CHAPTER 3

DENSITY, HABITAT-USE & DISTRIBUTION

The Guy Fawkes River Brumby
~By Bruce Brislane

'Colts and fillies playing, staying close and never straying,
As the mob spread on the flat above the ford.
Bays with greys and piebalds feeding, a mixed up line of breeding,
And were jealously watched over by a palomino lord'...

3.1 Introduction & Research Links

As we have seen from the previous chapters, there is a need for research into how free-ranging horses interact with the environment in temperate eastern Australia, and particularly in northern GFRNP. Population density is an important factor associated with habitat-use and distribution of free-ranging horses as well as impacts, and awareness of population parametres can assist in evaluating those variables more accurately. The objective of this chapter is to evaluate density, habitat-use and distribution of free-ranging horses on Paddy's Land plateau. The information provided is anticipated to assist our perception of resource-use so that both environmental consequences can be analysed and passive trapping can be planned with better understanding. As with any control operation, passive trapping of free-ranging horses on Paddy's Land plateau requires careful planning.

Population size is difficult to estimate and many different methods can be used. Aerial surveying methods can be a practical way to sample population abundance, but were not implemented in this research for the following reasons. Aerial surveys are costly and labour intensive and they can produce unreliable estimates. Groups of free-ranging horses ran, split and merged in response to helicopters in the Kaimanawa Mountains of New Zealand, which resulted in double-counting individuals and overestimating population size (Linklater & Cameron, 2002). Accuracy can also be limited by observer experience, weather conditions, animal activity and other factors (Black, 2000). Moreover, aerial surveys might destabilise social structure of the free-ranging horse population in GFRNP. During exclosure construction, which is discussed in Chapter 5, the use of a helicopter over 6 hours was shown to discourage horses from the river flats for a period exceeding 1 month (pers. obs., July-August 2002). Horses are known to have excellent memories (Pilliner, 1996) and the Guy Fawkes River helicopter horse-culling exercise was performed less than 2 years prior to this study. To decrease the chances of impacting the social structure and behaviour of GFRNP horses, transect methods on foot were implemented rather than aerial surveys.

Relative density or indices can be effective population estimators and it is best to use more than one method of analysis to increase accuracy (Caughley, 1977; Seber, 1982 in Dyring, 1990). Distance-sampling techniques are widely implemented for estimating the density of biological populations (Thomas *et al.,* 2002). With this method, data are collected by conducting standardised surveys along a series of line-transects where objects or clusters are searched for (Thomas *et al.,* 2002). When each object or cluster is detected, perpendicular distance to the line-transect is recorded. Because clusters become harder to detect with increasing distance, the distance-sampling analysis fits a detection function to the observed distances, which is used to estimate the proportion of objects missed by the survey. Point and interval estimates for the density of clusters are then obtained and density is estimated (Thomas *et al.,* 2002).

When using many population estimation techniques there is no certainty that populations being measured fit assumptions of the model. Estimates could be wildly inaccurate and confidence limits may not be realistic (Caughley & Sinclair, 1994). Many ecologists have adopted the 'known-to-be alive' estimation method, which, is inaccurate, but predictably so, and does not depend on a set of assumptions of doubtful reliability (Caughley & Sinclair, 1994). The known-to-be-alive method is simply the number of animals that the researcher knows, with certainty, to be in the study area.

This method has the advantage of yielding a real number rather than an abstract concept to work with.

To determine relative habitat-use, Duncan (1983) recommended *a priori* stratification at levels meaningful to the animals (Duncan, 1983 in Dyring, 1990). Landscape positions, or 'catena levels' may support vegetation differing in composition and productivity. These may be associated with horse habitat-use (P. Jarman, UNE pers. comm., April 2002), which can be determined from counting faeces and band sightings. The catena levels were represented by drainage-line, mid-slope and ridge-top landscape positions. Rowe-Rowe (1983) used topographic positions such as valley bottom, valley and ridge-top positions to determine habitat-use of antelope. Perrin and Everett (1999) quantified habitat-use in relation to topography. Riney (1957) suggested that faecal counts could delineate preferred habitat and seasonal-use by various mammals (Riney, 1957 in Collins, 1981).

3.2 Methods

In addition to relative density estimation, null hypotheses were formed and tested to investigate habitat-use and distribution of free-ranging horses on Paddy's Land plateau. A replicated line-transect study was developed and surveys of free-ranging horses took place.

H_o = Average band size did not vary between seasons.

H_{o1} = Density of horses and dung in habitats is random with respect to season

H_{o2} = There is no correlation between distribution of horse use and water sources

H_{o3} = Density of horses is randomly distributed across the plateau within a season

H_{o4} = Seedling establishment in dung is not evident on the plateau

Initially, nine transects were plotted on the 1:25 000 Kookabookra Topographic Map Paddy's Land plateau sector. Transect locations were focused on the Paddy's Land plateau for determination of use of 40 km^2 of the plateau by horses. Transects were situated more or less perpendicular to the local drainage line, valley and ridge systems, thus representing catena levels roughly proportionately. Situating transects in an east-to-west direction across the grain of the landscape was thought to maximise habitat coverage. Nine possible transects were marked on a map, in three clusters of three, the clusters distributed to represent the plateau. One transect was selected randomly from each cluster and marked for surveying. This method was used to ensure that transects were randomly chosen but not clumped in one area (Figure 3.1). Drainage lines and dams are distributed across the plateau and, by chance, each transect was located in close proximity (less than 1 km) to water sources (Figure 3.1). Transect 1 started at zone 56J N 6672524 E^o 0420056 and was situated on the western plateau, Transect 2 started at N 56J 6670330 E^o 0421526 and was situated in the middle southern sector of the plateau and Transect 3 started at N 56J 6673324 E^o 042 was situated on the eastern edge of the plateau.

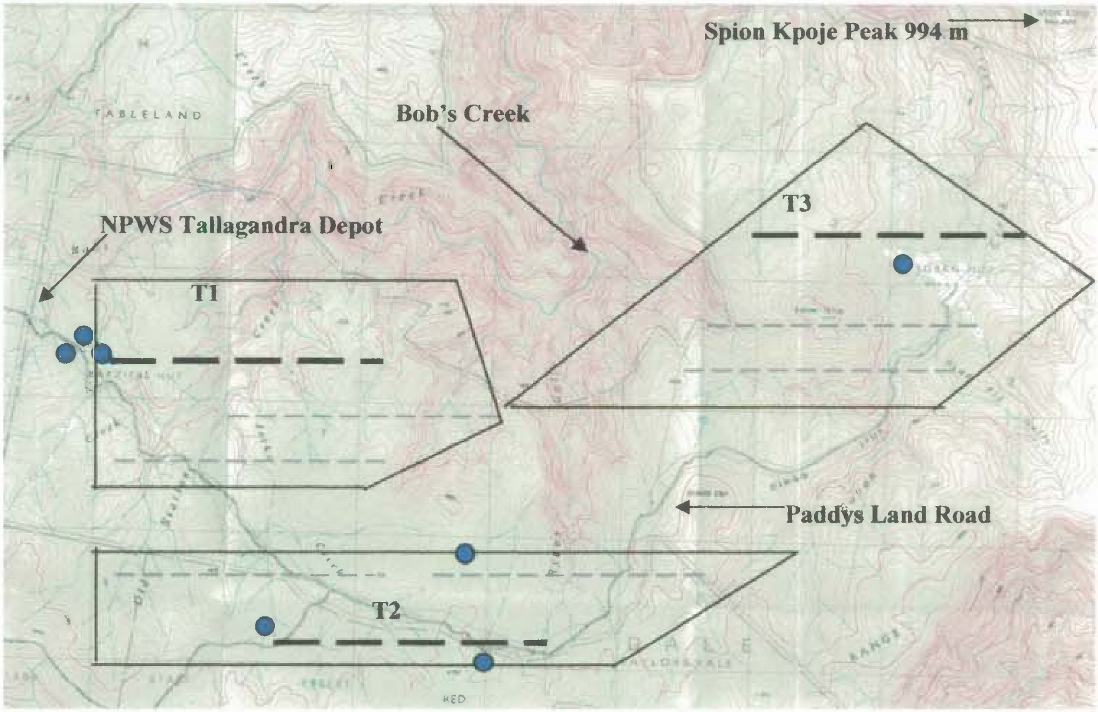

Figure 3.1 Transect sampling design and randomly selected 2 km transect locations: Transect 1 west, Transect 2 south, and Transect 3 east. ● =Represents dams (not to scale) within 1 km of the selected transects.

Surveys along the transects were conducted four times in spring 2002 and four times in summer 2003 at weekly or fortnightly intervals, depending on weather conditions and accessibility. Data were collected on horse band sightings, horse dung, and catena level (Drainage-Line, Mid-Slope, Ridge-Top). Analysing the possibility of seedling germination in horse dung was attempted in this study, and during all dung-counts seedling establishment was recorded.

Transects were 2 km in length. Each had one to two dams located within 1 km of it and numerous drainage lines intersecting it as well. Refer to Appendix 3.4 for locations of drainage lines along each transect, and to Figure 3.1 for locations of dams near transects. Time taken to patrol each transect was approximately 2 hours. Observers patrolled transects at different times of the day over each season during the surveys to eliminate time bias. Data for the spring season were collected from late September to early November 2002 and data for the summer season were collected from mid-January to mid-February 2003 (Table 3.1). The transect study unavoidably coincided with the drought of 2002 to 2003. Results from the survey revealed that horses were visible from transects at a distance of approximately 150 m. Therefore the replicated transect survey yielded a sampling intensity of 4.5%. A fixed width of 10 m was used for the dung survey and yielded a sampling intensity of 0.15%. Direct as well as indirect methods of data collection were used. Relative density, habitat-use and distribution analyses were determined from transect dung-counts supplemented with horse-band-counts.

Table 3.1 Transect patrol dates and times for density, habitat-use and distribution examination.

Transect	Spring 2002	Time	Summer 2003	Time
T1	29 September	2pm	18 January	10am
T1	14 October	4pm	27 January	8am
T1	27 October	10am	3 February	2pm
T1	4 November	8am	9 February	4pm
T2	29 September	2pm	20 January	8am
T2	13 October	10am	25 January	4pm
T2	28 October	8am	4 February	10am
T2	3 November	4pm	9 February	2pm
T3	30 September	2pm	19 January	2pm
T3	14 October	10am	26 January	4pm
T3	29 October	8am	3 February	8am
T3	4 November	4pm	9 February	10am

3.2.1 Density Methods

Two direct methods of animal counting were attempted for density estimation. Systematic transect surveys, using distance-sampling techniques, were implemented and opportunistic sightings of horse bands and individuals were counted. The indirect method of dung-counting was also employed. Dung-counting is a method frequently used for obtaining population indices for large ungulates. Indirect methods, such as dung-counting, have the advantage of accuracy being less dependent on the skill of the observer and there is less chance of influencing what is to be observed (Eberhardt & Van Etten, 1956; Wallmo *et al.,* 1962; Caughley, 1977; Seber, 1982 in Dyring, 1990).

Using distance-sampling techniques data were collected by conducting standardised surveys along a series of line-transects where horse bands were searched for. Horse band sightings were used for cluster data. When each cluster was detected, perpendicular distance to the transect was recorded. The perpendicular distances and group sizes were entered into distance line-transect software (Buckland *et al.,* 1993) to estimate relative density of free-ranging horses. During transect patrols the catena level occupied by each band of horses (drainage-line, mid-slope and ridge-top) was recorded. Some bands moved in response to observers. In these circumstances, the site occupied by bands which was recorded may not have been independent of observers, which is a limitation that will be discussed further in this chapter.

In addition to relative-density estimation, this study pilot tested the 'known-to-be-alive estimation' method. Opportunistic observations were recorded along the road and in the woodland while carrying out research on numerous occasions. Applicability of observation procedures depends on animals moving independently of each other. The temporal spacing of observations must be such that they are not auto-correlated (i.e. that observations are collected in a random unbiased manner) (Byers *et al.,* 1984 in Perrin & Everett, 1999).

Detailed descriptions of horses such as body, mane and tail colour were documented along with group composition and other distinguishing characteristics such as scars and condition of individuals using binoculars (10-15x). Photographs were taken whenever possible for comparison during future observations. Identification and recognition of individual horses is a difficult task, and care was taken to prevent duplicating observations. When individual horses horses were interacting within a close range, they were counted as one group. General descriptions of all horse bands identified on the plateau are listed in Appendix 3.1 followed by mapped encounter locations in Appendix 3.2 and photographs of individuals and bands in 3.3. Bob's Creek band encounters are included but were not used for analyses. By using a descriptive history of all bands sighted, and comparing characteristics of previously sighted bands with new bands, the known-to-be-alive estimate was determined for each season on Paddy's Land plateau.

Analyses were focused on seasonal observations separately to decrease the chance of double-counting bands and individuals. Double-counting could produce unreliable estimates. The decision to analyse seasonal observations separately was confirmed as necessary when four groups were seen in more than one season and three groups were identified to have changed composition over seasons. Individual bands and horses were distinguished as carefully as possible. However, there is a chance that a few horses may have switched groups within the same season's sampling and, as a result, been double-counted. During band encounters, landscape position was documented when the band was first sighted.

3.2.2 Habitat-Use & Distribution Methods

Heterogeneity of habitat-use by free-ranging horses was tested by a quantitative study that investigated selection in terms of the proportion of animals and dung seen in different catena levels along the transects. Drainage-line, mid-slope, and ridge-top habitats represented the catena levels. Dung was sampled along transects in both spring and summer. Dung samples were destroyed during the spring sampling so that they would not be recounted in the summer.

Sections of each transect that fell within the defined catena level (Drainage-line, Mid-slope, and Ridge-top) were measured to the nearest 10 m along transects and are documented in Appendix 3.4. Transect totals were merged for each catena level and then averaged to obtain mean relative proportions of catena levels across the plateau (Table 3.2). Table 3.2 shows that transects differed little in relative proportions of catena levels, so those proportions were taken to represent average proportions of catena levels across the plateau generally.

Activities during which opportunistic recordings of horses took place were assumed to be randomly distributed across the plateau, and thus the chances of observing horse bands opportunistically were not biased towards any catena level or part of the plateau. The plateau-average values of catena level areas were used to set expected rates of opportunistic sightings and transect sightings of horse bands in the catena levels.

It was assumed that the Paddy's Land Road intercepted the three catena levels in similar proportions to transects because, at a larger scale of roughly 13 km, it paralleled the direction of transects (east to west across the plateau). Catena values obtained from the transect surveys-assisted in generating expected values of dung and horse band sightings in each catena. Expected values of dung and band sightings in each catena level were generated by using the average percent of each catena level and the total amount of dung or band sightings recorded.

To supplement habitat-use analyses, transects originating at three water sources were surveyed for dung density. To supplement habitat-use analyses, local and landscape level sub-transects were selected. Each of 3 sub-transects originated at a water source along each of the 3 original transects. Sub-transects were surveyed for dung density at coarse-grained (landscape level) and fine-grained (local level) distance classes. The data were analysed to examine the association between horses and water both across the landscape and at the local level.

Table 3.2 Transect catena levels averaged for expected values across the landscape.

Catena Level >	Drainage-Line (C1)	Mid-Slope (C2)	Ridge-Top (C3)
Transect 1	215 m = 11%	1600 m = 80%	185 m = 9%
Transect 2	165 m = 8%	1685 m = 84%	150 m = 8%
Transect 3	200 m = 10%	1500 m = 75%	300 m = 15%
Average and %	**193.3 m = 9%**	**1595m = 80%**	**211.6 = 11%**

To test whether density and distribution of horse dung were random in all three transects over the spring and summer seasons, chi-square distribution analyses were carried out. Horse sightings from the systematic transect surveys yielded very small sample sizes, which means that the significance of chi-squared values may be questioned. The data generated were not used in chi-squared analyses for distribution but observational data were used to demonstrate large band formation during the summer 2003 season. For additional assistance in distribution analyses across the plateau, stallion or stud piles as well as individual dung-counts were carried out in October 2002 along 13 km of Paddy's Land Road running east to west across the plateau.

As mentioned in Chapter 2, free-ranging stallions tend to limit defecation to certain areas and establish fecal mounds called 'stallion' or 'stud' piles throughout their range and are added to by other stallions and younger males. All horses defecate sometimes while moving and create individual piles of dung, which are smaller in size and have fewer fecal pellets than the stallion piles. The distribution analyses were intended to obtain information on time spent and habitat use by stallions and individuals, with Irby's (1981) assumption that ungulates defecate at random and proportionately deposit dung groups according to time spent in various areas.

3.3.1 Density Results

Results from distance-sampling analyses are documented in Table 3.3. Density results are reported as horse bands/km^2 and lower to upper limits of density are listed according to distance-sampling confidence levels of 95%. Distance-sampling statistics produced a density estimate of 14.9 horse bands/km^2 based on 16 band observations over the systematic spring and summer surveys. Multiplying that number by the approximate area of the plateau (40 km^2) yields a relative occupancy estimate of 596 horse bands during spring and summer. That estimate multiplied by the average band size for spring and summer (3.72 individuals/band) produced a probably unrealistic estimate of 2,217 individuals. Distance software produced this probably unrealistic estimate of band density because the horses fled at maximal sighting range, so usually straight ahead on the transect, producing an apparently very narrow surveyed strip, and thus surveyed area; and that produced an inflated density.

Table 3.3 Horse band density estimates on Paddy's Land plateau yielded from distance-sampling statistics (Buckland *et al.,* 1993).

Season	Clusters/Bands Observed	Density Bands/km^2	Lower Limit	Upper Limit	Analytic Coefficient of Variance
Spring 2002 Transects	6	5.9	1.2	28.4	0.737
Summer 2003 Transects	10	15.1	6.3	35.9	0.43
Sp. & Sum. Together	16	14.9	6.5	34	0.417

Horse band data collected for all seasons for the known-to-be-alive estimation method, are listed in Appendix 3.1 followed by mapped encounter locations in Appendix 3.2 and photographs in Appendix 3.3. A density summary is located in Table 3.4. The numbers produced must be acknowledged as minimum estimates because only 52 days were surveyed through the year. The table reveals that the known-to-be-alive estimate of free-ranging horses was highest during the summer months with 32 bands comprising 127 individuals encountered. This seasonal increase in density corresponds to a seasonal increase in bark-chewing damage, which is discussed in Chapter 4.

Table 3.4 Known-to-be-alive estimate results analysed for each season separately.

Paddy's Land Plateau Season and Year	No. Days Surveyed	Number of Different Bands Encountered	Number of Individual Horses
Autumn 2002	8 days	6 bands	29 individuals
Winter 2002	12 days	11 bands	34 individuals
Spring 2002	16 days	13 bands	46 individuals
Summer 2003	16 days	32 bands	127 individuals

The seasonal averages of sampled band sizes are illustrated in Figure 3.2. A one-way analysis of variance (ANOVA) of the seasonal band size data was undertaken to determine if the between-season variation was significant. One-way analysis of variance is used to compare several population means based on independent Simple Random Samples (SRS's) from each population (Moore and Mcabe, 1998). The populations are assumed to be normal with possibly different means (Moore and Mcabe, 1998). Results revealed that seasonal variation in band size was not significant df=3 p-value$\geq$0.05, F-ratio=0.62. See Table 3.4a for a summary of the statistics.

Table 3.4a Statistic summary of sampled seasonal band sizes.

Season	Count	Avg.	Variance	Std. Error	Min	Max	Range
Autumn	6	4.83	12.5	1.44	1	10	9
Winter	11	3.09	3.29	0.54	1	6	5
Spring	13	3.54	4.60	0.59	1	9	8
Summer	32	3.96	5.57	0.41	1	9	8

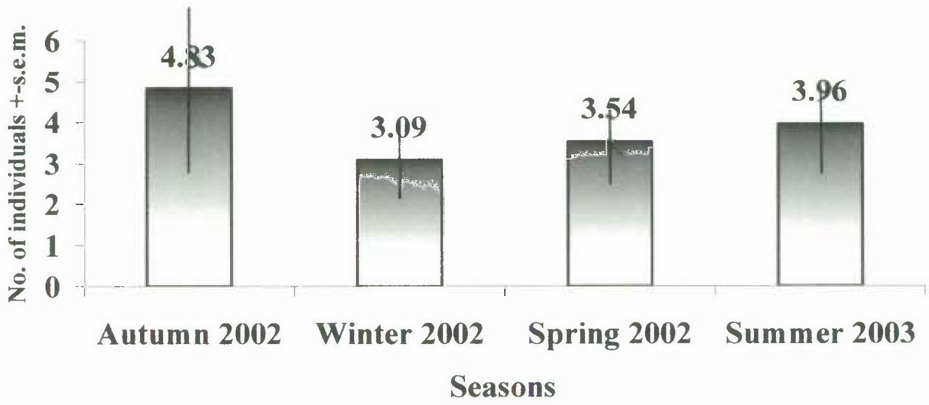

Figure 3.2 Average band sizes (number of individuals in a sighted group) in different sampled seasons on the plateau, with mean given above each bar and error bars representing $\pm$ 1 standard error of the mean (s.e.m.)." Autumn N= 6 bands, Winter N=11 bands, Spring N=13 bands, and Summer N=32 bands.

Frequency of encounters with bands of different sizes are illustrated in Figure 3.3 and observations of identifiable bands are detailed further in Appendix 3.1. Bands with two to three individuals were encountered most frequently over the entire period of study followed by lone individuals. I attempted to distinguish bachelor groups from harem groups, but the flight of horses during observation made sex identification difficult on many occasions. Horse group position and distance into the woodland in addition to their flight further complicated this attempt. It was not possible to make a positive identification on all individuals in bands that were observed.

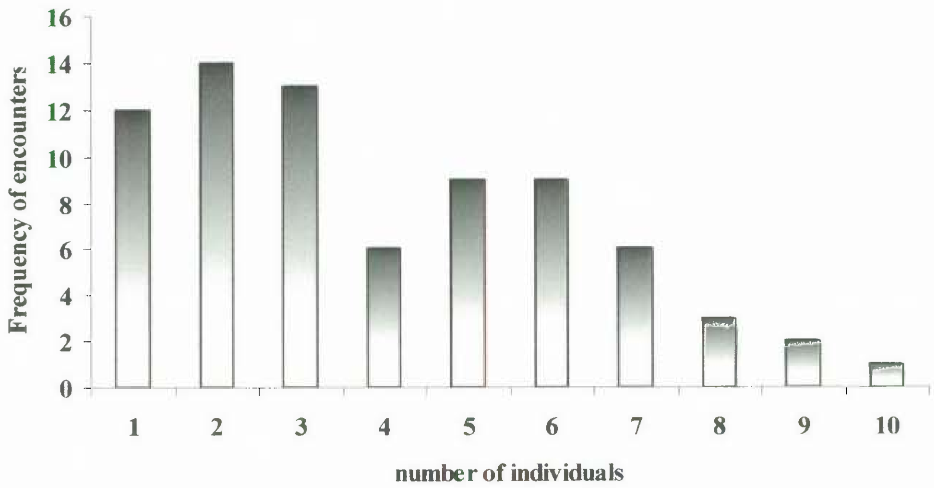

Figure 3.3 Frequency of observations of horse bands given sizes (data from all seasons combined); total sample size of band observations = 75.

3.3.2 Habitat-Use & Distribution Results

It was attempted to test the significance of horse-use of habitats by observations and dung counts in catena levels. To test whether habitat-use varied across the landscape seasonally, it was attempted to compare horse sightings and dung-counts between seasons. Very few horse sightings were recorded leading to expected and observed values <5. There were not enough sightings in any single season to test for distribution differences between seasons. Figure 3.4 shows the percentage of opportunistic horse band sightings in each catena level over different seasons. Transect catena level measurements taken in every 100 m section are presented in Appendix 3.4.

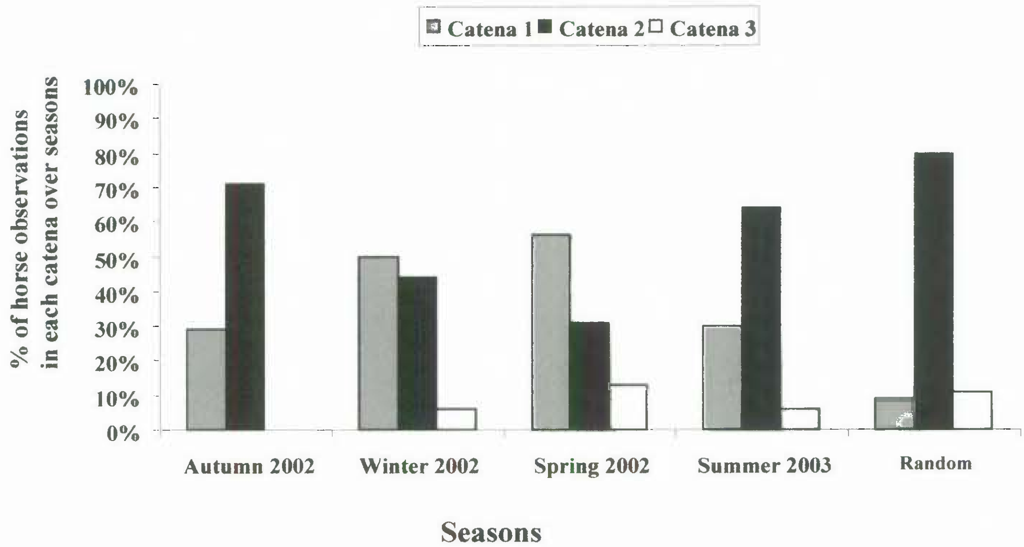

Figure 3.4 Percent of opportunistic horse band counts in each catena level over autumn to summer 2003. Catena 1 – Drainage-line, Catena 2 – Mid-slope, Catena 3 – Ridge-top.

It would have been interesting to investigate whether horse-use of habitats (as shown by observations in catena levels) varied significantly across the landscape seasonally. However, very few horse sightings were recorded, so it was impossible to test the significance of seasonal variation in horse use of habitats using data from opportunistic observations of bands and dung in catena levels because sample sizes within each season were too small. Because seasonal data were too few for statistically valid tests, a single comparison was carried out for all records combined to investigate heterogeneity of distribution of horses amongst catena levels. Refer to Table 3.5 for the raw data. The data shows strongly significant heterogeneity, $X^2 = 99.54$, ($P<0.001$, df=2), with more of an occurrence in the drainage-lines than expected by chance, and less of an occurrence in the ridge-tops than expected by chance.

Table 3.5 Free-ranging horse opportunistic observations across three catena levels in four seasons.

Observed Numbers of Horse Bands						
Catena	**Autumn 2002**	**Winter 2002**	**Spring 2002**	**Summer 2002-03**	**Total**	**Expected**
Drainage-Line	2	8	9	11	30	6.75
Mid-Slope	5	7	5	23	40	60.00
Ridge-Top	0	1	2	2	5	8.25

Dung count sample sizes were adequate in spring and summer to analyse for heterogeneity of dung occurrence between catena levels. Refer to Table 3.6 for the raw data. In spring there was no significant heterogeneity X^2=1.25 (P>0.05, df=2), but in summer there was highly significant heterogeneity X^2=27.35 (P<0.001, df=2) with more dung than expected being counted in drainage-lines and on ridge-tops. The change from spring homogeneity to summer heterogeneity indicate that horses were selective towards drainage-lines during summer.

Table 3.6 Distribution of fresh dung among catena levels in spring and summer, and comparison of the totals with the expected frequencies if horses were homogenously distributed between catena levels.

Transect	Season	DL Catena	MS Catena	RT Catena
Transect 1	Spring	Obs=1	Obs=30	Obs=10
Transect 2		Obs=3	Obs=11	Obs=0
Transect 3		Obs=5	Obs=19	Obs=1
Total		Obs=9	Obs=60	Obs=11
Transect 1	Summer	Obs=9	Obs=18	Obs=18
Transect 2		Obs=4	Obs=13	Obs=0
Transect 3		Obs=7	Obs=27	Obs=2
Total		Obs=20	Obs=58	Obs=20
Total Obs.	**Spring & Summer**	**Obs=29**	**Obs=118**	**Obs=31**
Total Exp.		**Exp= 16**	**Exp=142**	**Exp=20**

Figure 3.5 shows frequency, on each transect, of dung observed in each catena level over spring and summer. Expected frequencies for random distribution are illustrated along side in black for visual comparisons.

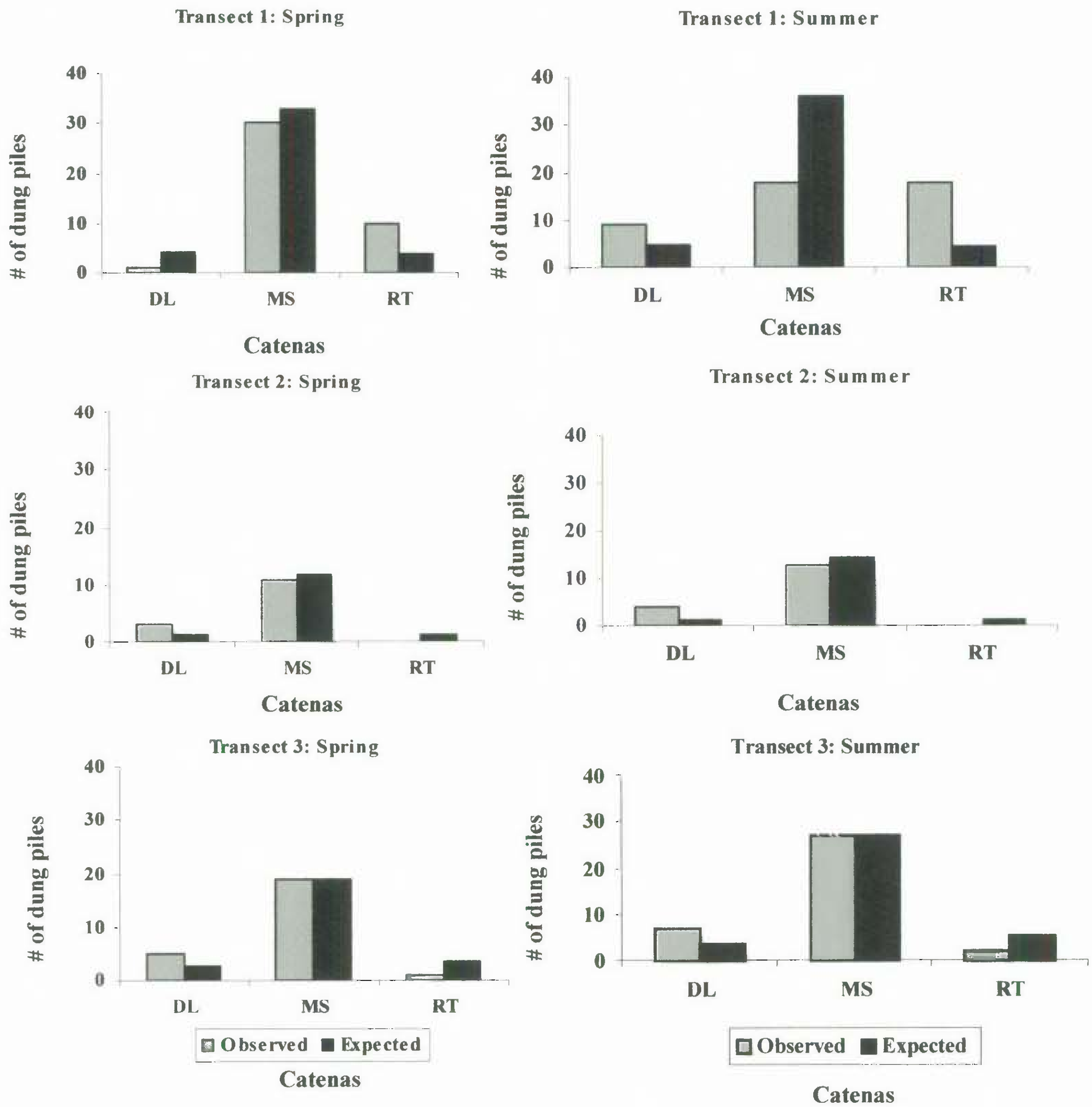

Figure 3.5 Frequency of dung observed and expected (if randomly distributed) in each catena level on each transect in spring and in summer. Y-axis shows frequency of dung piles. X-axis shows Catenas: DL= Drainage Line, MS= Mid-slope, and RT= Ridge-top.

Figure 3.6 shows the frequency of dung of all age in fine- and coarse-grained distance classes originating from the water source located nearest to each of the three transects, and suggests a correlation between horse use and distance to water. Density of dung decreased with increasing distance from the water source at both fine (500 m) and coarse (2000 m) scales. These two scales were adopted to determine the frequency of dung near water sources to determine whether horses preferred to spend time near water. Using a landscape-level approach allowed for investigation of the effect of distance to water upon habitat-use, while the fine-scale approach allowed for analysis of use within habitat immediately around dams. Using the common assumption that horses defecate randomly in space and time, it was assumed that more dung counted meant more use of that area by horses.

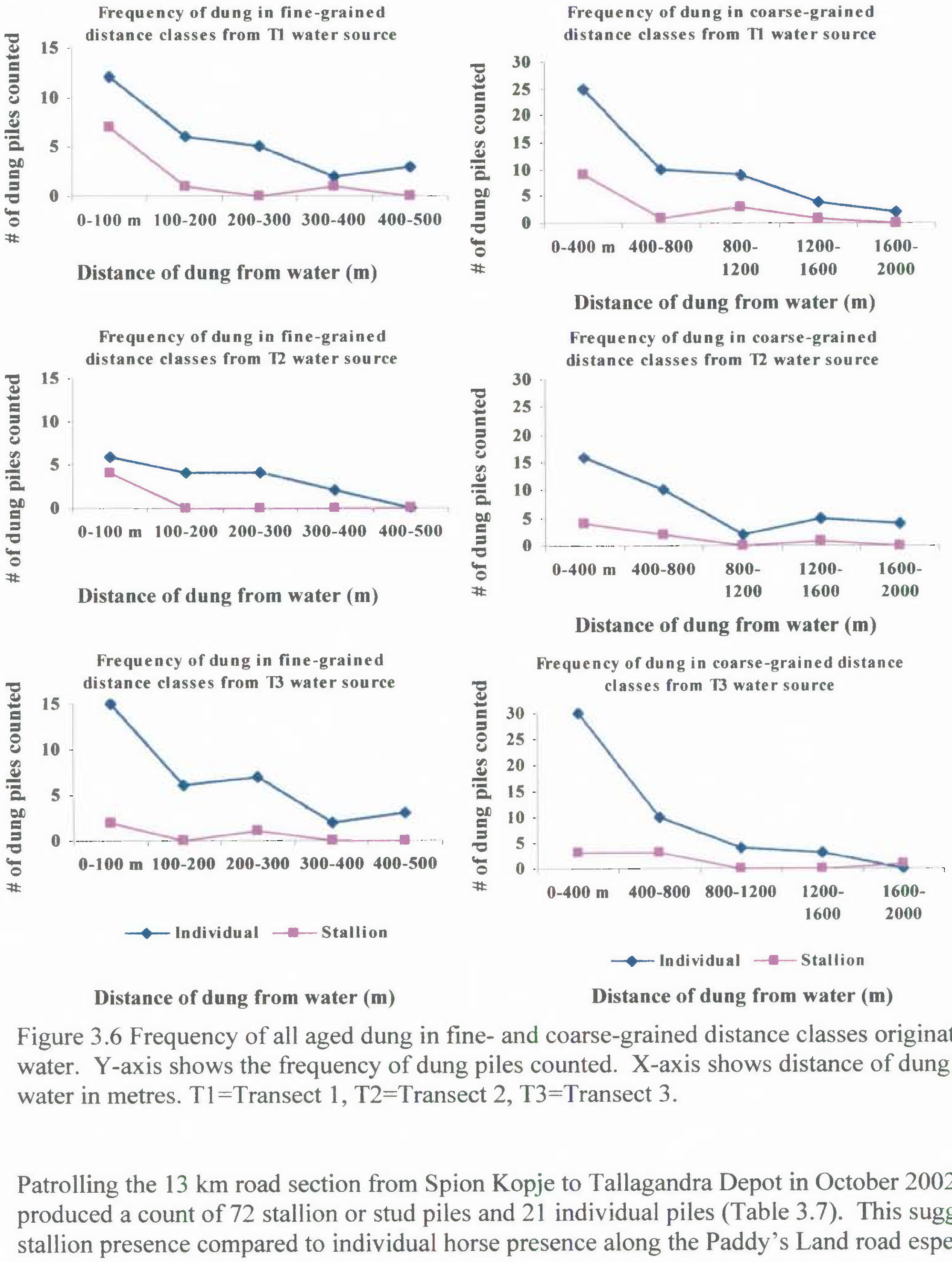

Figure 3.6 Frequency of all aged dung in fine- and coarse-grained distance classes originating at water. Y-axis shows the frequency of dung piles counted. X-axis shows distance of dung from water in metres. T1=Transect 1, T2=Transect 2, T3=Transect 3.

Patrolling the 13 km road section from Spion Kopje to Tallagandra Depot in October 2002 produced a count of 72 stallion or stud piles and 21 individual piles (Table 3.7). This suggests high stallion presence compared to individual horse presence along the Paddy's Land road especially near Spion Kopje and Jock's Creek in the spring. Both locations are near bark-chewing patches, which will be discussed in Chapter 4.

Table 3.7 Patrol for dung along Paddy's Land Road from Spion Kopje Peak to Tallagandra Depot: Conducted October 2002.

Mileage	Individual Dung Piles	Stallion or Stud Piles
0.0 km – Spion Kopje	2	11
1 km	2	18
2 km Boban Hut	1	8
3 km	0	3
4 km	1	2
5 km Dingo Top	1	4
6 km	0	1
7 km	0	2
8 km Ryan's Gully	0	3
9 km Jock's Creek	0	6
10 km	0	3
11 km Old Station Creek	5	4
12 km Braziers Hut	2	4
13 km – NPWS Tallagandra	7	3
Total	**21**	**72**

3.4 Discussion, Implications & Future Research

Although distance-sampling techniques can be useful, a limitation was encountered that affected the results of the transect density surveys. Buckland *et al.* (2001) gave three assumptions that are essential for reliable estimation of density from line-transect sampling. Listed in order from the most to least critical the assumptions are objects directly on the line or point are always detected; objects are detected at their initial location prior to any movement in response to the observer; and distances are measured accurately or objects are correctly counted in the proper distance interval (Buckland *et al.*, 2001). Violation of the second assumption was encountered in this research. Horses moved away from surveyors creating a situation in which almost all the bands were seen near the observable limits on the transect far in front of the surveyors. An under-estimate of observed strip-width was created and hence an over-estimate of horse band density was produced (Buckland *et al.*, 2001; P. Jarman, UNE pers. comm., May 2003). The sample-sizes obtained from systematic counts were extremely small producing very wide confidence intervals. This problem was caused by field conditions not meeting the requirements of the technique.

Highest densities of horses were counted in the summer with 127 individuals counted. Six bands or 29 individuals were known to occupy the plateau over autumn 2002; 11 bands or 34 individuals were known to occupy the plateau over winter 2002; 13 horse bands or 46 individuals were known to occupy the plateau over spring 2002 and 23 horse bands or 127 individual horses were known to occupy the plateau over summer 2003. These numbers should be acknowledged as minimum estimates of the population.

Results from the 13 km Paddy's Land plateau Road patrol generated in September 2002 suggested high stallion presence along the road, especially near Spion Kopje and Jock's Creek. Spion Kopje.

Many more stallion piles of dung were found along the road than individual piles, whereas individual piles outnumbered stallion piles by 2 or 3 times along transects through the woodland. This interesting difference may suggest free-ranging horse band home-ranges. It is common for animals to deposit scent marks (which is what a stallion pile is) along tracks and routes, so that other animals will know they are passing through the home-range of a stallion (P. Jarman pers. comm. August 2004). Horses near Jock's Creek, which was dry through the course of this study, were observed in the drainage-line catena level. As stated in Chapter 2, bachelor males tend to occupy the largest living areas while harem bands occupy smaller, more stable, living areas near water sources (Linklater *et al.* 2000). Both dams in that area had been depleted since the end of spring 2002 (pers. obs., October 2002), so conceivably, the horses sighted there were bachelor males.

Larger band formation was observed near the eastern plateau during one end of the summer patrol. Three bands with seven or more individuals were seen near the dam and two of the bands were occupying the same area of approximately 100 m x 100 m. The eastern edge of the plateau has access to Bob's Creek via Boban Creek, and had both available water and large pasture during summer 2003 (pers. obs. February 2003). Horses and cattle were seen frequently on the eastern sector of the plateau grazing the pasture and near the dam, particularly during summer. Perhaps the horses (and cattle) aggregate regularly in this area. There were observed stock trails along many drainage line areas on the plateau, and perhaps these trails lead horses from Bob's Creek to the plateau during summer when water and nutritional demands are high.

Results from this chapter combined with results from Chapter 4 are consistent with a migration of free-ranging horses out of the gorge country on to the plateau in Summer 2002-2003. This evidence is compatible with anecdotal reports (T. Prior pers. comm. 2002) of horse migrations up Bob's Creek and onto the plateau and back to the gorge system again. Perhaps a migration only occurs sporadically during droughts. Heavy Rains came at the end of summer and observations during a sampling field trip showed that Bob's Creek started flowing (pers. obs. February 2003). Conceivably the horses dispersed back down to Bob's Creek, as a NSW NPWS helicopter survey over the plateau, on 14 July, yielded not one horse (pers. obs. July, 2003).

Migrations by free-ranging horse bands have been reported (Linklater et al., 2000). Crane *et al.* (1997) stated that the lower use than availability of lowland sagebrush habitats by free-ranging horses might be related to forage productivity and succulence compared to higher elevation habitats. The avoidance of lowland habitats by free-ranging horses led Crane *et al.* (1997) to believe that there was a seasonal migration from lower to higher elevations in summer.

A management option would be to implement passive trapping during the dry times when bands are more abundant on the plateau. Trapping locations could be centered around the five known resource-use areas, where horses chew bark and drink at dams on the plateau. The major resource use areas where trees are damaged and dams are utilised surround Bob's Creek drainage (see Chapter 4). Figure 3.6 illustrated that horse use can be correlated with available water sources and showed decreasing frequency of horse dung with increasing distance from water sources.

The degree of selection for seasonal drainage-line habitats over the study area seems noteworthy considering concern for native species diversity and conservation. Springs and other drainage-line areas are oases of higher productivity, especially if not overly disturbed. Because they receive continuous water and nutrient inputs, undisturbed high productivity areas provide a useful benchmark of diversity against which to compare horse occupied areas (Beever & Brussard, 2000). Spring and drainage-line areas are used by many taxa far more than predicted by their area extent and these areas play vital roles in maintaining diversity at landscape or regional scales (in Beever & Brussard, 2000). Chapter 5 explores methods for measuring grazing in a drainage-line corridor.

Selection for drainage-lines leads to an interesting correlation between both migration patterns and impacts. A migration of horses out of the gorge country on Paddy's Land plateau in summer and their reliance on dams for water raises an interesting question. Do the plateau dams, which were originally sunk for cattle, support free-ranging horses in the park? It has been suggested that the restoration of the seasonal drainage lines, by stock pond removal and ecosystem repair, would reduce the advantage that the dams offer to non-native species (G. Elliott pers. comm. July 2004) and could possibly restrict the natural rate of increase of horses in the park (N. Reid pers. comm. April 2004). Shifting the eucalypt woodland back to a natural system by restoring seasonal drainage-lines could benefit native biodiversity and reduced horse numbers on the plateau as well.

Studies of restoration success for native Australian vegetation are limited, and similar conclusions have emerged from restoration studies in different Australian ecosystems (Wilkins et al., 2003). The development of species composition in restored Australian sites towards a state that resembles appropriate reference sites is, at best, extremely slow and may not eventuate at all (Wilkins et al., 2003). However, the limited success of Australian restoration projects should not be interpreted as a reason for their abandonment. Perhaps the option or restoring the dams to a stable drainage-line system should be considered. This recommendation will be further discussed in Chapter 6.