until he loses mares. In this way I believe the "stable" harem groups become unstable and decrease in size when food resources are limiting. A further factor may involve a mare's tendency to seek new males if she fails to conceive. Once destablized, pregnant members of groups taken over by new stallions may abort. Thus a low rainfall on The Garden station and the resulting lack of pasture growth has caused a reduction in the rate of reproduction which was facilitated by a complex chain of social events. But the primary cause was lack of available food.

There were only a small proportion (9%) of multiple male and female harem groups (Multiple-male bands) on The Garden station compared to the Wyoming's Red Desert where 23 to 45% of the horse groups identified by Miller (1979) were multiple male bands. Miller (1979) found multiple male bands to be consistently more stable than single male bands and ascribed this to sub-ordinate males helping repel intruding males. He suggested that having more than one adult male increased the reproductive potential of group members. Miller stated that "multiple male bands may be formed whenever environmental conditions permit formation of large bands of feral horses." Conditions may not have been suitable during Berger's (1986) study, however, because he found multiple male bands to be relatively unstable. They did not confer greater reproductive advantages per male nor did they result in longer periods of tenure. Why did Miller and Berger have conflicting results? What environmental factors control these details of feral horse social organisation? I suspect environmental factors that influence the sex ratio may be important. The adult sex ratio in Berger's study was 0.76 males to 1.0 female. Miller did not provide an indication of the sex ratio of the Red Desert feral horse population but I suspect there may have been more male adults than female adults. If there are many males and competition for females is fierce and resources are suited to formation of large groups then multiple-male bands may provide dominant stallions with the potential to sire more foals. The factor that caused the formation of large numbers of multiple male bands in the Wyoming's Red Desert certainly appears absent in central Australia. Incidently the adult (>2 years) sex ratio for horses in central Australia was 1 male to 1 female (Chapter 7).

There was absolutely no evidence to suggest horses in central Australia defend true territories. In fact, on one occasion, dry conditions and a resource (free water) that was extremely limited in distribution appeared to result (for a short time at least) in behaviour completely contrasting to territoriality. In March 1988 at Porter's Soak the need to obtain water appeared to override even the harem stallions' desire to keep other stallions away from their mares. I observed over 100 horses (stallions, mares and foals) standing within kicking and biting distance, showing no aggression towards each other as they waited for their turn to drink water that seeped into the holes they scraped in the sand. Under such conditions social organisation must be flexible.

Herds were described as structured social units by Miller and Denniston (1979) for feral horses in the Wyoming's Red Desert. They found there to be an interband dominance hierarchy with interband recognition. The movement of harem groups and bachelor groups is therefore probably influenced by other groups. However, further detailed studies are required to determine whether the large aggregations of feral horses on The Garden station are indeed structured social units. These large aggregations were made up of smaller breeding (harem) and non-breeding (bachelor) social groups. As time since rain increased and pasture became scarce the aggregations were no longer seen; the horses dispersed in smaller groups to search for pasture further from water.

In the Porter's Well study area Dobbie & Berman (1990) found evidence to suggest the herd is a structured social unit. The feral horse herd appeared to be organised into 'harem areas' and 'bachelor areas' as influenced by water supply. Results indicate that permanent water-holes attract the greatest number of horses, larger groups and a high proportion of harem groups. Bachelor groups appear more confined to, or more able to use temporary watering points long distances from permanent water (Table 6.4).

A similar "segregation" of herds appeared to occur on the Hale Plain but this was not due to permanence of water since the waters (bores) were mostly permanent. The watering points favoured by harems and avoided by bachelors (White Dam and Top Bore) were closely surrounded by a greater area of land units having a large annual grass component (C,G and B) than alternative watering points (Gidyea Bore and Cox Bore respectively) (Table 6.3). Perhaps even more striking was the difference in the amount of area of alluvial flat (land unit D) within 3 km. Horses appeared to have a preference for areas around watering points with highest proportions of land units C, G and B over areas where land unit D predominates. The presence of aggregated herds and the greatest proportion of harems in some areas but not others on the Hale Plain seems therefore a result of avoidance of alluvial areas (land unit D) and/or selection of areas which grow annual pasture (land units C, G and B). Possible reasons for avoidance of alluvial areas by horses are:

- the presence of poisonous plants (*Indigofera linnaei* and *Swainsona* spp.) which grew only on alluvial areas during the study.
- alluvial areas grew mainly perennial grasses while the terraces of land unit C grew the more preferred annual grasses (Chapter 4).

I do not believe members of harem groups are actually consciously selecting areas where there is an absence of poisonous plants or permanent water. However, those groups that happen to live in areas with these attributes will be more likely to survive the drought and less likely to succumb to poisonous plants and will have time to establish large and stable harem groups. Horses that colonise areas where the water dries up say once every 5 years could perish. Bachelors may move into areas where plants are poisonous or the water is ephemeral as a means to avoid dominant stallions.

Rubenstein (1986) found territorial harem groups in the more favourable areas of habitat on Shackleford Banks and temporary groups in areas where he believed the habitat characteristics prevented long-term associations. This I believe is another example of a horse herd being segregated into areas containing groups of increasing complexity and stability. In the best habitat stable, large and even territorial groups have time to develop. Their development requires the establishment of bonds between adults (male-female, female-female). In the poorest most unpredictable habitat bachelors and unstable harem groups will be found. In Chapter 10 I present a model describing the horse social system as a hierarchy of types of social groups within herds from the least complex (single individual) to the most complex (territorial harem). I believe territorial groups to be the most mature groups that require stability and time to develop. Many environments inhabited by horses are too unpredictable or food and water is too sparsely distributed to allow horse groups to develop into territorial groups. The best they can do in most areas is to form single-male harem groups. I hypothesise that in all horse herds there is a correlation between maturity of social groups and suitability of habitat.

Should there be a "solid line" drawn through the equids based on territorial behaviour? In my opinion the answer is no and in Chapter 10, based on my studies of feral horses in central Australia and with reference to the literature I present a model that may simplify perception of equid social organisation. "Solid lines" once drawn tend to become wider and more solid as people favour one side or the other. I intend to remove the "solid line" between the 2 basic types of equid social systems and replace it with a "dotted line". Both types of equids in my opinion are essentially territorial, one type usually defends spatially fixed territories while the other defends mobile territories (see Chapter 10).

6.5 Conclusion

The social organisation of feral horses in central Australia appears to conform with the basic pattern for horses studied elsewhere in the world. Harem groups maintained relatively stable adult composition. Strong bonds therefore may existed between adults. Bachelor groups appeared less stable.

As dry weather continued and pasture became dry and sparse harem group size decreased. This decrease was at least partly a consequence of loss of mares, to bachelors, by stallions with more than 1 mare.

The greatest proportion of harem groups occurred in habitat with a low proportion of alluvial country, plenty of hills or terraces with annual pasture and permanent water. Horses may require the stability of this favourable habitat for development of the strong bonds necessary for large harem formation.