CHAPTER FOUR

IMPACT LEVELS OF GRAZING AND MOVEMENT

4.1 Introduction

Animal species can alter the environment they inhabit by excessively grazing introduced and native plant species, disturbing the leaf litter and over-compacting the soil surface and regenerating vegetation (Neave and Tanton 1989, Belsky 1992, Pettit *et al.* 1995, Ramsey and Wilson 1997, Sheath and Carlson 1998, Bennett 1999). The aim of the project component described in this chapter was to gain better knowledge of the effects Black-striped Wallabies were having upon the native and introduced vegetation at the Study Site. Wallaby impact was measured in selected areas of the Reference Site and adjacent pastures by using exclosures.

Various exclosure designs have been used by researchers to determine the regeneration ability or the effect of grazing by a number of different species; for example, studies have looked at the effects of grazing by cattle in south east Australia (Carr and Turner 1959), macropods in south east Queensland (Ramsey and Wilson 1997), kangaroos and rabbits in south east Australia (Neave and Tanton 1989), sheep and ponies in Wales (Latham and Blackstock 1998), large ungulates in the United States (Kay and Bartos 2000), ungulates in Kenya (Oba *et al.* 2001), cattle in north eastern Australia (McIvor 2001), cattle and medium-sized macropods in central Queensland (Baxter *et al.* 2001) and White-tailed Deer in New Zealand (Bellingham and Allan 2003). The exclosure monitoring technique was used in the current study, as exclosures were relatively low-cost to set up and could be monitored by one person.

Comparisons of vegetation growth between grazed and un-grazed exclosures would demonstrate if the wallabies affected regeneration of remnant biomass. Exclosures were also established in a paddock of introduced pasture grass to investigate the affect of wallaby grazing on pasture biomass.

It is thought that scrub-dwelling species such as Black-striped Wallabies do not venture far from shelter habitat, travelling only a couple of hundred metres to feed (Evans 1996). However, little research has been undertaken to determine whether this distance is influenced by factors such as season, pasture type, shelter type, or numbers of wallabies in the area. Faecal pellet counts during different seasons, along transects perpendicular to the remnant edge in various areas, were implemented to give an indication of how the level of wallaby usage changed with distance into the paddock from the shelter habitat.

This chapter also focused on the effects of trampling the ground, forming what are commonly referred to as pads. As with most animal species, it was expected that the Black-striped Wallabies disturb the environment in which they live, simply by moving around within it; but the degree of effect was unknown. Bhuju and Ohsawa (1998) report how nature trails walked by humans affect soil surface compaction, vegetation cover, understorey succession and species richness. However, as found by Cole and Spildie (1998), the intensity of impact varies with the type of animal doing the impacting and, although higher trampling intensities cause more disturbance, the relationship is non-linear. In their experiment, a six-fold increase in trampling intensity approximately doubled the loss of vegetation cover and height reduction. The level of

effect may depend upon the soil type, the vegetation species and its regeneration capabilities.

It is possible that the amount of impact exerted by Black-striped wallabies in this area was affecting regeneration. Although determining the effect of such impacts would require similar studies to those of Bhuju and Ohsawa (1998), an important preliminary step was to determine how much ground is affected by wallaby movement (i.e. the proportion of ground covered by wallaby pads/tracks).

Finally, the monitoring of water usage by Black-striped Wallabies at the Study Site is also detailed in this chapter. Limiting the availability of water may be a management strategy for a species that requires a regular intake of water. Larger macropods such as the Eastern Grey Kangaroo (*M. giganteus*) need to drink regularly (Dawson *et al.* 1975), whereas other macropod species, e.g. Tammar Wallaby (*M. eugenii*), are facultative drinkers and have been reported to not drink at all, satisfying their water requirements through the plants they eat (Lentle *et al.* 1999).

It has not been established in published literature whether Black-striped Wallabies are obligate or facultative drinkers. To determine the Black-striped Wallabies' need to drink, water utilisation was monitored by recording the number of macropod footprints around water bodies. It was expected that, if drinking was required daily or frequently, then there would be a high number of prints surrounding available surface water.

4.2 Methodology

4.2.1 Exclosures

a) Exclosures in Scrub

To examine the effects of wallaby feeding on vegetation in representative areas of remnant scrub, exclosures were erected in the scrub components of Sampling Areas 1, 2 and 4 in August 2000. Exclosures (= a treatment 'Closed' to some or all herbivores) were 3x3m square, and surrounded by 900mm-high chicken wire mesh fence. An unfenced 3x3m control area (= 'Open' to herbivores) was also chosen near each closed pen within similar vegetation and marked only by pegs at each corner so as to not obstruct herbivore access (Figure 4.1a and b). Each of these two types of exclosures (Open and Closed) were replicated in each of the Sampling Areas with one Closed and one Open pen approximately 20m apart and the replicate pair located approximately 100m away. These pairs formed the blocks in statistical analysis.

Preliminary monitoring in October 2000 and January 2001 defined the number of quadrats and frequency of sampling. During that time skills in identification of plant species were also practised. Monitoring of exclosures began after an 8-month settling-down period in April 2001, and exclosures were then revisited in October 2001 (~14 months after initial fencing), April 2002 (~20 months), October 2002 (~26 months) and April 2003 (~32months after initial fencing).

a. 'Open'

b. 'Closed'

Figure 4.1a&b. Scrub exclosures in Sampling Area 1.

Twenty-five 0.5x0.5m ($0.25m^2$) quadrats were mapped for monitoring in each exclosure, with a 0.25m buffer left unsampled around the inside edge of the pen perimeter, allowing for any grazing through the mesh fence, Figure 4.2.

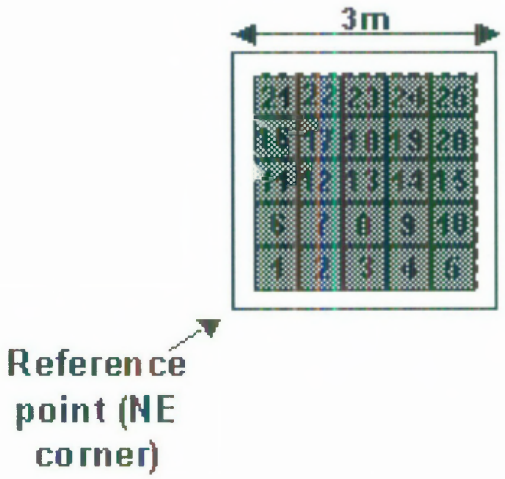

Figure 4.2 Diagram of scrub exclosures. Exclosures were 3x3m with a 0.25m perimeter buffer. Quadrats numbered 1 to 25 were ordered from the north east corner as shown. Each season 10 quadrats were monitored by randomly selecting 10 numbers from between 1 and 25.

Black-striped Wallaby utilisation of the area and habitat description was determined by recording the number of Recent and Old faecal pellets, the percentage of ground that was bare, covered in leaf litter (including logs, stones, bark) and covered by vegetation, the number and types of vascular plant species present and the height of the vegetation. Additionally, during some monitoring periods the number of grasses with seed heads was recorded. The criteria for recording all these variables were the same as described in Section 3.2.4.

Preliminary analysis of the data was done by Analysis of Variance (ANOVA) using Genstat (Genstat 2002). Transformation of the data set was required due to a large number of zeros making it highly left skewed (Poisson distribution). In addition, the data for a number of variables were scaled between 0 and 100%, causing problems with

analysis. Therefore those percentage variables (bare ground, ground covered by vegetation, ground covered by the combined leaf litter and ground covered by each vegetation type) were transformed to a ratio of each variable to the sum of the other percentage-ground-cover values ([x]:[100-x]). Individual species' percentage-ground-cover values were also transformed by converting them to a ratio value of each species to the sum of the other species percentage ground cover values ([x]:[100-x]). Even though the ratio distributions were still one-tailed, the transformed values could be analysed by ANOVA with Time (April 2001, October 2001, April 2002, October 2002, April 2003) and Treatment (Open, Closed) as fixed effects and exclosure replicates as the block structure.

The averaged seasonal values of the non-percentage variables (number of faecal pellets, general height of vegetation, number of species, number of grasses with seed, and the individual height of each vegetation species) were analysed by ANOVA without transformation. Time (April 2001, October 2001, April 2002, October 2002, April 2003) and Treatment (Open, Closed) were used as fixed effects and replicates as the block structure. The fixed-effect interactions were tested but then removed if found to be not significant. Within each Sampling Area the predicted means of each variable in each Treatment were compared for significance using the LSD method; however, where transformation was undertaken results are presented as back-transformed means.

b) Exclosures in Pasture

To investigate the impact of wallaby feeding on vegetation in the paddock, six 10x10m exclosures were erected in August 2000 within Area 4 at the northern end of 'P2 paddock', a developed paddock of Buffel grass (*Cenchrus ciliaris*) and Rhodes grass

(*Chloris gayana*) in an area known to be grazed by high densities of Black-striped Wallabies. Exclosures were constructed 10m apart from each other in a parallel line 13.5m out from the paddock fence, or ~23.5m out from the scrub edge

The first exclosure type, the Fully-Closed (FC) Treatment, was fenced with 900mm-high chicken wire and a top strand of barbed wire approximately 110cm high, excluding all vertebrate grazers. The second exclosure type, the Half-Open (HO) Treatment, was designed to exclude cattle but not wallabies and so was fenced with three strands of barbed wire, the first approximately 40cm from the ground and the third approximately 110cm from the ground (Figure 4.3). The third exclosure type, Fully-Open (FO), was a control treatment consisting of a pegged area allowing access by all herbivores. The three exclosure Treatments each had two replicates, making a total of six exclosures.

Figure 4.3 A Half-Open pasture exclosure in a paddock of introduced pasture grass. In the top right hand corner a Fully-Closed exclosure with 50cm high grass can be seen.

During the experimental period, Black-striped Wallabies were observed in the area (northern end Sampling Area 4) during all seasons. Cattle were present in the paddock for 2 months from mid-September to mid-November 2000, for 3 months from 30th October 2001 to 6th February 2002 and for 2.5 months from 12th April to 3rd July 2002. Spotlighting and daytime observations of the surrounding area prior to and throughout the period of the study (approximately 3 years) only once detected Eastern Grey Kangaroos (one group of three individuals) and so it was assumed that Black-striped Wallabies and cattle were the principal mammalian grazers within the Sampling Area. This assumption was supported by the absence of faecal pellets from any grazers other than Black-striped Wallabies and cattle within the area surrounding the exclosures.

Preliminary monitoring in October 2000 and January 2001 defined the methodology, the number of quadrats and frequency of sampling required, and allowed familiarisation with vegetation species identification.

A 1m wide perimeter buffer was left unmonitored (Figure 4.4), to allow for grazing by animals reaching over the top or through the wire or influences of the fencing. In the original experimental design exclosures were monitored each season by sampling eight $0.25m^2$ quadrats spaced 1m apart, along the two randomly selected transects per pen, giving a total of 16 quadrats monitored in each exclosure, in each season. Therefore, a total of 8 transects were to be monitored once in each pen by the end of the fourth sampling season.

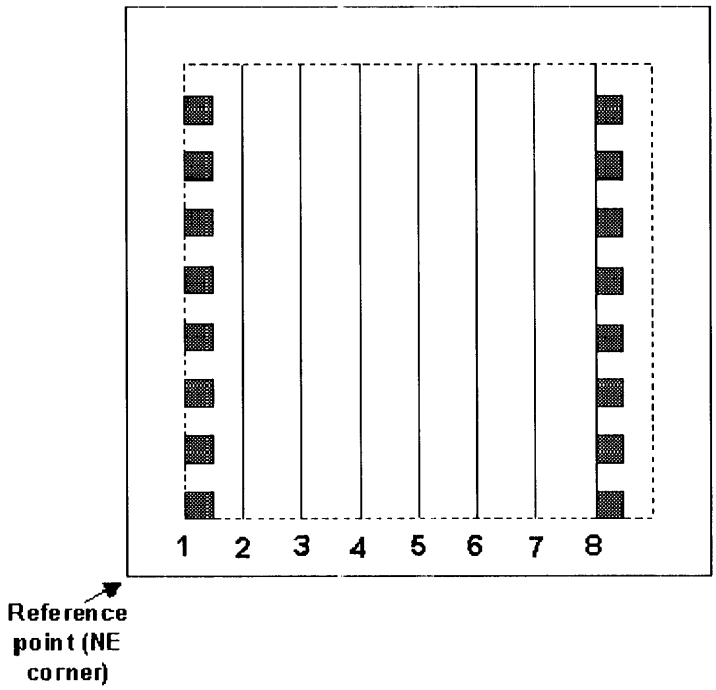

Figure 4.4 Diagram of pasture exclosures. The 10x10m fence is shown by the largest square and the 1m-wide perimeter buffer zone by the dotted line box inside it. Transects spaced 1m apart are shown numbered and quadrats 0.5m apart, are shown by the square boxes along Transects 1 and 8 to demonstrate quadrat placement.

Monitoring of exclosures and cutting of quadrats began in April 2001 after a settling-down period of ~8 months (covering one growing season) after exclosure establishment. Exclosures were then re-monitored in October 2001 (13 months after establishment), April 2002 (19 months after establishment) and October 2002 (25 months after establishment), Table 4.1a.

The nearly complete absence of cattle through the first year of the experimental period disrupted the experimental design. In an attempt to simulate a re-start to plant growth under the experimental conditions with cattle present, transects 3 and 7 that were cut originally in October 2001 were re-monitored and re-cut in April 2002, and then again

in October 2002, sampling the same eight 0.25m^2 quadrat positions along each transect that were originally monitored in October 2001, Table 4.1b.

Table 4.1a. Timeline of events for pasture exclosures, Experiment 1.

Season	Grazers Present - Exclosure Type (Treatment)#			Rainfall (mm)	Transects Monitored	Transects Cut
	FC	HO	FO			
October 2000	*Exclosures established*					
April 2001	*none*	*wallabies*	*wallabies, cattle for 2wks*	538.5	2, 4	2, 4
October 2001	*none*	*wallabies*	*wallabies, no cattle*	48.4	3, 7	3, 7
April 2002	*none*	*wallabies*	*wallabies, cattle for13wks*	481.6	5, 8	5, 8
October 2002	*none*	*wallabies*	*wallabies, cattle for12wks*	172.9	1, 6	1, 6

FC=Fully-Closed, HO=Half-Open, FO=Fully-Open.

Table 4.1b. Timeline of events for pasture exclosures, Experiment 2. Transects were re-cut to simulate a restart to the experimental design.

Season	Grazers Present - Exclosure Type (Treatment)#			Rainfall (mm)	Transects Monitored & Cut
	FC	HO	FO		
October 2001	Transects 3 and 7 cut to ground level				
April 2002	*none*	*wallabies*	*wallabies, cattle for13wks*	481.6	3, 7 (2nd cut)
October 2002	*none*	*wallabies*	*wallabies, cattle for 12wks*	172.9	3, 7 (3rd cut)

FC=Fully-Closed, HO=Half-Open, FO=Fully-Open.

Monitoring included recording the number of Recent and Old faecal pellets, biomass rank on a scale of 1-5, vegetation height, percentage of bare ground, percentage of ground covered by leaf litter (including stones and logs etc), the number of vegetation species and percentage of ground covered by each. The methodology for recording these variables was the same as described in Section 3.2.4. Once all parameters had

been recorded, above-ground vegetation within the quadrat was cut to ground level, collected and dried to constant weight in a ventilated oven at 75°C.

Analyses of the originally designed experiment and the additional experiment were undertaken separately. As with the transect description data and the scrub exclosure data, variables recorded as a percentage value and scaled between 0 and 100% (bare ground, leaf litter, total vegetation cover), were transformed to a ratio of the sum of the other percentage ground cover values ([x]:[100-x]); except total vegetation cover which had values of 100% cover and therefore could not be transformed. That variable had normal distribution so it was analysed without transformation. The percentage ground cover for each species were also transformed to the ratio value to the sum of the other species percentage ground cover values. The biomass rank scale values (0-5) were converted to t/ha using reference cut weight ranks taken each season. All other variables (density of faecal pellets, number of plant species, height of vegetation and height of individual plant species) did not require transformation.

The cut biomass weight data (converted to t/ha) was not replicated the same way as the other variables, as the cut vegetation from each quadrat was collected and combined for each transect. Therefore, instead of 32 values for each treatment there were only 4.

For the first experiment, data was analysed by ANOVA (Genstat 2002) with a Year (2001 and 2002), Season (April and October) and Treatment (Fully-Open, Half-Open and Fully-Closed) as fixed effects and replicates as the block structure. The fixed-effect interactions were tested but removed if found to be not significant.

Data from the second experiment was also analysed by ANOVA (Genstat 2002) but with only Season (April and October) and Treatment (Fully-Open, Half-Open and Fully-Closed) as fixed effects and replicates as the block structure. The fixed-effect interactions were tested but then removed if found to be not significant.

For both experiments the predicted means of each variable, in each Treatment, were compared for significance using the LSD method; however where transformation was undertaken results are presented as back-transformed means.

4.2.2 Faecal Pellet Counts – Pasture Transects

Faecal pellet counts were undertaken a third time along a number of transects in pasture paddocks adjacent to the Reference Site, to determine if the Black-striped Wallabies on Brigalow Research Station were grazing up to a couple of hundred metres from shelter as previously suggested by Evans (1996). It was also of interest to determine how far out from the shelter scrub edge the wallabies undertook the highest amount of grazing (highest degree of wallaby usage).

Transects started at the paddock boundary and traversed up to 300m into the pasture paddocks. Transects were monitored in the following Seasons: Autumn 2001, 1; Winter 2001, 2; Spring 2001, 3; Summer 2002(a), 4; Winter 2002, 5; Summer 2002(b), 6. In May, July and September 2001 three transects were monitored, all located in the vicinity of the pasture exclosures (northern end Sampling Area 4). In January and July 2002, twenty-four transects were chosen from around the perimeter of the entire remnant area with 12 on the southern side (two in each paddock) and 12 on the northern side. However, in January only 13 transects could be recorded, mainly on the southern

side of the remnant area. The remaining 11 were inaccessible due to Parthenium (*Parthenium hysterophorus*) infestation. By July 2002, access had improved and 21 transects were monitored. In December 2002, four transects were monitored, one each located in each of the Sampling Areas 1, 2 and 4, and one in Sampling Area 3 beside the dam.

Along each transect monitoring was carried out within 0.25m^2 quadrats placed squarely at the toe of the recorder at ~4m intervals (5 paces). The number of Recent and Old faecal pellets were counted within each quadrat, with pellets identified and categorised using the same techniques as used for counting faecal pellets along Reference Site transects (Section 3.2.3.). Pasture transects were set at a maximum length of 300m; however, if the pellet count was extremely low to zero over a consecutive number (4-5) of quadrats then monitoring of the transect ceased before the 300m endpoint was reached (Table 4.2).

Table 4.2 Number of pasture transects monitored and the length covered in the Sampling Area each Season monitored.

Season	Sampling Area	No. of Transects	Transect Lengths (m)
1. Autumn 2001	4	3	200, 200, 200
2. Winter 2001	4	3	300, 300, 300
3. Spring 2001	4	3	300, 300, 300
4. Summer 2002	2	2	300, 248
	3	7	100, 52, 52, 80, 60, 70, 300
	4	1	200
5. Winter 2002	2	11	60, 300, 76, 76, 100, 100, 152, 252, 300, 200, 300
	3	6	300, 200, 252, 100, 200, 224
	4	3	300, 252, 276
6. Summer 2002	2	6	76, 52, 112, 100, 100, 68
	4	2	300, 300

Counts of Recent and Old faecal pellets per quadrat were converted to density per m^2. Each transect was assigned to a Sampling Area (2, 3 or 4) and values for quadrat position along the transects were averaged within those Areas for each Season. The inconsistency in data collection (different transects monitored to different distances within different seasons) meant data analysis was not feasible. However, the seasonal mean densities of Recent and Old faecal pellets in each Sampling Area are displayed graphically using a scatter plot with line of best fit.

4.2.3 Pad Coverage

Pad coverage measurements were undertaken during Summer 2002 and Winter 2002 to determine the extent of disturbance Black-striped Wallaby activity to each Sampling Area. Forty locations were selected randomly throughout the Reference Site and adjacent paddocks, ensuring all Sampling Areas and Vegetation Categories (scrub and pasture) were sampled. However, because of heavy Parthenium infestation, not every location could be sampled in both seasons.

At each monitored location, five 10m tape transects were cast out along the ground, each in a different random direction. The number of wallaby pads that crossed each 10m length was recorded, along with the perpendicular width of each pad at that point (Figure 4.5).

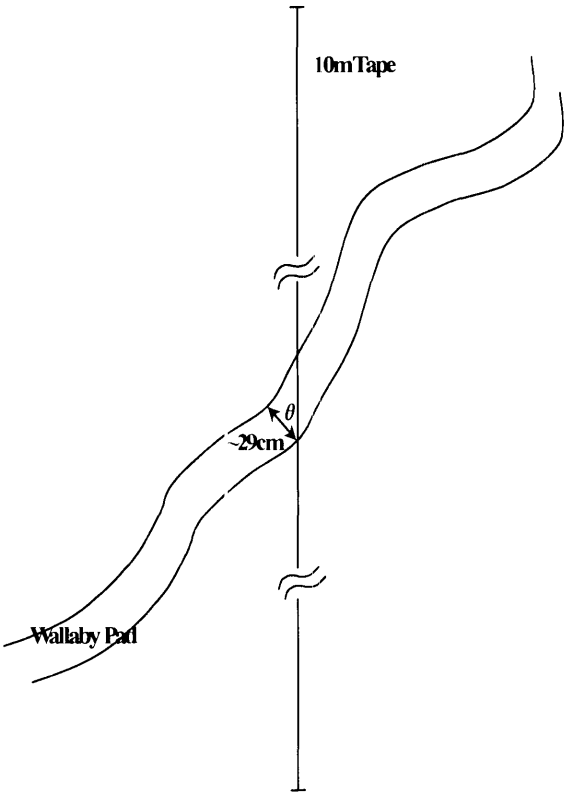

Figure 4.5 Measuring the proportion of 10m tape covered by Black-striped Wallaby pads.

As all 10m tapes were laid in random directions, the average angle at which pads crossed the tapes (θ) can be assumed to average 45° because, as direction is not important, all the angles will randomly fall between 0° and 90° to the tape. The mean recorded pad width was calculated to be 29cm. A pad crossing a tape at 45° forms a right angle triangle with its mean width (29cm) making the length of the two even sides, and its hypotenuse equalling the unknown proportion length, or length of wallaby pad, that crosses the 10m length of tape. Using the following formula:

$$\sqrt{l^2 x 2}$$

the unknown length, or hypotenuse, was calculated to be 41cm. Therefore, for each pad recorded, the proportion of 10m tape (or ground) that was impacted upon by the pad equalled 0.041. Each pad width was converted to a proportion of the 10m tape and then

multiplied by 0.041 to determine the proportionate amount of ground along each 10m tape that was impacted upon by a wallaby pad in each location during summer and winter.

For analysis each location was assigned to a Sampling Area (1, 2, 3 or 4) and a Vegetation category (scrub or pasture). Comparisons of the proportion of ground affected by pads was made using REML (Genstat 2002) with Season, Sampling Area and Vegetation Category as factors.

4.2.4 Water Usage

Water usage was studied by monitoring wallaby prints around water bodies to establish whether water was a primary requirement for Black-striped Wallabies, and therefore perhaps a determinant of movement and habitat use in the area by individuals.

During January 2002 (summer, wet season) any gilgai or melonhole that was found containing water was inspected. The location, surrounding vegetation and general characteristics of each gilgai were noted. While circumnavigating the gilgai, all prints around the waters edge were recorded by noting, if possible, what species had made them and the direction the prints were heading (up to or around the gilgai). Prints were identified with the aid of Triggs (1997). All macropod prints recorded were assumed to belong to Black-striped Wallabies; except very large macropod prints, which were recorded as being 'Eastern Grey Kangaroo'. Although not the focus of the study, tracks of non-macropod species (dog, cat, pig, bird and cow) were also noted if present. In July and October 2002 (mid and late dry season), observations using similar techniques were made around the water's edge of N4 dam and Becker's dam, north of Sampling Area 2.

4.3 Results

4.3.1 Exclosures

a) Exclosures in Scrub

Large differences between numerous monitored variables' suggest that Black-striped Wallabies were affecting each of the Sampling Areas monitored. Table 4.3 gives the means for the Open and Closed exclosures in each Sampling Area. The significantly higher faecal pellet density (Recent and Old) in the open exclosure, compared to the Closed exclosure, establishes that the Open exclosures were being utilised by wallabies in each Sampling Area. The small density of pellets in the Closed treatment is thought to have occurred by pellets being washed in by rain or kicked in by wallabies.

Treatment difference patterns in Sampling Areas 1 and 2 (Fenced and unfenced Brigalow forest) resembled each other more than either resembled the pattern in Sampling Area 4 (Softwood Scrub). In Sampling Areas 1 and 2 nearly all the means differed significantly between the treatments (Table 4.3). In most cases, means were greater in the Closed treatment (e.g. percent vegetation cover, percent leaf litter cover, height of vegetation, number of plant species, number of seedheads). The percent bare ground in Sampling Area 1, however, was higher in the Open treatment. Fewer means differed significantly between the treatments in Sampling Area 4; only the amount of bare ground, percent cover of leaf litter, and percent vegetation cover. The means relating to vegetation (height, number of species, etc.) were generally low to zero making it difficult to find significant differences between the treatments.

A number of means were consistently different between treatments every season (dependent on Sampling Area); however, other means exhibited significant differences

only in certain seasons. Table 4.4 gives the means for each variable by season. The density of Old pellets was consistently higher in the Open treatments each season for Sampling Areas 1 and 2, but only during the October monitorings in Sampling Area 4. The seasonal variation in the remaining habitat variables suggests that any overall significant difference between the treatments (Table 4.3) was most likely due to sporadic events. In spite of the seasonal differences, the general conclusions to be drawn from the results in Table 4.3 remain valid.

Table 4.3 Variables monitored within the Scrub exclosures, Brigalow Research Station, 2000-2003.

	Sampling Area 1				Sampling Area 2				Sampling Area 4			
	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.
Old pellets /m^2	0.1	5.8	0.5	***	3.2	14.6	1.1	***	0.2	10.5	0.8	***
Recent pellets /m^2	0.0	0.7	0.2	**	0.0	0.2	0.3	***	0.0	112.0	1.2	***
Percent bare ground	16.5	34.0	4.1	***	67.2	56.7	18.0	*	43.4	58.4	10.3	***
Percent litter cover	60.8	67.1	22.3		39.6	49.0	7.1	**	78.3	57.6	21.4	***
Percent veg. cover	38.6	25.5	4.8	***	23.8	18.1	3.6		6.3	4.0	0.8	*
No. of veg species	3.5	3.3	0.1		3.4	2.9	0.1	**	1.23	1.23	0.1	
No. with seedheads	1.6	0.1	0.1	***	2.3	0.9	0.2	***	0.0	0.0	---	
Mean ht (mm)	36.5	19.3	2.3	***	35.4	22.0	3.1	**	9.2	4.5	2.6	
Minimum ht (mm)	3.6	0.0	1.0	**	3.3	0.5	1.8		0.0	0.0	---	
Maximum ht (mm)	75.2	53.3	4.8	***	86.7	60.9	6.0	**	29.4	13.3	10.3	
Median ht (mm)	33.6	12.0	2.4	***	25.9	13.3	3.3	**	3.7	2.5	0.6	

Means and standard errors of means (SEM) from ANOVA, n=200 for each Sampling Area. Averaged seasonal values within a Sampling Area on each row were tested for significant difference. Asterisks denote level of significance *** $p<0.001$, ** $p<0.01$, * $p<0.05$.

Table 4.4 Seasonal values of variables monitored within the Scrub exclosures, Brigalow Research Station, 2000-2003.

		Sampling Area 1				Sampling Area 2				Sampling Area 4			
	Season	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.
Old faecal pellets/m^2	April 01	0.0	3.2			4.4	9.2			0.0	0.8		
	October 01	0.4	10.8		*	6.6	16.8		*	0.6	11.2		*
	April 02	0.2	3.8	1.2	*	1.6	18.6	2.4	*	0.0	0.4	1.7	
	October 02	0.0	7.0		*	0.8	16.4		*	0.2	39.0		*
	April 03	0.0	4.4		*	2.8	12.0		*	0.0	1.2		
Recent faecal pellets/m^2	April 01	0.0	1.2		*	0.0	0.0			0.0	1.2		
	October 01	0.0	0.6			0.0	5.8		*	0.0	24.8		*
	April 02	0.0	0.0	0.4		0.0	0.2	0.6		0.0	0.0	2.6	
	October 02	0.0	0.8			0.0	2.0			0.0	33.8		*
	April 03	0.0	0.8			0.0	0.0			0.0	0.0		
Percent bare ground	April 01	20.4	27.1			72.0	54.6		*	50.9	55.6		
	October 01	21.6	46.4		*	71.1	53.3		*	30.2	48.8		
	April 02	15.3	31.6	8.6	*	60.2	47.6	32.9		54.7	63.9	20.4	
	October 02	13.3	28.4		*	62.4	58.5			25.0	70.5		*
	April 03	11.2	32.2		*	67.4	65.4			45.2	39.5		
Percent litter cover	April 01	46.8	70.3			39.1	36.3			64.5	64.8		
	October 01	52.4	51.5			41.2	49.1			77.9	63.0		*
	April 02	64.9	59.0	39.2		40.2	51.4	14.5		51.9	55.6	37.8	
	October 02	70.9	76.5			43.6	59.5		*	91.4	37.9		*
	April 03	60.2	67.3			32.8	33.7			48.7	56.3		
Percent veg. cover	April 01	48.5	31.6		*	28.1	23.1			2.1	0.8		
	October 01	32.8	16.7			15.8	15.3			0.8	3.1		
	April 02	26.3	33.2	10.1		19.1	17.7	7.7		2.6	0.5	1.8	
	October 02	31.6	16.3			25.8	11.2		*	1.9	1.1		
	April 03	47.2	26.5		*	28.8	21.9			20.6	13.2		*
No. with seedheads	April 02	1.7	0.0	0.2	*	1.8	1.0	0.4		0.0	0.0	0.0	
	April 03	1.6	0.2		*	2.8	0.9		*	0.0	0.0		

Means and standard errors of means (SEM) from ANOVA, n=20 for each Sampling Area. Averaged seasonal values within a Sampling Area on each row were tested for significant difference. Asterisks denote $p<0.05$.

Table 4.4 *cont.* Seasonal values of variables monitored within the Scrub exclosures, Brigalow Research Station, 2000-2003.

No. of plant species	April 01	4.4	4.5			4.6	3.7		*	1.1	0.9		
	October 01	3.2	3.0			2.8	2.4			0.4	0.5		
	April 02	3.8	2.9	2.9	*	3.2	2.9	0.3		0.5	0.4	0.2	
	October 02	2.3	2.5			2.7	2.1		*	0.1	0.2		
	April 03	4.0	3.8			3.8	3.7			4.1	4.3		
Mean height (mm)	April 01	37.5	18.4		*	39.5	23.0			0.0	0.0		
	October 01	24.5	12.7			21.8	18.9			1.3	0.0		
	April 02	25.0	19.4	5.0		34.4	23.4	6.9		2.2	0.6	5.8	
	October 02	22.9	10.9			32.1	11.3		*	0.0	0.1		
	April 03	72.6	35.1		*	49.4	27.0		*	42.5	22.0		*
Minimum ht. (mm)	April 01	4.0	0.0			1.0	2.5			0.0	0.0		
	October 01	0.0	0.0			0.0	0.0			0.0	0.0		
	April 02	0.0	0.0	1.0		0.0	0.0	4.1		0.0	0.0	---	
	October 02	0.0	0.0			2.5	0.0			0.0	0.0		
	April 03	14.0	0.0		*	13.0	0.0		*	0.0	0.0		
Maximum ht. (mm)	April 01	78.0	46.0		*	107.5	85.5			0.0	0.0		
	October 01	52.0	42.0			65.0	55.0			5.0	0.0		
	April 02	52.5	46.5	10.7		88.5	62.0	13.4		9.0	2.5	23.2	
	October 02	55.0	32.5			75.0	33.0		*	0.0	0.5		
	April 03	138.5	99.3		*	97.5	69.0			133.0	63.5		*
Median ht. (mm)	April 01	34.0	13.8		*	24.7	15.0			0.0	0.0		
	October 01	23.0	4.5		*	11.0	10.2			0.0	0.0		
	April 02	23.8	15.5	5.4		24.5	15.8	7.3		0.0	0.0	13.6	
	October 02	18.3	5.5			25.5	6.0			0.0	0.0		
	April 03	69.0	20.6		*	43.5	19.5		*	18.5	12.3		*

Means and standard errors of means (SEM) from ANOVA, n=20 for each Sampling Area. Averaged seasonal values within a Sampling Area on each row were tested for significant difference. Asterisks denote $p<0.05$.

The percent ground covered by, and maximum height of, individual plant species are also given (Tables 4.5 and 4.6). Once again Sampling Areas 1 and 2 were more similar to each other than either was to Sampling Area 4, with Sampling Area 4 having a lower number of species, lower percent vegetation ground cover and lower vegetation height, regardless of treatment. Two species did differ significantly in both percent ground cover and height between treatments in Sampling Area 4. *Cyperus* spp. and *Sida* sp. both showed higher ground cover and height in the Closed treatment.

In Sampling Areas 1 and 2, a number of grass species (e.g. *Chloris* spp., *Paspalidium* spp., *Sporobolus* spp.) had significantly more ground cover and were higher in the Closed treatment. In addition, *Thellungia advena* was significantly higher in ground cover and height in Sampling Area 2. There was a mixed response from the browse species in Sampling Area 1 with Ruby Saltbush, *Enchylaena tomentosa*, higher in ground cover and height in the Closed treatment but Small-leaved cottonbush, *Maireana microphylla*, significantly higher in ground cover and height in the Open treatment. Very few non-grass species differed between treatments in Sampling Area 2.

The percentage ground covered by, and maximum heights of, individual species were also analysed (data not shown); however, very few species showed any significant treatment-by-season interaction effect. Those that did show significant difference between the Open and Closed treatments in the separate seasons, did not do so in any pattern or trend, but generally followed the overall trends as given in Tables 4.5 and 4.6., i.e. most variables were higher in the Closed treatment.

Table 4.5 Percent ground cover by vegetation species recorded within the Scrub exclosures, Brigalow Research Station, 2000-2003.

	Percent Ground Covered (%)											
	Sampling Area 1				Sampling Area 2				Sampling Area 4			
	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.
Aristida spp.					1.2	0.7	0.3					
Astrebla sp.	0.05	0.00	0.04		0.1	0.1	0.1					
Bothriochloa sp.	0.00	0.05	0.04		1.0	0.2	0.2	**				
Cenchrus ciliaris					0.2	0.0	0.1					
Chloris spp.	1.5	0.2	0.3	**	0.4	0.1	0.1	*				
Digitaria sp.	0.01	0.00	0.01									
Enteropogon acicularis	0.05	0.00	0.04									
Panicum maximum									0.2	0.0	0.1	
Paspalidium spp.	4.1	0.6	0.6	***	4.2	6.9	0.8	**				
Paspalum sp.	0.01	0.00	0.01		0.1	0.1	0.1					
Sporobolus spp.	1.8	0.5	0.3	***	0.8	0.2	0.2	*	0.00	0.01	0.01	
Thellungia advena					3.8	0.1	0.7	***				
Unknown grass spp.	0.1	0.9	0.2	***	0.2	0.5	0.1		0.5	0.4	0.1	
Cyperus spp.	0.1	0.0	0.1		0.6	0.3	0.1	*	0.05	0.00	0.01	*
Clover spp.	0.2	0.1	0.1		0.2	0.0	0.1	*				
Chenopodium spp.	0.9	0.2	0.2	*	3.3	1.1	2.1					
Enchylaena tomentosa	6.8	3.9	1.1	*	0.1	0.4	0.1					
Forb sp. 1	0.1	0.1	0.1						0.07	0.02	0.04	
Forb sp. 2	2.2	1.9	0.3		2.3	2.4	0.5					
Forb spp.	0.6	0.7	0.1		0.5	0.2	0.1		3.6	2.5	0.4	*
Maireana microphylla	0.0	2.5	0.3	***	1.0	1.1	0.8					
Portulaca spp.	1.2	0.0	0.3	*	0.3	0.3	0.2					
Sclerolena tricuspis	16.8	7.8	2.1	***	3.3	3.3	0.5					
Sida sp.	0.2	0.2	0.1		0.3	0.1	0.1		0.05	0.00	0.01	*
Solanum spp.	0.1	0.0	0.1						0.00	0.01	0.01	
Capparis lasiantha	0.2	0.2	0.1									
Vine spp.	0.3	0.0	0.1	*	0.06	0.00	0.04					
Carissa ovata	0.0	2.3	0.6	*								
Trees	0.7	1.2	0.3		0.4	0.3	0.2		1.0	1.4	0.4	

Means and standard errors of means (SEM) from ANOVA, n=200 for each Sampling Area. Averaged seasonal values within a Sampling Area on each row were tested for significant difference. Asterisks denote level of significance *** $p<0.001$, ** $p<0.01$, * $p<0.05$.

Table 4.6 Maximum heights of vegetation species recorded within the Scrub exclosures, Brigalow Research Station, 2000-2003.

	Maximum Height (mm)											
	Sampling Area 1				Sampling Area 2				Sampling Area 4			
	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.	Closed	Open	SEM	Sign.
Aristida spp.					13.4	5.9	3.2					
Astrebla sp.	0.7	0.0	0.5		1.1	1.5	1.0					
Bothriochloa sp.	0.0	0.5	0.4		9.3	2.0	2.1	*				
Cenchrus ciliaris					2.5	0.0	1.8					
Chloris spp.	12.7	0.6	2.7	**	6.9	0.1	2.2	*				
Digitaria sp.	2.0	0.0	1.4									
Enteropogon acicularis	0.7	0.0	0.5									
Panicum maximum									19.0	0.0	10.8	
Paspalidium spp.	35.8	4.9	3.9	***	37.6	39.4	4.2					
Paspalum sp.	1.0	0.0	0.7		1.7	1.2	0.9					
Sporobolus spp.	21.6	2.9	2.7	***	9.2	2.5	1.7	**	0.0	0.2	0.1	
Thellungia advena					27.0	0.5	3.4	***				
Unknown grass spp.	2.0	3.6	1.0		0.9	2.0	0.5		5.2	3.4	1.1	
Cyperus spp.	1.1	0.0	0.7		9.8	4.8	1.7	*	0.7	0.0	0.2	*
Clover spp.	0.6	0.7	0.2		2.9	0.0	0.7	**				
Chenopodium spp.	6.4	2.8	1.7		9.0	5.8	4.4					
Enchylaena tomentosa	24.3	16.5	2.5	*	4.5	5.9	2.7					
Forb sp. 1	1.7	1.1	0.7						1.0	0.3	0.5	
Forb sp. 2	16.4	15.3	2.1		19.2	15.7	2.6					
Forb spp.	6.2	3.3	1.2	*	7.9	3.1	1.8		13.3	13.9	1.7	
Maireana microphylla	0.7	12.7	2.3	*	3.5	7.9	3.0					
Portulaca spp.	6.3	0.0	1.8	*	2.4	0.7	0.7					
Sclerolena tricuspis	42.3	26.7	2.6	***	3.9	0.8	2.0					
Sida sp.	2.7	2.0	0.7		59.1	33.0	1.1	*	1.7	0.0	0.5	*
Solanum spp.	2.9	0.0	0.9	*					0.0	0.2	0.1	
Capparis lasiantha	4.7	3.2	2.0									
Vine spp.	3.7	0.0	1.4		1.3	0.0	0.7					
Carissa ovata	0.0	11.0	3.1	*								
Trees	347.0	150.0	124.9		36.0	129.0	72.3		270.0	780.0	188.0	

Means and standard errors of means (SEM) from ANOVA, n=200 for each Sampling Area. Averaged seasonal values within a Sampling Area on each row were tested for significant difference. Asterisks denote level of significance *** $p<0.001$, ** $p<0.01$, * $p<0.05$.

b) Exclosures in Pasture

Experiment 1.

Monitoring of pasture exclosures showed large differences between the wallaby-accessible and wallaby-inaccessible treatments (Table 4.7).

In all surveys except the first (April 2001), the density of Old and Recent faecal pellets was significantly lower in the Fully Closed (FC) exclosures than the Half Open (HO) or Fully Open (FO) exclosures. The presence of faecal pellets within the FO and HO pens suggests that the wallabies were utilising the accessible exclosures; and while there were some significant differences between the HO and FO pens there was no trend to one or the other treatment, which might have been the case if the wallabies were favouring either treatment. There was an increase in Old faecal pellets in the FO treatment compared to the HO treatment in October 2002. The lower 'mean height' of the vegetation in the FO treatment suggests that 'green pick' (the short green regrowth of grass) may have been more abundant within this treatment during this time. There were also significant differences in faecal pellet densities between the October and April monitorings in both years.

The cut dry biomass taken from the FC exclosures was significantly greater than the cut dry biomass taken from the FO and HO treatments for each season. Eight months after exclosure construction the FO and HO pens had 19 and 14% of the standing biomass of the FC pens. Another six months later, percentages were 16 and 15%, respectively. In April 2002, after a growing period, the FO and HO pens had 14 and 45% of the standing biomass of the FC pens. After winter (October 2002) the percentages dropped again, as they did the previous year, to 4 and 34%, respectively.

The amount of bare ground was significantly higher in the FO treatment compared to the FC and HO treatments, but only during October 2001 and 2002. Related to the cut dry biomass, the variables biomass rank, percent cover by vegetation and the maximum, minimum, median and mean heights of vegetation were also significantly higher in the FC treatment than the HO and FO treatments in all seasons. Generally though, not many variables differed significantly between the HO and FO pens, except during April and October of the second year. Most variables did not differ significantly between the HO and FO pens in the first year; however, during the second year the cut dry biomass, biomass rank, percent ground covered by vegetation, vegetation height was significantly lower in the FO treatment. During the periods prior to both monitoring periods in April and October 2002, cattle had been present for 3 months in the paddock. There were also differences between the level of species diversity in each treatment, which varied each year. There was little significant difference in the level of species diversity during the first year of monitoring; however, during the second year of monitoring there was significantly more species diversity in the HO treatment, but no difference between the FO and FC treatments.

Table 4.7 Variables recorded during pasture exclosure monitoring, Experiment 1.

Variable	Treatment#	2001 April	2001 October	2002 April	2002 October
Old faecal pellets (m^{-2})	FO	5.9^{b}	36.8^{b}	13.5^{a}	37.9^{a}
	HO	13.2^{a}	43.9^{a}	12.8^{a}	18.6^{b}
	FC	0.2^{b}	0.9^{c}	0.4^{b}	0.0^{c}
	SEM		2.7		
Recent faecal pellet (m^{-2})	FO	0.8^{a}	12.6^{a}	2.3^{a}	7.5^{a}
	HO	3.2^{a}	14.4^{a}	0.6^{a}	8.4^{a}
	FC	0.00	0.0^{b}	0.0^{b}	0.0^{b}
	SEM		1.2		
Cut dry biomass (t/ha)	FO	1.2^{b}	0.8^{b}	0.9^{c}	0.2^{c}
	HO	0.9^{b}	0.8^{b}	2.7^{b}	1.7^{b}
	FC	6.4^{a}	5.0^{a}	6.0^{a}	5.1^{a}
	SEM		0.4		
Biomass from rank (t/ha)	FO	2.4^{b}	0.4^{b}	0.5^{c}	0.4^{c}
	HO	1.3^{c}	0.4^{b}	2.7^{b}	1.4^{b}
	FC	5.2^{a}	2.9^{a}	7.0^{a}	8.9^{a}
	SEM		0.4		
Percent bare ground	FO	19.6^{a}	35.0^{a}	18.3^{a}	29.7^{a}
	HO	15.8^{a}	14.6^{b}	9.5^{a}	10.8^{b}
	FC	1.2^{a}	6.4^{b}	5.8^{a}	0.7^{b}
	SEM		9.0		
Percent leaf litter	FO	14.1^{b}	36.6^{b}	17.8^{a}	26.8^{ab}
	HO	45.7^{a}	47.4^{a}	16.2^{a}	32.8^{a}
	FC	8.3^{b}	11.4^{c}	11.0^{a}	17.8^{b}
	SEM		7.6		
Percent vegetation cover	FO	78.4^{b}	48.1^{b}	65.5^{b}	46.4^{c}
	HO	55.0^{c}	43.8^{b}	77.4^{a}	61.3^{b}
	FC	92.2^{a}	83.0^{a}	84.2^{a}	84.7^{a}
	SEM		2.7		
Number of species	FO	2.1^{a}	1.8^{b}	1.9^{ab}	1.4^{b}
	HO	2.3^{a}	1.9^{ab}	2.3^{a}	2.3^{a}
	FC	2.2^{a}	2.3^{a}	1.7^{b}	1.4^{b}
	SEM		0.2		
Mean height (mm)	FO	119.5^{b}	28.4^{b}	50.3^{c}	18.4^{c}
	HO	83.4^{b}	30.8^{b}	218.5^{b}	86.1^{b}
	FC	585.9^{a}	331.2^{a}	467.2^{a}	452.3^{a}
	SEM		30.4		
Minimum height (mm)	FO	68.1^{b}	1.9^{b}	19.4^{c}	2.2^{b}
	HO	32.8^{b}	3.8^{b}	148.1^{b}	24.1^{b}
	FC	528.1^{a}	245.3^{a}	420.3^{a}	434.4^{a}
	SEM		22.7		
Maximum height (mm)	FO	166.6^{b}	61.9^{b}	77.2^{c}	36.6^{c}
	HO	142.5^{b}	65.9^{b}	290.6^{b}	154.7^{b}
	FC	634.4^{a}	407.8^{a}	510.9^{a}	475.0^{a}
	SEM		26.5		
Median height (mm)	FO	121.7^{b}	24.8^{b}	52.3^{c}	17.5^{c}
	HO	79.1^{c}	26.7^{b}	217.7^{b}	82.8^{b}
	FC	590.6^{a}	335.9^{a}	468.7^{a}	450.0^{a}
	SEM		21.8		

Means and standard errors of means (SEM) from ANOVA, n=32 for each variable during each season except 'cut dry biomass' n=4. For each variable, values within columns with like superscript letter is are not significantly different, $p<0.05$.

FO=Fully-Open, HO=Half-Open, FC=Fully-Closed.

The percent ground cover and height of selected species are given in Table 4.8. A large percentage of the exclosures consisted of Buffel grass (*Cenchrus ciliaris*) and the FC treatment had significantly more coverage of Buffel grass than the HO and FO treatments, although the percentage Buffel grass cover did not change greatly from year to year in any treatment. The percent ground cover by other species differed significantly between treatments but only during one or two monitorings. These species also exhibited some large year-to-year variations in percentage ground cover. Over the period of time the exclosures were monitored some species appeared to decline. In the April monitorings *Chloris divaricata* was less abundant in the FO and FC treatments from one year to the next, although persisting within the HO treatment. The low to zero abundance during the October monitorings is thought to be due to the species being unable to be readily identified without seedhead. Similarly, the overall presence of *Thellungia advena* declined, particularly in the second year of monitoring. Although percent ground covered by *Thellungia advena* was significantly higher in the HO treatment during October 2001, the percent cover declined in all treatments and did not differ significantly between the treatments the following year.

The heights of *Cenchrus ciliaris* and *Cyperus gracilis* were significantly greater in the FC treatment, than the FO and HO treatments which did not differ during the first year of monitoring. During the second year the height of *Cenchrus ciliaris* was still significantly greatest in the FC treatment, but a significant difference between the FO and HO treatments also existed, with the FO treatment having the shortest *Cenchrus ciliaris*. There was little treatment difference in the heights of the other vegetation species.

Table 4.8 Percent ground cover and height of selected plant species recorded within the pasture exclosures, Experiment 1.

		Percent Ground Cover				Height (mm)			
		2001		2002		2001		2002	
Species	Treatment#	April	October	April	October	April	October	April	October
Cenchrus ciliaris	FO	76.3[b]	45.7[b]	63.0[c]	44.4[b]	154.1[b]	57.2[b]	65.3[c]	32.5[c]
	HO	64.3[c]	41.3[b]	75.5[b]	60.2[b]	131.2[b]	50.9[b]	257.8[b]	130.3[b]
	FC	82.5[a]	74.7[a]	85.0[a]	85.1[a]	628.1[a]	404.7[a]	507.8[a]	468.7[a]
	SEM	30.7				25.3			
Chloris divaricata	FO	7.0[a]	0.0[a]	0.0[b]	0.0[a]	45.6[a]	0.0[a]	0.0[b]	0.0[a]
	HO	7.4[a]	0.0[a]	17.3[a]	2.3[a]	37.5[a]	0.0[a]	93.7[a]	10.9[a]
	FC	6.3[a]	1.6[a]	0.0[b]	0.0[a]	59.4[a]	14.1[a]	0.0[b]	0.0[a]
	SEM	2.6				13.2			
Thellungia advena	FO	4.1[a]	4.6[b]	0.2[a]	0.0[a]	24.4[b]	16.2[a]	0.3[a]	0.0[a]
	HO	1.9[a]	14.7[a]	0.5[a]	0.0[a]	14.7[b]	19.1[a]	14.1[a]	0.0[a]
	FC	3.1[a]	5.3[b]	0.8[a]	0.0[a]	89.1[a]	45.3[a]	9.4[a]	0.0[a]
	SEM	1.8				11.4			
Cyperus gracilis	FO	4.7[a]	0.2[b]	2.3[a]	2.2[a]	36.9[ab]	0.6[b]	8.8[b]	5.9[b]
	HO	3.0[a]	0.0[b]	5.2[a]	4.4[a]	20.0[b]	0.0[b]	12.5[ab]	16.3[b]
	FC	6.2[a]	8.1[a]	3.6[a]	5.6[a]	45.3[a]	54.1[a]	32.8[a]	43.8[a]
	SEM	1.5				7.9			

Means and standard errors of means (SEM) from ANOVA, n=32. For each plant species, values within columns with like superscript letters are not significantly different, $p<0.05$.

FO=Fully-Open, HO=Half-Open, FC=Fully-Closed.

Experiment 2.

Due to the nearly complete absence of cattle through the first year of the experimental period, a simulated re-start to plant growth under the experimental conditions with cattle present was attempted. Transects 3 and 7 that were cut originally in October 2001 were re-monitored and re-cut in April 2002, and then again in October 2002. Results are given in Table 4.9.

Once again the density of Old and Recent faecal pellets differed between the FC treatments and the FO and HO. The amount of cut dry biomass in the FC exclosure was still significantly higher in April 2002 but after the non-growing season recovery in the FC treatment was no different to the HO treatment and only slightly more than in the FO treatment.

Most of the other variables (e.g. biomass rank, vegetation cover and height) recovered after being cut in October 2001 to be significantly higher in the FC treatment in April 2002, but after the winter non-growing season there were not the trends in difference between the treatments as seen in Experiment 1.

Table 4.9 Variables recorded during pasture exclosure monitoring during 2002, Experiment 2.

Variable	Treatment#	April 2002	October 2002
Old faecal pellets (m^{-2})	FO	13.4^{a}	44.1^{a}
	HO	10.5^{a}	35.4^{b}
	FC	0.2^{b}	0.2^{c}
	SEM	3.1	
Recent faecal pellet (m^{-2})	FO	1.5^{a}	8.9^{b}
	HO	1.4^{a}	15.1^{a}
	FC	0.0^{a}	0.0^{c}
	SEM	1.4	
Cut dry biomass (t/ha)	FO	0.7^{c}	0.1^{b}
	HO	2.3^{b}	0.5^{ab}
	FC	4.5^{a}	1.4^{a}
	SEM	0.3	
Biomass from rank scale (t/ha)	FO	0.39^{c}	0.33^{b}
	HO	2.06^{b}	0.48^{b}
	FC	5.13^{a}	2.45^{a}
	SEM	0.2	
Percent bare ground	FO	21.7^{a}	31.1^{a}
	HO	11.9^{b}	18.2^{b}
	FC	18.8^{ab}	18.5^{b}
	SEM	3.2	
Percent leaf litter	FO	20.4^{a}	25.4^{b}
	HO	16.3^{a}	38.9^{a}
	FC	16.5^{a}	23.0^{b}
	SEM	4.3	
Percent vegetation cover	FO	64.8^{b}	46.5^{b}
	HO	79.4^{a}	53.5^{ab}
	FC	80.1^{a}	66.9^{a}
	SEM	24.4	
Number of species	FO	1.6^{b}	1.6^{b}
	HO	2.3^{a}	2.2^{a}
	FC	1.4^{b}	1.8^{ab}
	SEM	0.2	
Mean height (mm)	FO	44.6^{c}	12.0^{b}
	HO	207.2^{b}	28.8^{b}
	FC	441.8^{a}	218.0^{a}
	SEM	19.0	
Minimum height (mm)	FO	18.4^{c}	0.3^{b}
	HO	146.6^{b}	6.9^{b}
	FC	320.3^{a}	98.4^{a}
	SEM	24.6	
Maximum height (mm)	FO	65.6^{c}	24.4^{b}
	HO	286.6^{b}	58.8^{b}
	FC	518.8^{a}	298.4^{a}
	SEM	23.7	
Median height (mm)	FO	47.2^{c}	11.6^{b}
	HO	197.8^{b}	24.7^{b}
	FC	464.1^{a}	237.5^{a}
	SEM	19.2	

Means and standard errors of means (SEM) from ANOVA, n=32 for each variable during each season except 'cut dry biomass' n=4. For each variable, values within columns with like superscript letters are not significantly different, $p<0.05$.

FO=Fully-Open, HO=Half-Open, FC=Fully-Closed.

The percent cover and height of selected plant species monitored in Experiment 2 are given in Table 4.10. Again, the trends or patterns in April 2002 were very similar to those seen in Experiment 1; however, in October 2002, recovery was not as good although Buffel grass still had significantly more ground cover and height in the FC treatment than the FO or HO treatment. Other plant species (e.g. *Chloris divaricata*, *Cyperus gracilis*) were significantly higher in the HO treatment in October 2002.

Table 4.10 Percent ground cover and height of selected plant species recorded within the pasture exclosures during 2002, Experiment 2.

		Percent Ground Cover		Height (mm)	
Species	Treatment	April	October	April	October
Cenchrus ciliaris	FO	61.1^{b}	45.1^{b}	66.2^{c}	24.7^{b}
	HO	65.8^{b}	46.8^{b}	226.6^{b}	67.5^{b}
	FC	75.8^{a}	64.2^{a}	521.9^{a}	309.4^{a}
	SEM	21.7		17.8	
Chloris divaricata	FO	0.0^{b}	0.0^{a}	0.0^{b}	0.0^{a}
	HO	19.5^{a}	1.4^{a}	115.3^{a}	2.5^{a}
	FC	0.0^{b}	0.0^{a}	0.0^{b}	0.0^{a}
	SEM	2.5		12.1	
Cyperus gracilis	FO	2.3^{a}	1.7^{b}	3.4^{b}	4.7^{a}
	HO	3.1^{a}	4.8^{a}	10.9^{b}	5.0^{a}
	FC	2.2^{a}	2.1^{b}	29.7^{a}	11.9^{a}
	SEM	1.1		5.3	
Salsola kali	FO	0.1^{b}	0.0^{a}	12.0^{b}	0.0^{a}
	HO	7.0^{a}	0.4^{a}	234.0^{a}	31.0^{a}
	FC	0.0^{b}	0.0^{a}	0.0^{b}	0.0^{a}
	SEM	1.0		31.5	

Means and standard errors of means (SEM) from ANOVA, n=32. For each plant species, values within columns with like superscript letters are not significantly different, $p<0.05$.

FO=Fully-Open, HO=Half-Open, FC=Fully-Closed.

4.3.2 Faecal Pellet Counts – Pasture Transects

Faecal pellet counts were undertaken along transects radiating out into paddocks from the shelter habitat edge, to determine the degree of wallaby utilisation of the pasture areas. The seasonal densities of Old and Recent faecal pellets recorded are given in Figures 4.6, 4.7 and 4.8.

In Sampling Area 2 (Figure 4.6a-c) pellet density changed little over 300m during Season 4 (Summer 2002(a)) or Season 5 (Winter 2002); however, during Season 6 (Summer 2002(b)) considerably more pellets were recorded closer (up to 100m out) to the scrub-paddock interface. Over the next 200m the density then dropped to be at similar levels to the two previous seasons.

Sampling Area 3 was monitored only during two seasons, Summer 2002a and Winter 2002 (Figure 4.7a-b). In general, density of faecal pellets was low during the Summer season and tapered off with distance from scrub edge quickly, hence the reason recording was cut short at 100m. In the Winter season the density was higher and remained constant for up to 250-300m out from the scrub-paddock interface.

Monitoring in Sampling Area 4 occurred in 6 seasons (Figure 4.8a-f). Overall the density of faecal pellets was higher closer to the shelter habitat during the Summer seasons, dropping off considerably before 150m. During Winter the density of faecal pellets was lower closer to the scrub-paddock interface but maintained at that density further out into the paddock.

a. Season 4 (Summer 2002a) *b. Season 5 (Winter 2002)* *c. Season 6 (Summer 2002b).*

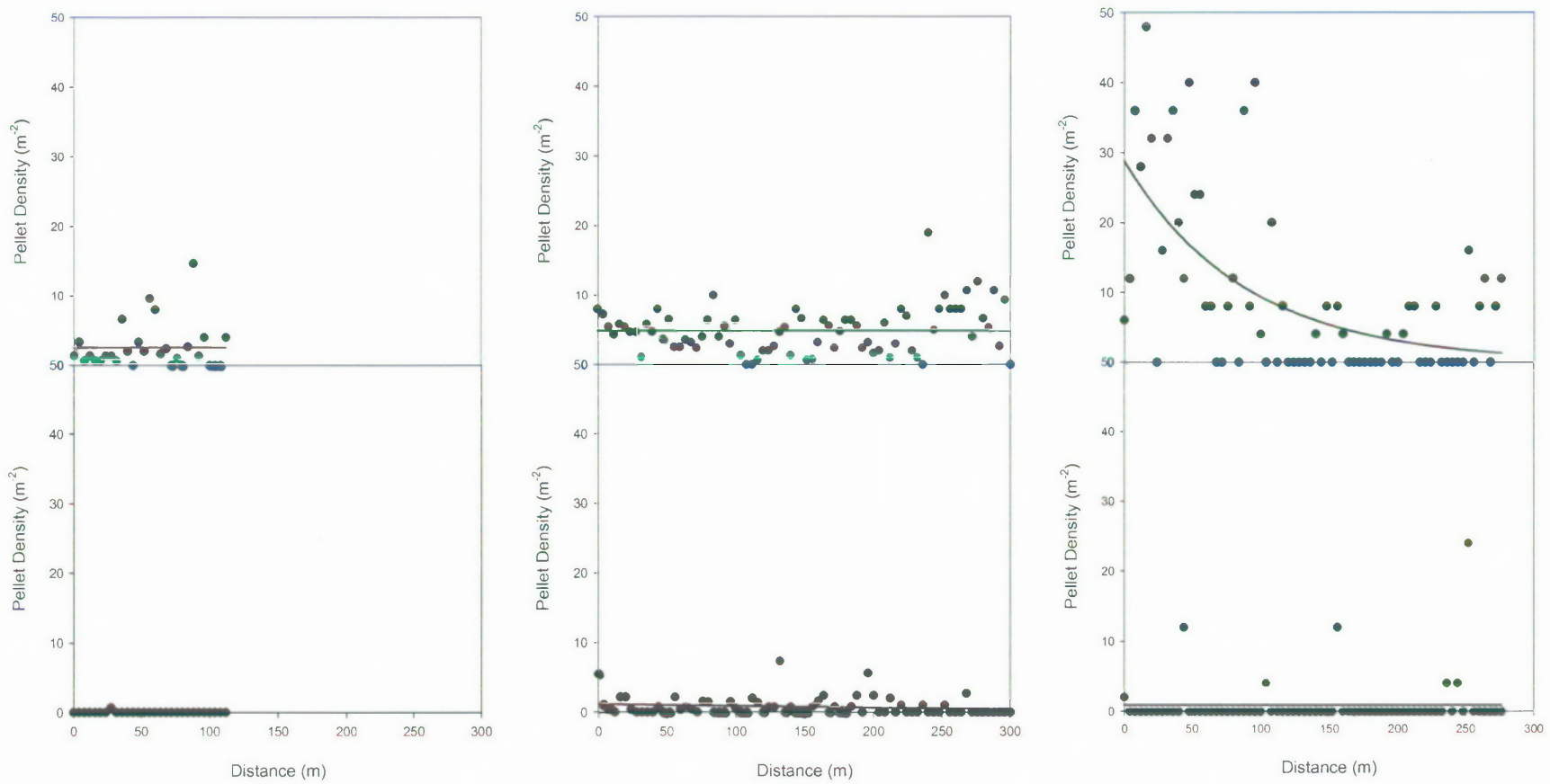

Figure 4.6a-c. Mean density of Old (top graph) and Recent (bottom graph) faecal pellets along transects which start at the fence line near the shelter scrub and extend out into the pasture in Sampling Area 2.

a. Season 4 (Summer 2002a)

b. Season 5 (Winter 2002)

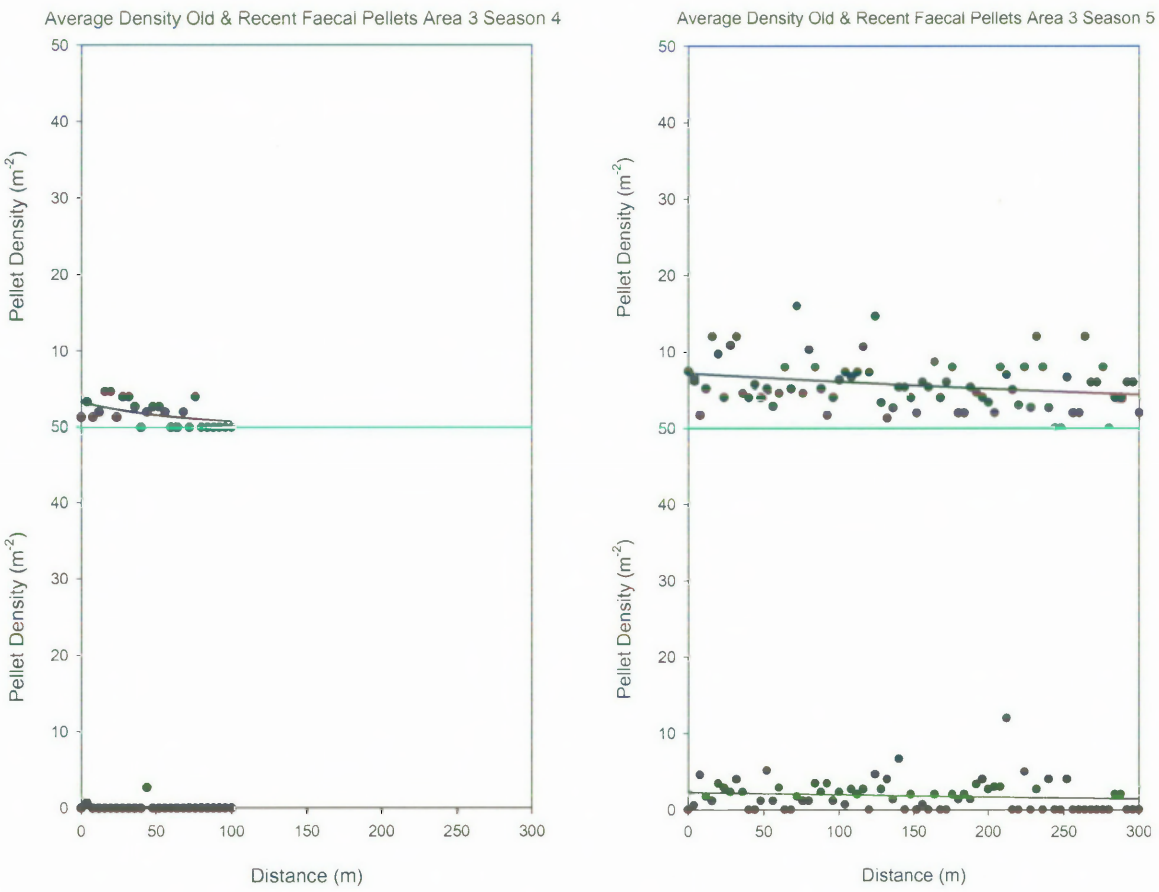

Figure 4.7a-b. Mean density of Old (top graph) and Recent (bottom graph) faecal pellets along transects which start at the fence line near the shelter scrub and extend out into the pasture in Sampling Area 3.

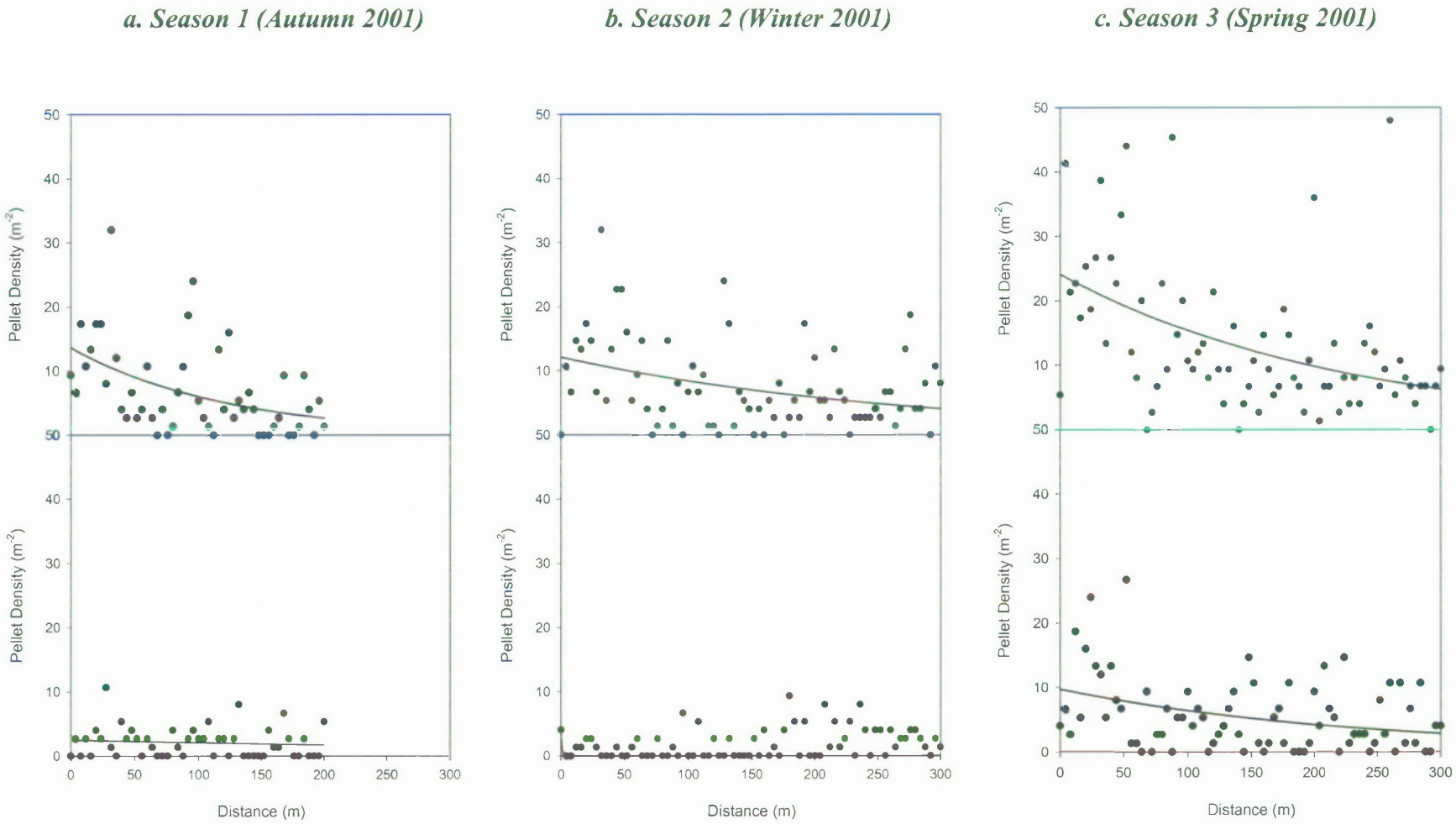

Figure 4.8a-c. Mean density of Old (top graph) and Recent (bottom graph) faecal pellets along transects which start at the fence line near the shelter scrub and extend out into the pasture in Sampling Area 4.

d. Season 4 (Summer 2002(a)) *e. Season 5 (Winter 2002)* *f. Season 6 (Summer 2002(b))*

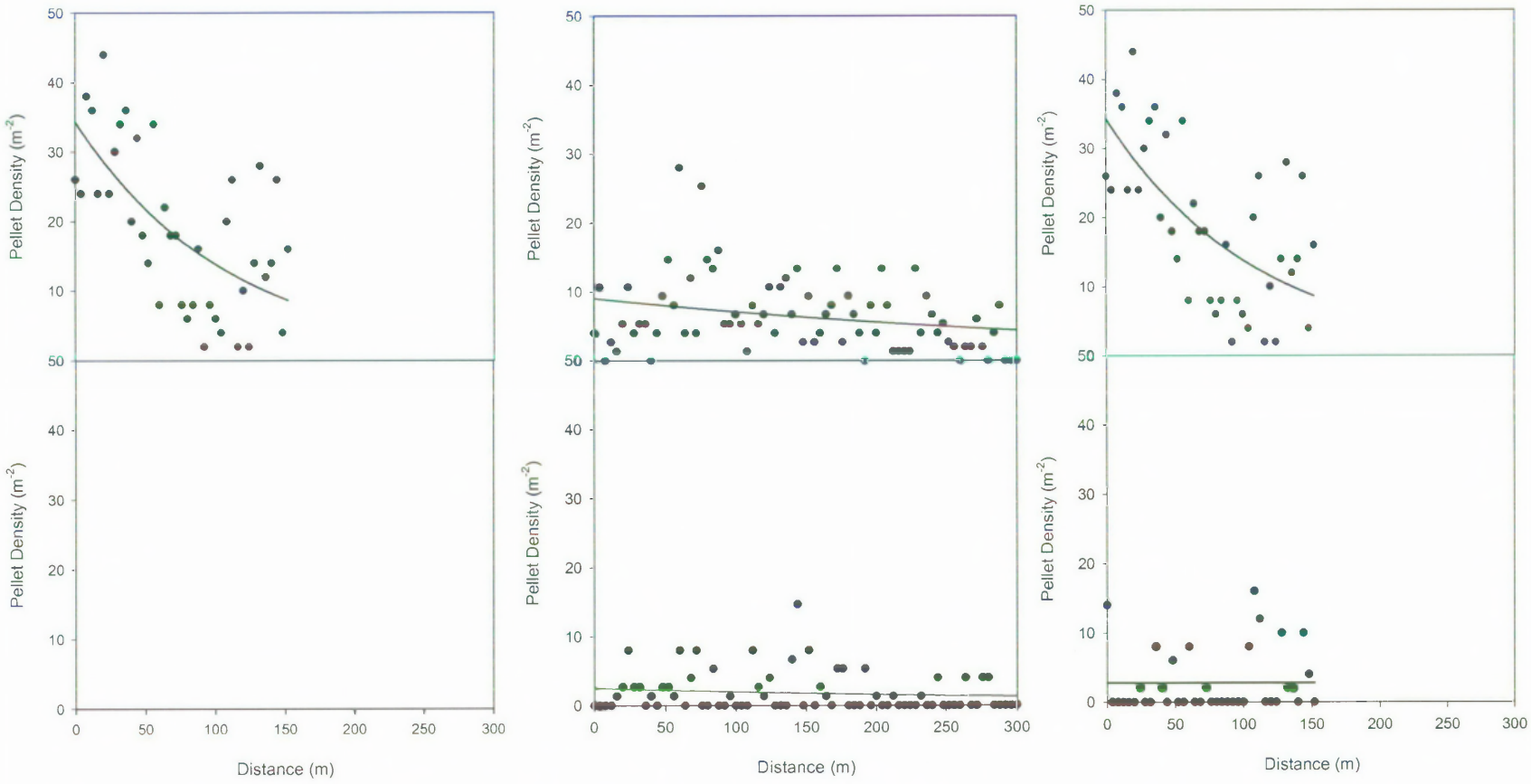

Figure 4.8d-f. Mean density of Old (top graph) and Recent (bottom graph) faecal pellets along transects which start at the fence line near the shelter scrub and extend out into the pasture in Sampling Area 4.

4.3.3 Pad Coverage

A total of 160 tapes were monitored during summer and 190 during winter. The total number of pads recorded in summer was 196, intersecting a total length of 56.25m out of the 1600m of inspected tape and averaging 0.29m in width. The total number of pads recorded in winter was 393, intersecting a total length of 113.35m out of 1900m of inspected tape and with the same Mean pad width of 0.29m.

Seasonally, there was a significant difference in the proportion of ground covered by wallaby pads, with a proportional cover mean of 0.0471 (4.7% of the area) during summer and 0.0796 (8.0% of the area) in winter (REML, n=350, mean SEM=0.39, $p<0.05$). Significantly more ground was covered by wallaby pads during winter in all Sampling Areas and all Vegetation Categories. However, there was no significant difference in predicted proportional cover means between the Sampling Areas or between the Vegetation Categories, except between Areas 2 and 4 in the pasture during winter, with more ground covered by pads in Area 4 (Table 4.11). The mean seasonal percent ground covers were not significantly different, in any of the Sampling Areas though (Table 4.12).

Table 4.11 Seasonal percent ground cover by wallaby pads in each of the Vegetation Categories of each Sampling Area.

	Summer		Winter	
Area	% Cover in Pasture	% Cover in Scrub	% Cover in Pasture	% Cover in Scrub
1	na	4.10[a]	na	7.79[a]
2	4.33[a]	6.56[a]	6.15[b]	7.15[a]
3	5.08[a]	6.01[a]	9.02[ab]	8.20[a]
4	4.10[a]	4.10[a]	11.62[a]	8.20[a]
Mean SEM	0.85			

Estimated means and mean standard errors of means (SEM) from REML, n=350. Means within columns with like superscript letters are not significantly different, $p<0.05$.

Table 4.12 Percent of ground covered by wallaby pads in each of the Vegetation Categories of each Sampling Area.

Area	% Cover in Pasture	% Cover in Scrub
1	na	5.95[a]
2	5.44[a]	6.85[a]
3	7.13[a]	6.98[a]
4	8.27[a]	6.24[a]
Mean SEM	0.61	

Estimated means and mean standard errors of means (SEM) from REML, n=350. Means within columns with like superscript letters are not significantly different, $p<0.05$.

4.3.4 Water Usage

A total of thirty gilgais from both scrub and pasture were found and examined in January 2002. The combined circumference of these gilgais equalled 1.44kms. Over this distance twelve sets of 'macropod' prints were recorded 'leading up to' a gilgai's water edge and another nine were recorded as 'going around' the gilgai (i.e. not approaching the water). Dog tracks were detected seven times, along with two sets of

cat prints, two from cattle and two from birds. Pig digging and wallowing was also evident at one gilgai.

Monitoring at N4 dam for water usage during July 2002 found twenty sets of 'macropod' prints, three sets of Eastern Grey Kangaroo (*M. giganteus*) prints, three sets of dog prints, four bird prints and evidence of pig digging and wallowing. During October 2002, approximately 200 cattle were grazing N4 paddock and had direct access to the dam's entire perimeter. Consequently, recording the number of tracks in the trampled mud at the water's edge was difficult; however, cow, pig and bird prints were recorded, but no macropod tracks. Macropod faecal pellets were found amongst the 'green pick' close to the waters edge though.

Becker's dam, a deep turkey-mound-shape dam on neighbouring 'Highworth' on the northern boundary of the Research Station, was less than half full during July 2002 but there were also several muddy gilgai-type pools along the southern edge of the dam. There were few prints of macropods around the dam; although, there were a substantial number of Black-striped Wallaby faecal pellets on the ground around the water body. In October 2002 the dam was still less than half full with the water in the dam covering an area of approximately 800m^2. Circumnavigating the dam, eighteen sets of 'macropod' prints were found at the water's edge. In addition to these prints there were a substantial number of faecal pellets noted on the ground around the dam and twenty-six clumps of faecal pellets counted on the water's edge.

4.4 Discussion

It is generally accepted that increases in herbivore populations exert increased pressure on the vegetation they feed on by limiting effective regeneration of trees, scrubs, forbs and grasses (Neave and Tanton 1989, Belsky 1992, Pettit *et al.* 1995, Ramsey and Wilson 1997, Mountford and Peterken 2003). However, a study by Bellingham and Allan (2003) found no evidence to suggest White-tailed Deer (*Odocoileus virginianus*) threaten population structures of tree canopies in New Zealand, the authors concluded that other factors such as canopy openings and competition with other species may largely influence forest regeneration. Pinpointing the effects of one herbivore may not be so straightforward, as Bellingham and Allan (2003) point out that other browsers maybe affect regeneration as well (in their study, Common Brush-tailed Possums, *Trichosurus vulpecula*). In my study, the effect of invertebrates (e.g. grasshoppers) grazing vegetation within the exclosures may have been important, even though invertebrate grazing was not noted as extreme during monitoring.

It is probable that the impacts caused by a species are dependent on the density of the species within that environment and the length of time the effect has been occurring. As commented by Bellingham and Allan (2003), the species they studied (White-tailed Deer) was introduced 80 years before the study and the majority of changes in species diversity most likely occurred shortly after the introduction. Black-striped Wallabies most likely existed on Brigalow Research Station before it was developed for agricultural production; but the agricultural context and pastoral vegetation are only 40 years old. Whether that length of time is long enough for the impacts of a change in Black-striped wallaby population density to be no longer noticeable cannot be established from this study. Moreover, anecdotal evidence suggests the increase in

Black-striped Wallaby numbers occurred only about a decade ago. Future comparative studies of the wallaby population and the Reference Site may help to determine if the effects of the population have stabilised or whether major changes are still occurring.

Russell *et al.* (2001) noted that exclosures have a number of experimental problems. Their often-subjective placement and generally low level of replication mean that a large range of area, and therefore conditions, are not sampled. Ideally exclosures should also be monitored over long periods of time to allow the effect of exclusion from grazing to really take effect. Even though monitoring of the exclosures in the scrub or shelter occurred over only 3 years, significant differences arose between the treatments, especially in Sampling Areas 1 and 2 (Fenced and unfenced Brigalow forest). This rapid response may be because the impact of wallaby feeding was high and so the effect of its removal was visible quite early, or that the exclosures were able to display such differences on short time scales because of the regeneration capability of species in the Brigalow community when not being grazed. In particular, in Sampling Areas 1 and 2 the higher number of seedheads and greater ground cover and height of vegetation (particularly of native *Chloris* spp., *Paspalidium* spp. and *Sporobolus* spp.) does suggest Black-striped Wallabies graze those species. However, whether they graze them to such an extent that they limit the grasses' regeneration capabilities would require monitoring over a longer period of time.

A regeneration response in species of grasses and forbs was not noted within the Softwood Scrub (Sampling Area 4). However, Softwood Scrub is generally considered to have very few ground cover species (grasses, forbs, etc.) (Hansman 2001), which

may explain the lack of response of vegetation species to exclusion of vertebrate herbivores, compared to the Brigalow forest.

Impacts other than from grazing were also apparent within the scrub exclosures with less leaf litter accumulated in the open exclosures, particularly in the October surveys. If wallabies influence the amount of leaf litter at the end of the dry season, this may affect the regeneration of seedlings that require high amounts of humus for germination, or the abundance of ground-dwelling reptiles that require leaf litter for shelter or egg-laying.

There is little doubt from exclosure monitoring within the remnant scrub communities that Black-striped Wallabies are affecting their floristic and structural attributes in the short term. However, whether they are doing so to such an extent that severely impacts upon regeneration cannot be claimed without more long-term and detailed floristic studies of the area.

Pasture exclosures indicate that a high level of wallaby grazing also occurs at least in the area where the exclosures were located. Wallaby grazing alone (HO treatment), or with cattle (FO treatment), produced a standing biomass of pasture that was significantly less than that of the ungrazed pasture (FC pens). In the first survey period the difference in biomass between FC and HO/FO pens ranged from 3.3 to 5.2 t/ha dry weight. However, further decline of the biomass over the following survey periods was as great in the FC pens as in the HO and FO pens. This suggests that the significant impacts of wallaby grazing occurred early in the seasonal growth of the pastures. These results show that grazing by Black-striped Wallabies can, by the end of the wet season, leave a standing pasture biomass substantially less than that of ungrazed pasture.

However, their continued dry-season grazing reduced standing pasture biomass proportionately no more than the seasonal decline in ungrazed pasture. Russell *et al.* (2001) suggests that timing of herbivory is important in determining the scale of the effect of the grazing by white-tailed deer in New Zealand.

At the time of establishment all treatments were similar in terms of biomass and vegetation height as the entire paddock was accessible to cattle and wallabies. The growth (recovery) of grass species in terms of biomass and height within the FC treatment after just one growing season suggests that exclusion of grazers in the area would allow the pasture to re-establish quite quickly.

However, not all species respond to different grazing regimes the same way, explaining the change in species diversity levels. *Chloris divaricata* for example, did not respond well to the higher level of grazing exerted in the FO treatment during the second year of grazing when cattle were present for 5-6 months; however, nor did it compete very well with the strong growth of *Cenchrus ciliaris*, which occurred with the complete absence of herbivore grazing in the FC treatment. An invasive and profuse seeder, *Cenchrus ciliaris* has been reported as responsible for decreasing plant species diversity (McDonald and Jones 2002). The higher level of species diversity in the HO (wallaby only access) treatment suggests that wallaby grazing does not negatively affect plant species diversity; rather, grazing of *Cenchrus ciliaris* allows the growth of other species. While the level of plant species diversity was also low in the FO treatment it was not significantly lower to the diversity levels in the HO treatment, except during October 2002. This may be an artefact of sampling error as there was a lower rate of success in species identification during and after the dry season with grass species

heavily grazed and without identifiable seedheads. However, it is probable that the effect of wallaby-plus-cattle grazing during the winter dry period (October 2002) was greater than during the April 2002, as plants are unable to recover from grazing as quickly.

Faecal pellet densities did not suggest that the wallabies favoured either of the wallaby accessible treatments except during the last monitoring (October 2002) where there were significantly more Old faecal pellets in the FO treatment than in the HO treatment. The attractiveness of short green grass regrowth (green pick) to macropods is well recognised. The shorter pasture grass in the Fully-Open treatment, due to cattle grazing for 5-6 months during 2002, is likely to have made 'green-pick' more available in that treatment than compared to the Half-Open (cattle excluded) treatment. The presence of 'green-pick', particularly at the end of the dry season, is likely to encourage wallaby grazing in the Fully-Open treatment area.

A higher density of faecal pellets was recorded during the October monitorings in both the scrub and pasture exclosures. As explained in Section 3.4, it is suspected that this difference is due to reduced removal or breakdown of pellets because of less active or a reduced number of dung beetles at the end of winter (Davis 1989, Bishop *et al.* 2000).

The high level of wallaby grazing recorded within the pasture exclosures is unlikely to occur over the entire paddock though; rather, it is focussed around the paddock's perimeter. Previous reports suggest that Black-striped Wallabies only emerge from the scrub edge up to a couple of hundred metres to graze (Kirkpatrick 1995, Evans 1996). Therefore, any impacts of wallaby grazing would probably be confined to a relatively

short distance of the paddock/scrub boundary. In my study, Black-striped Wallabies on Brigalow Research Station were found to be emerging from scrub onto pasture as previously reported in other studies, up to a couple of hundred metres. However, the distance travelled out from the scrub-paddock interface seems to be dependent upon and Season and to some degree Sampling Area, as faecal pellet densities persisted further into the paddock (>300m) during winter than in summer. Seasonal differences in the distance travelled from the scrub edge was expected, as wallabies needed to forage further into the pasture during winter or the dry season in search of food. During the summer wet season the abundance of food closer to the scrub edge means wallabies did not need to move as far away from the shelter of the scrub to find sufficient food each night.

While the larger focus of this study was to establish the degree of impact imposed by the wallabies' feeding, it was also of interest to determine how much impact the wallabies were exerting through disturbance of soil, leaf litter and vegetation. Numerous studies have looked at the effect of trampling (usually by humans) on soil compaction, water run-off, vegetation species diversity, resilience of vegetation and length of recovery time (e.g. Whinum and Chilcott 1999). However, the majority of these studies looked at the degree of impact on the contact area not the proportion of area impacted. The density of Black-striped Wallabies at the Study Site was thought to be causing a large proportion of ground to be covered by wallaby tracks or pads. Counting the number of wallaby pads in each Sampling Area during different seasons gives an indication of another aspect of the wallabies' presence on the environment in the area.

The percentage of area covered by wallaby pads was consistently high (>5% of ground) both seasonally and in each of the different Areas. An approximate near doubling of percentage pad cover from summer to winter may be due to plants slowing in growth, becoming dry and less resilient and being more easily broken during the winter season; in summer, plant species generally grow quickly with the presence of rain. Sun (1992) reports that growth rate determines a plant's success at tolerating trampling.

The percentage of ground covered by wallaby pads did not differ significantly between Sampling Areas even though, as it was shown in Section 3.3.1, a higher density of wallabies was present in Sampling Area 4. Sampling Area 4 (Softwood Scrub) consisted of loamy soil that is more easily disturbed than are the soils in other Sampling Areas. With more wallabies and therefore activity in the area, a soil type that does not hold together well and with few ground covering plant species, wallaby pads were probably not so well defined. The other Sampling Areas consisted of clay soil, which compacted harder than loamy soil so that pads were more defined and therefore more easily observed. Alternatively, the number of pads may not necessarily be proportional to the number of wallabies in that area. Cole and Spildie (1998) reported that increased trampling density caused more disturbance, but the relationship was not linear. Black-striped Wallabies are reported to follow set paths and many individuals will use the same pad (Kirkpatrick 1995). Therefore, pad area will probably plateau off even if density continues to rise, as the population does not use more than 10% of the area for travelling between and within feeding and shelter habitats. Further work needs to be undertaken to determine levels of effects on soil compaction and plant species regeneration and diversity in each of the vegetation types.

The last section of this Chapter reported Black-striped Wallaby use of water on Brigalow Research Station. Water in the dam in paddock N4 receded quickly during the dryer winter months but spread out to become a shallow, wide expanse of water during the usually wetter and hotter summer months. Monitoring around this dam was undertaken in July 2002 during that year's driest period (refer rainfall chart Section 2.4.1). It was expected that, if Black-striped Wallabies required a drink every day, this water body would be a congregating area for that purpose and that there would be many more prints at the water's edge than were observed. Gilgai monitoring also found that while wallabies grazed or walked close to water they rarely went to the water's edge. No published studies establishing that macropods need to drink often, if at all under certain conditions, were found; however, there are anecdotal reports that macropods, such as Eastern Grey Kangaroos, do not need to drink on a daily basis (P. Jarman pers. comm.). Although further work is required, this study suggests the same could be said for Black-striped Wallabies. If Black-striped Wallabies are facultative drinkers and not strongly water-dependent, obtaining moisture from the plant species they eat or from nightly dew falls for example, efforts to manage the species through controlling water access would probably be limited in success.

CHAPTER FIVE

DIETARY ANALYSIS

5.1 Introduction

Black-striped Wallaby diets have been studied in NSW, south-west of Narrabri and north-east of Moree, by Jarman *et al.* (1991) and near Dingo in Central Queensland by Ellis *et al.* (1992) and Evans and Jarman (1999). These detailed studies showed the Black-striped Wallaby to be primarily a grazer, but eating a large variety of plant species including both monocotyledonous and dicotyledonous species, at sites with access to tree-cleared pasture. The effect of improved pastures adjacent to shelter habitat on Black-striped Wallaby feeding ecology has not been established but anecdotal reports suggest that the wallaby species has taken advantage of the abundance of high-quality feed and thereby increased into locally high densities. However, there has been no study has showing that the pasture species are either high-quality food for wallabies or selectively grazed by them.

Knowledge of the species dietary ecology is required to help determine the effects of grazing by the population of Black-striped Wallabies on the Reference Site and adjacent pastures. This chapter aims to determine whether the diets of Black-striped Wallabies on Brigalow Research Station were similar to those found in other studies or whether their diet was strongly affected by the availability of introduced pastures. The temporal and spatial variations exhibited by the population were considered of importance in establishing feeding habits within the shelter scrub and adjacent pastures throughout the year. Secondary aims were to establish which plant species the Black-striped Wallabies selected, and in what proportions.

5.2 Methodology

Microscopic faecal analysis, was chosen to conform with previous dietary studies of this species, thus minimizing possible differences due to technique (Jarman *et al.* 1991, Ellis *et al.* 1992, Evans and Jarman 1999). Microscopic faecal analysis has advantages over other methods of determining dietary composition including minimal impact on the study species, the ability to store samples and the possibility of a determining a dietary composition to fine detail (Holechek *et al.* 1982). However, the technique also has a number of limitations including: the equipment required and time it takes to learn and undertake the technique, inability to identify fragments because they are not in the Reference Collection or digestion has removed key characteristic structures, and certain 'softer' species (e.g. forbs), are more easily broken down either during digestion or sample preparation (therefore giving an over abundance of tougher species) (Slater and Jones 1971, Vavra and Holechek 1980, Holechek *et al.* 1982, Samuel and Howard 1983, Barker 1986).

Suppliers of Chemicals Used

- Liquid Bleach - Hurricane, Campbell Consumer Products, Sydney, Australia.
- Ethanol, absolute - Recochem Inc., Lytton, Queensland, Australia
- Safranin O - Sigma Chemical Company, St Louis, MO, USA.
- Potassium dichromate - Sigma Chemical Company, St Louis, MO, USA.
- Sulphuric acid, concentrated - BDH Chemicals, Australia Pty. Ltd., Kilsyth, Victoria, Australia.
- Nitric acid, 70% - BDH Chemicals, Australia Pty. Ltd., Kilsyth, Victoria, Australia.

- Glycerol - BDH Chemicals, Australia Pty. Ltd., Kilsyth, Victoria, Australia.
- Glycerol jelly - BDH Chemicals, Australia Pty. Ltd., Kilsyth, Victoria, Australia.

5.2.1 Reference Slide Preparation

To aid in fragment species identification, a collection of permanent slides of epidermal fragments of leaves, sheath, stem and flower from known species was created. Species were collected and grouped into the following Vegetation Categories; Browse species ('woody' trees and shrubs), Chenopods (soft-leaved forbs), Malvaceae (species with stellate hairs), Other Forbs (species that were not classified as Chenopods), Crops, Sedge, Major Pasture Grass Species (ntroduced and native abundant pasture species), General Grass Species (less abundant mostly native species). To some extent categories reflected those used in previous studies (e.g. Ellis *et al.* (1992) and Evans (1992)). While a large number of grass, forb and shrub species were collected, only a few tree species and no cactus, mistletoe, orchid or fern species were collected. Each plant species was separated into leaf, sheath, stem, flower, fruit and seed part, and stored in 70% ethanol.

Preparation of the cuticle Reference Collection followed the methodologies of Sparks and Malechek (1968) and Evans (1992). The cuticle or epidermis of 'softer' grasses was scraped with a scalpel blade and then brushed with small paintbrush (with a few drops of water added to minimize tearing) to remove the flesh from the epidermis. In some cases the piece of grass was placed in 10% hypochlorite solution (Hurricane Liquid Bleach) for a short period softening it enough to allow for more effective scraping and brushing. Alternatively, 'tougher' grasses that could not be scraped clean

were placed in a small amount of 10% chromic/nitric acid and heated over a Bunsen burner. Chromic acid was prepared by dissolving potassium dichromate in one litre of boiling concentrated sulphuric acid to saturation. The chromic/nitric acid mix was then made with 25mls of chromic acid, 25mls of 70% nitric acid, making it up to 500mls with deionised water. Once the epidermis had parted from the flesh and was cleaned using a soft paintbrush, the piece of epidermis was soaked in 1% Safranin O stain in 50% ethanol for a few minutes, rinsed in 70% ethanol and placed in a 1:1 glycerol/water mix before being transferred to a slide with a small amount of melted glycerol jelly and covered with a coverslip.

5.2.2 Faecal Pellet Collection, Preparation and Analysis

Faecal pellet collection was undertaken during January, April, July and October 2001. Thirty pellets (recent and free of insect damage if possible) were collected from each of Sampling Areas 1, 2 and 4 by collecting a pellet from ten evenly spaced intervals along each of the three transects used for recording habitat description variables. An additional six pellets were also collected from the south-west corner of Sampling Area 1 (DNR Catchment Study Site). Thus, a total of ninety-six faecal pellets were collected each season.

On collection the faecal pellets were immediately placed into a labelled 5ml vial and covered with 70% ethanol. On return to the laboratory each pellet was transferred to a 20ml vial with addition of a few drops of 1% Safranin O stain. The pellet was then gently broken apart using a glass rod and the vial filled with 70% ethanol.

A small amount of stained faecal pellet material was placed on a microscope slide with a couple of drops of glycerol and covered with a coverslip. The material was scanned starting from either the top left or bottom right corner, working across and up or down the slide until 25 fragments were recorded. A fragment was recorded if it contained enough cells to enable identification by cellular characteristics.

Fragment size was determined under x10 magnification with one quarter of the field of view equalling 1 unit, therefore a fragment taking up half the field of view equalled 2, etc. In general, recorded fragments were a minimum of 0.25units in size.

Each fragment recorded was firstly categorised by Plant Part (Leaf, Leaf/Sheath, Sheath, Stem, Stellate Hairs, Reproductive Dicotyledon Part, Monocotyledon Seedhead, and Undetermined). Stellate hairs were not treated like fragments because it was hard to determine their total area; and so they were recorded as being present or absent. Cuticle fragments from faecal pellets were compared to those prepared and mounted on slides from plant species collected from the field (Reference Collection) and identified to Plant Type (monocotyledon or dicotyledon), and genus and species for grouping into Vegetation Categories (Browse, Chenopod, Malvaceae, Other Forbs, Sedges, Crops, Major Pasture Grasses, General Pasture Grasses, Unknown Monocotyledons, Unknown Dicotyledons and Reproductive Part Unknown Species). Even if no definite identification could be made, the fragment could generally be recorded as either monocotyledonous or dicotyledonous. Any descriptive details of the unidentifiable fragments were recorded, to help recognition of any further repeated viewing of similar fragments.

Once 25 fragments per slide had been studied the proportional area of each fragment was determined by dividing its size, in units of quarter field of view, by the totalled sizes of the 25 fragments. The proportional area of each category (Plant Part, Plant Type, Vegetation Category) was determined by summing the proportional area of each fragment in those groupings for each faecal pellet. Therefore Plants Parts, Plant Types and Vegetation Categories were recorded as contributing relative proportions of analysed epidermal area to the diet represent by that pellet.

Seasonal and Sampling Area differences between the averaged summed proportional amounts of each grouping in the categories (Plant Type, Vegetation Category and Plant Part) were tested using ANOVA and REML (Genstat 2002).

5.3 Results

A total of 74 species were collected for the Reference Collection. This list included 32 dicotyledons (16 Browse species, 5 Chenopod species, 4 Malvaceae species and 7 Other Forbs) and 42 monocotyledons (2 Crop Species, 2 Sedges, 3 Major Pasture Species and 35 General Grass Species), see Appendix C. Each species had multiple plant parts mounted (leaf, sheath, stem, reproductive part), giving a total of 207 slides prepared.

A total of 384 pellets were collected. Microscopic analysis was undertaken on 44 of the collected pellets (Table 5.1), which was sufficient to undertake a preliminary analysis of the Black-striped Wallaby feeding habits and to make comparisons to previous studies.

Table 5.1 The number of pellets from each Season and Sampling Area that were microscopically analysed.

Season	Sampling Area	No. of Pellets Analysed
Summer	1	16
	2	8
	4	4
Winter	1	15
	2	1
Total		44

Neither Season nor Sampling Area significantly influenced the number of identifiable species (diversity) within faecal pellets, Table 5.2.

Table 5.2 Mean count of species (± Mean SEM) identified in pellets collected from each Sampling Area during Summer and Winter.

	Sampling Area 1	Sampling Area 2	Sampling Area 4	Sign.
Summer	5.4 ± 0.7	5.1 ± 0.6	6.5 ± 0.8	ns
Winter	4.9 ± 0.4	4.00	---	ns
Sign.	ns	ns	---	

Estimated means from analyses using REML, n=44, $p<0.05$.

A total of thirty-four species were positively identified from faecal pellet analysis (Table 5.3). These included 3 Browse species, 2 Chenopods, 1 Malvaceae, 4 Other Forb Species, 1 Sedge, 2 Major Pasture Species and 21 General Grass Species.

Table 5.3 Identifiable plant species recorded within pellets collected in the various Seasons and Sampling Areas (SA). Transverse lines group species into Vegetation Categories. The number of faecal pellets analysed in each Treatment is in brackets.

Plant Species	*Summer SA 1 (16)*	*Summer SA 2 (8)*	*Summer SA 4 (4)*	*Winter SA 1 (15)*	*Winter SA 2 (1)*
Carissa ovata	✔				
Citrus glauca	✔				
Geijera parviflora	✔			✔	
Chenopodium spp.				✔	
Enchylaena tomentosa	✔				
Solanum ellipticum	✔	✔	✔	✔	✔
Forb sp.	✔			✔	✔
Scat fragment no.2 (dicot.)				✔	
Scat fragment no.3 (dicot.)		✔		✔	
Verbena tenuisecta	✔	✔			
Cyperus sp.	✔	✔	✔	✔	
Cenchrus ciliaris	✔	✔	✔	✔	✔
Chloris gayana		✔	✔		
Ancitrachne uncinulata		✔	✔		
Aristida sp.	✔		✔		
Bothriochloa ewartiana	✔	✔	✔		
Chloris spp. (*divaricata*)	✔	✔	✔	✔	
Digitaria spp.	✔	✔	✔	✔	
Enteropogon acicularis	✔				
Eragrostis cilianensis	✔		✔		
Eriochloa pseudocrotricha	✔	✔	✔		
Urochloa spp. (*mosambicensis*)	✔	✔	✔	✔	✔
Leptochloa sp.	✔	✔			
Melinis repens	✔		✔		
Panicum maximum			✔		
Paspalidium gracile	✔	✔		✔	
Paspalum sp.	✔	✔			
Setaria sp.	✔	✔	✔		
Sporobolus sp.	✔		✔	✔	
Thellungia advena	✔	✔	✔		
Tragus australianus	✔				
Collected monocot. species no. 68		✔			
Collected monocot. species no. 69		✔			
Scat fragment no.1 (monocot.)	✔	✔	✔	✔	
Reproductive part (fungus structure)					✔
Reproductive part (pollen structure)		✔			
Reproductive part (sunflower structure)	✔				
Unidentified	✔	✔	✔	✔	✔
Unidentified (seen more than once)	✔	✔	✔	✔	✔
Total Number of Species (not including Unidentifiable Categories)	22	21	18	14	5

In addition to the species recorded by microscopic analysis, there were a number of species noted as having been eaten in the field but which were not identified in faecal pellet material. It is possible that these plant species were either eaten only in small amounts reducing detectability, or were broken down easily when digested. It is also likely that they may be one of the '76 fragments' that were recognised on more than one occasion, but could not be positively identified due to difficulty in matching faecal pellet fragments with Reference Collection fragments. Two-thirds of these fragments were from monocotyledonous species. Assuming that for each monocotyledonous species there may be up to 4 differing plant parts (leaf topside, leaf underside, sheath and stem) the 76 repeatedly seen but unidentified types of fragments could represent an additional 19 species in the wallabies diet. So the total number of plant species eaten was minimally 34 and may have been as high as 53 species.

To determine whether differences in Plant Type, Vegetation Category and Plant Part proportions differed significantly between Seasons or Sampling Area, statistical analyses were carried out on the proportional amounts of the two Plant Types (monocotyledons and dicotyledons), the 12 Vegetation Categories (Browse, Chenopod, Malvaceae, Other Forbs, Sedges, Crops, Major Pasture Grasses, Other Grass Species, Reproductive Part Unknown Species, Unknown Species, Unknown Dicotyledon species, Unknown Monocotyledon Species) and the 8 Plant Part categories (Monocotyledon Leaf, Monocotyledon Sheath, Monocotyledon Leaf/Sheath, Monocotyledon Stem, Monocotyledon Seedhead, Unknown Monocotyledon, Dicotyledon Leaf, Dicotyledon stem. Dicotyledon Reproductive Part, Stellate hairs, Unknown).

There were significantly greater areas of epidermis of monocotyledons than dicotyledons recorded in the faecal pellets, with mean proportion of monocotyledons equalling 65% compared to 27% dicotyledons (ANOVA, n=44, SEM=3.3, $p<0.001$), the remaining 8% could not be identified to either category.

The Seasonal and Sampling Area differences between monocotyledons and dicotyledon areas are given in Table 5.4. There was a significantly lower proportion of dicotyledon parts than monocotyledon parts; however, the amounts of each plant type did not differ significantly between Seasons or Sampling Areas.

Table 5.4 The proportion (%) of monocotyledon and dicotyledon parts recorded from faecal pellets collected from three Sampling Areas on Brigalow Research Station, during summer and winter 2002.

Group	Season	SA1	SA2	SA4
Monocotyledon	Summer	77^{a}	86^{a}	94^{a}
	Winter	63^{b}	88^{a}	---
Dicotyledon	Summer	23^{cd}	13^{cd}	6^{d}
	Winter	37^{c}	12^{cd}	---
Mean SEM Group			11	
Mean SEM Season			12	
Mean SEM Site			11	

Estimated means and mean standard errors of means (SEM) from REML, n=88. Within a Sampling Area (SA), for each group values with like superscript letters are not significantly different, $p<0.05$.

As there were significantly more monocotyledons than dicotyledons it would make sense that there were also significant differences between the proportions of Vegetation Categories (Table 5.5). However, the largest significant difference in the Vegetation Categories was due to the very high proportion area of 'Unknown Monocot. Species'

and 'Unknown Dicot. Species'. The vegetation category 'Other Grass Species' was also significantly high, particularly in Sampling Area 4 during the summer season.

Table 5.5 The mean proportion (%) of each Vegetation Category in Black-striped Wallaby faecal pellets collected on Brigalow Research Station.

Vegetation Category	Season	SA1	SA2	SA4
Browse	Summer	2^{g}	0^{g}	0^{g}
	Winter	0^{g}	0^{g}	
Chenopods	Summer	2^{g}	0^{g}	0^{g}
	Winter	3^{g}	0^{g}	
Malvaceae	Summer	0^{g}	0^{g}	0^{g}
	Winter	0^{g}	0^{g}	
Other Forbs	Summer	1^{g}	3^{g}	0^{g}
	Winter	8^{g}	1^{g}	
Unknown Dicot. Species	Summer	19^{ef}	11^{fg}	6^{g}
	Winter	25^{d}	11^{efg}	
Sedges	Summer	4^{g}	3^{g}	2^{g}
	Winter	1^{g}	0^{g}	
Major Pasture Species	Summer	2^{g}	2^{g}	5^{g}
	Winter	7^{g}	4^{g}	
Other Grass Species	Summer	22^{de}	25^{de}	63^{ab}
	Winter	18^{ef}	10^{fg}	
Unknown Monocot. Species	Summer	50^{b}	56^{ab}	25^{de}
	Winter	38^{c}	74^{a}	
Unknown Species	Summer	0^{g}	0^{g}	0^{g}
	Winter	0^{g}	0^{g}	
Reproductive Part Unknown Species	Summer	0^{g}	0^{g}	0^{g}
	Winter	0^{g}	0^{g}	
Mean SEM Vegetation Category			5	
Mean SEM Season			5	
Mean SEM Site			5	

Estimated means and mean standard errors of means (SEM) from REML, n=484. Within a Sampling Area (SA), for each plant group values with like superscript letters are not significantly different, $p<0.05$.

Lastly, differences in the proportion of Plant Parts consumed by Black-striped Wallabies were investigated. Proportions of Plant Parts differed between Seasons and Sampling Areas significantly but there was no interaction between the factors (Table 5.6). In general, there were significantly higher proportions of monocotyledon parts

(leaf, sheath and stem) present. Moreover, significantly more monocotyledon leaf was present in Sampling Area 4 than 1 or 2. On the other hand, significantly more dicotyledon leaf cover occurred in Sampling Area 1. Monocotyledon seedhead was significantly predominant in summer compared to winter across all Sampling Areas.

Table 5.6 Proportion (%) of different plant parts in faecal pellets collected from Brigalow Research Station, 2002.

Part	Season	SA1	SA2	SA4
Monocot. Leaf	Summer	14^{b}	15^{bc}	34^{a}
	Winter	17^{b}	14^{bc}	
Monocot. Sheath	Summer	18^{b}	15^{b}	27^{ab}
	Winter	17^{b}	24^{ab}	
Monocot. Leaf or Sheath	Summer	5^{bc}	4^{bc}	13^{b}
	Winter	5^{bc}	11^{bc}	
Monocot. Stem	Summer	11^{bc}	19^{b}	0^{c}
	Winter	17^{b}	28^{ab}	
Monocot. Seedhead	Summer	24^{ab}	24^{ab}	15^{b}
	Winter	3^{c}	0^{c}	
Unknown Monocot.	Summer	7^{b}	10^{bc}	6^{bc}
	Winter	4^{c}	12^{bc}	
Dicot. Leaf	Summer	15^{b}	11^{bc}	2^{c}
	Winter	26^{ab}	12^{bc}	
Dicot. Stem	Summer	7^{bc}	10^{bc}	6^{bc}
	Winter	4^{b}	12^{bc}	
Reproductive Dicot. Part	Summer	1^{c}	1^{c}	0^{c}
	Winter	3^{c}	0^{c}	
Malvaceae Stellate hairs#	Summer	0^{c}	0^{c}	0^{c}
	Winter	0^{c}	0^{c}	
Unknown Dicot.	Summer	3^{c}	2^{c}	4^{c}
	Winter	3^{c}	0^{c}	
Unknown	Summer	0^{c}	0^{c}	0^{c}
	Winter	0^{c}	0^{c}	
Mean SEM Part			8	
Mean SEM Season			8	
Mean SEM Site			8	

Estimated means and mean standard errors of means (SEM) from REML, n=528. Within a Sampling Area (SA), for each plant part values with like superscript letters are not significantly different, $p<0.05$.

Malvaceae Stellate hairs have zero proportional cover as they were recorded as either present or absent, not by proportional amount. Stellate hairs (*Solanum* & *Sida* spp.) were present in each treatment, however.

5.4 Discussion

The primary aims of this Chapter was to establish whether Black-striped Wallabies on Brigalow Research Station have similar dietary ecology to other studied populations of Black-striped Wallabies; for example, whether they are consuming the same vegetation species, in similar proportions as found in previous studies. The chapter also aimed to establish if the species was feeding exclusively within either scrub or pasture and whether the species' feeding patterns differed between different areas (i.e. spatially) or changed through the year (i.e. temporally/seasonally).

Results from this study suggest that Black-striped Wallabies have a varied diet, with over 34 species, from 6 of the formed categories, found in faecal pellets collected on Brigalow Research Station. Moreover, individual pellets generally contained a diversity of species (a minimum of 4 identifiable species plus unidentifiable) and this did not change between Seasons or Sampling Areas. Also, there were significantly more monocotyledons consumed than dicotyledons each season (Table 5.4); although, the ratio of dicotyledons to monocotyledons was higher in winter than in summer.

Ellis *et al.* (1992) and Evans and Jarman (1999) also report a diverse range of plant species consumed by Black-striped Wallabies, with at least 75 species found in the diet of the wallaby species studied in Central Queensland. Of that number, 84% were monocotyledon species, including *Bothriochloa bladhii*, *B. deciphens*, *B. pertusa*, *Cenchrus ciliaris*, *Chloris divaricata*, *C. truncata*, *Dichanthium sericeum*, *Eriochloa crebra*, *Enteropogon ramosus*, *Heteropogon contortus*, *Sporobolus caroli*, *Paspalidium criniforme*, and *P. globoidium*. A study by Jarman *et al.* (1991) on Black-striped

Wallaby faecal pellets collected from various sites across northern New South Wales reports between 13 and 24 distinguishable monocotyledon species, including *Echinochloa colona* and *Sporobolus caroli* in Summer and *Danthonia*, *Stipa* and *Vulpia* species in winter, which contributed to 74-93% of fragments. Dicotyledons recorded by Evans and Jarman (1999) were most y forb species (12%), particularly those species most abundant or available in the field or those species with stellate hairs e.g. *Sida cordifolia*, *Solanum* spp., *Portulacca oleracea*, *Zalea galericulata* and *Trianthema triquetra*. Evans and Jarman (1999) also report the browse species *Eremophila mitchelli*, *Myoporum montanum*, *Cassia brewsteri* and *Atalaya hemiglauca* made up only 4% of the Black-striped Wallaby diet.

Both Jarman *et al.* (1991) and Evans and Jarman (1999) report some seasonal variation in proportions of species eaten with Jarman *et al.* (1991) finding a nearly complete change of species seasonally at one New South Wales site and Evans and Jarman (1999) reporting some seasonal changes, mainly in the ratio of grasses to sedge in Central Queensland. Nevertheless, grasses were still the major component of the diet in all seasons, as was found in this study, and the small seasonal changes in the proportions of vegetation categories are probably a simple reflection of what plant species are available. There may be less native monocotyledon species available during winter or the attractiveness of major introduced pasture species may decrease as they dry off, so the wallaby chooses more forb and browse species during that time. Unfortunately, the influence of availability on wallaby choice of plant species in this study was not determined as seasonal plant availability in the Sampling Areas was not measured.

In addition to information regarding the proportion of species in the diet, Evans and Jarman (1999) report that leaf was the most abundant plant part consumed (54%), with stem/sheath making up 38% and reproductive parts (the majority being grass seed) making up 8%. Jarman *et al.* (1991) had similar findings with almost entirely leaf constituting the diet in winter but a higher ratio of sheath, stem and seedhead in summer. Results of this study also suggest that eaten plant parts are largely leaf, followed by sheath and stem. The higher proportion of monocotyledon seedhead found during summer in this study is of particular interest as it follows findings of Jarman (1994) that macropods can utilise the availability of seedheads to improve seasonal dietary quality. This may imply that the wallabies do not gain all the nutritional quality they need simply by grazing on introduced 'improved' pasture. This adds to the impression that grass species that are sown because they are thought to be ideal for cattle (e.g. Buffel grass) are not necessarily of attractive quality for Black-striped Wallabies.

This study, although based on relatively fewer analysed faecal pellets has similar findings to the two described above, the main findings being that the wallabies eat a high number of species, the majority being grasses; and that grasses contribute the highest proportion of identified epidermal area. In all seasons and throughout the Reference Site at Brigalow Research Station, a wide variety of species were eaten; including small proportions of highly abundant introduced pasture species, much higher proportions of less abundant native grasses, and a small percentage of browse and forbs.

In the study by Evans and Jarman (1999) there were a number of forb and grass species not selected by Black-striped Wallabies, including *Aristida* spp., *Heteropogon contortus*

and *Brachyachne convergens*. Jarman *et al.* (1991) also reported that while nearly all plant species available were found during microscopic analysis of the faeces, a small number of plant species (*Carex*, *Juncus*, *Danthonia*, *Paspalidium*, *Axonopus* and *Imperata* species) were avoided. Results from the current study also suggest that wallabies did not necessarily eat every plant species present, and that the readily available introduced pasture species were not preferred. Failure to recognise the pasture species microscopically is unlikely as Buffel grass in particular has a distinctive, readily recognisable epidermal patterning. Therefore, this study suggests that the wallaby has not changed its usual feeding habits with pastoral development and the plant species within the remnant scrub are equally, or more significantly, important to the diet; and the wallaby is not relying upon crops or introduced pastures (e.g. Buffel grass) for survival.