CHAPTER 3

BIOMASS, COMPOSITION AND QUALITY OF THE PASTURE

An analysis of pasture biomass, composition and quality was undertaken in order to: (1) compare the food resources available to kangaroos on the two study areas; (2) compare food resources in each habitat with a view to determining the influence of food abundance and quality on habitat usage by kangaroos; (3) compare pasture composition with the composition of the diet of kangaroos; and (4) to document seasonal changes in pasture composition and quality in order to account for changes in the diet and condition of kangaroos between seasons.

3.1 Methods

3.1.1 Pasture biomass and composition

Two main methods have been employed in studies of pasture availability. The first is based on the frequency of occurrence of plant species. This is measured by quantifying the presence or absence of species in a series of quadrats or by estimating the percentage cover of species by a point quadrat analysis (Brown, 1954). This method has been used extensively in North American studies on large herbivores (e.g., Bayless, 1969; Crouch, 1968). Studies of diet selectivity in macropods have also utilized this technique for assessing pasture availability (e.g. Kirkpatrick, 1965a; Ellis *et al.*, 1977; Bailey *et al.*, 1971; Chippendale, 1968). The second method used in pasture studies is based on direct measurements of pasture biomass. The weights of plant species are taken for a series of quadrats and direct measures of weight per area or percentage of total pasture biomass can be given. Notable examples using this technique are Milner and Gwynne (1974) and Arnold (1960).

Since on the present study area individual plants differed markedly in biomass, I considered the measurement of pasture availability in terms of the frequency of occurrence of individual plants to be too inaccurate for the requirements of the present study. Hence pasture availability was assessed directly by weighing cut plots from sample quadrats. Pasture composition was sampled in each habitat type. Square quadrats with an area of 0.25 m^2 were used as sampling units. The number of quadrats sampled in any habitat was based loosely on that habitat's percentage occurrence on the study area and its importance as a feeding habitat for kangaroos. Quadrats were placed in habitats on a stratified random basis. Thus quadrats were distributed over different portions of a habitat but within a given area the position of the quadrat was chosen randomly. Dense-rock and large-boulder-slope habitats on Lana were sampled only during the first sampling period because of their presumed low importance as feeding areas and the lack of marked seasonal changes in pasture composition in these areas.

Pasture composition was sampled in 1978. The pasture samples were taken at such a time as to co-ordinate as closely as possible to the times when a shot sample of kangaroos was obtained†. Since the field work was carried out unassisted, as much as two weeks sometimes elapsed between the dietary sampling and pasture sampling. On Lana pasture composition was sampled in February, May, July and November and on Newholme in March, May, July and November. Quadrats were not placed on bare rocks or in patches of stinging nettle (*Urtica incisa*) or horehound (*Marrubium vulgare*) (both found in sheep camps). In order to compensate for this in the analysis a weighted mean was calculated based on the percentage occurrence of rock, stinging nettle, horehound and pasture in a habitat. The percentage cover for rock, stinging nettle and horehound was estimated by recording their presence at points one metre apart on transects of varying lenth in different patches of each habitat over the study area. The number of points sampled in each habitat varied from 100 to 3500 depending on the area of a habitat. Rock, stinging nettle and horehound were classed as having no biomass. Stinging nettle and horehound are not eaten by kangaroos. Because subhabitats could be recognized which differed slightly in pasture composition and/or rock density, subhabitats were weighted according to the percentage of the total area of a habitat which they represented. The proportion of the area of a habitat which a subhabitat occupied over the whole of the study area was not known so the proportional area of subhabitats sampled on the habitat use transects was used instead. Weighting was also sometimes carried out when two types of pasture were closely intermingled within an area. For example, when the pasture was composed of clumps of tussock grasses interspersed with areas of short grass it was easiest to sample the short grass areas and the tussock areas and then estimate the percentage cover of each to give an estimate of percentage biomass. This was done for *Cymbopogon* slope and some *Poa-Pennisetum* grassland areas on Newholme.

When a quadrat was sampled all pasture biomass was cut off at ground level and placed into paper bags. The samples were later dried in an oven at 80°C for 48 hours. Because of the enormous amount of time involved in separating a sample into plant species it was necessary to

†A sample of kangaroos was also taken in August 1979. However time did not permit an examination of pasture availability at this time.

group species and/or plant parts of similar quality. The categories into which plant species were sortedwere based on what other studies had found to be important components of kangaroo diets as well as guesses as to what factors might influence a kangaroo's preference for a plant species or plant part. On Lana cut plots were separated into six categories. These were:

(1) Grass stem and infloresence. The leaf present on stems was separated from this category but the sheath attached to stem was included.

(2) Low-fibre grass leaf and sheath. Grass speices were included in this category if they were non-tussock species and if they were not included in category 3. Examples of species included here are *Bothriochloa*, *Eragrostis*, *Sporobolus*, *Microlaena*, *Danthonia* (excluding *Danthonia pallida*), *Phalaris* and *Vulpia*.

(3) High-fibre grasses. This category consisted of the leaf and sheath from grass species with a high fibre content or which were thought to be unpalatable. Species included in this category were *Arisitida*, *Pennisetum*, *Cymbopogon* and *Imperata*. The stems of *Aristida* were also included in this category and not in category 1 because of the growth form of this species. For this grass species, unlike others, there was no tuft of leaves at ground level. Stems were clumped together and leaves grew out from the stems.

(4) Tussock grasses. These species are present as dense tufts of green and dead leaves. The leaves are curled and have a relatively high fibre content. Species included here were *Poa* (excluding *Poa annua*), *Stipa* and *Danthonia pallida*.

(5) Non-grass monocotyledons. This category included all non-grass monocotyledons except *Carex inversa* which was included with the low-fibre grass leaf and sheath category. Examples of species included in this category are *Juncus*, *Fimbristylis*, *Cyperus*, *Schoenus* and *Tricoryne*. *Lomandra* species were not included in this category as it was thought that their high fibre content would discourage kangaroos from eating them. However one species, *Lomandra filiformis*, was eaten by grey kangaroo during winter.

(6) Forb. This category contained all other sampled plant species not included above. The species in this category were dicotyledons and pteridophytes with the exception of *Lomandra filiformis* which was included here for reasons given above. Shrubs, tree seedling and *Xanthorrhoea* were not included in the pasture sampling.

On Newholme a seventh category was included. This consisted of

Pteridium esculentum and *Lomandra longifolia.* Both were species with individuals of large biomass in relation to other pasture species and of high fibre content. Both were not eaten by kangaroos. Both species were rare on Lana.

For all categories except tussock grasses only the live portions of the plants were included in the biomass estimates. This was done as it was expected that kangaroos would select mainly for live material in preference to dead. Grass tussocks, since they contained dense tufts of intermingled live and dead leaves, were expected to be difficult for kangaroos to select only green leaves from and hence both dead and live material was included in the biomass estimates for this category. Examination of mouth contents of shot kangaroos on the whole verified this assumption. Tussock grasses eaten contained both live and dead leaves whereas leaves of other grasses eaten were green. It was noticed that some dead leaves of *Bothriochloa macera* did occur in stomach samples in the May sample. However I was unable to tell whether these were from dead leaves or if they were just the dead tip off green leaves.

3.1.2 Pasture Quality

Both the grey kangaroo and wallaroo rely on foregut fermentation by micro-organisms for the majority of their energy requirements (Dellow, 1980). For the micro-organisms to function properly it is necessary for them to have access to a readily fermentable source of energy and an adequate supply of protein. The two measures of food quality most relevant to animals with foregut fermentation are the protein and digestible energy content of forage. Measurement of the nitrogen content of forage can be used as an index to protein content as there is a constant relationship between nitrogen and protein content for most plant species (% nitrogen x 6.25% = % protein). The best index to the digestible energy content of forage is the acid-detergent fibre content (see Van Soest, 1963).

Samples of pasture plants from the two study areas were collected and dried at 85^{o}C for 24 hours. The samples were sorted to remove any dirt or other species or plant parts present. Only live material was included in the sample (unless stated otherwise in Tables 3.4, 3.5, 3.6 or 3.7). Sorted samples were ground in a mill using a 1 mm sieve. The samples were then analysed for nitrogen and fibre. All samples were analysed in duplicate and an average taken. Analysis was repeated if replicates differed by more than 5%. Nitrogen content was measured by the Kjeldahl method on a Technicon auto-analyser. Fibre was measured using the method of Van Soest (1963). Ash content of the fibre was obtained by combustion at 500°C for 4 hrs. The ash content was subtracted from the fibre content to give a measure of organic matter fibre as well as total fibre. Plant samples for analysis of nitrogen and fibre were obtained at the same time as sampling for pasture composition took place. Additional samples for analysis were obtained in August 1979 when kangaroos were obtained for an analysis of diet but when no pasture composition samples were obtained. Pasture species were chosen for sampling on the basis of their abundance as well as their presumed importance in the diet of the kangaroos.

3.2 Results

3.2.1 Qualitative description of seasonal changes in pasture composition and a comparison of the two study areas

Four major groups of pasture species could be recognized on the basis of changes in their abundance between seasons. These are:

(1) Warm season "annuals"[†]. These species are most abundant during the summer months when flowering takes place. Their growth starts during spring and they quickly die as autumn progresses. During winter they are either not present or in very small quantities. Examples are: for grasses; *Bothriochloa, Eulalia, Panicum, Digitaria*; for non-grass monocotyledons, *Cyperus brevifolius*; for forbs, *Centaurium minus*.

(2) Cool season annuals. These species start growth during winter and are most abundant and flower during spring. During summer they rapidly die and few are present during late summer or autumn. Examples of these species are *Vulpia, Bromus molliformis*, many *Trifolium* species and *Petrorhagia*.

(3) Warm season perennials. These can be found all year but the majority of plants or parts of plants die off during winter. Examples are *Ergrostis, Cymbopogon, Helichrysum, Wahlenbergia, Aristida, Sporobolus*.

(4) Cool season perennials. These species do not die-off to as great an extent as species in category 3 and for the most part remain green during winter. A decrease in biomass can occur in some species in this category due mainly to an increase in grazing pressure during winter (e.g. *Stipa nervosa*). Most of the grass species in this category flower in spring. Examples are *Poa, Stipa, Danthonia, Microlaena, Phalaris, Agropyron, Carex inversa* and *Hypochoeris*.

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† Some of these species (e.g. *Bothriochloa*) are not strictly annuals but were classified as such for the purposes of this study.

Differences exist between Newholme and Lana in the extent to which these categories dominate in different seasons. Warm season annual grasses account for a much larger proportion of the biomass on Lana compared to Newholme when they are present. Cool season annuals such as *Vulpia* and *Bromus molliformis* are abundant over most of Lana when present whereas on Newholme they occur mainly in sheep camp areas. Forb species like *Petrorhagia* and most *Trifolium* species are abundant on Lana during spring, but on Newholme, although some of these species are present, they do not assume the abundance which characterizes their presence on Lana. Tussock grasses are much more abundant on Newholme in most areas compared to Lana.

A list of pasture species found on Lana and Newhome is given in Appendix I .

3.2.2 Seasonal changes in pasture composition

Estimates of the total biomass and the biomass of each plant-type category in each habitat for each season are given in Table 3.1 for Lana and Table 3.2 for Newholme. On the whole, biomass is greatest in summer and then declines during autumn and winter and increases again in spring. On Lana total biomass is greatest in savanna woodland. However the low-fibre grass leaf and sheath biomass is greatest in sheep-affected pasture in summer and winter. Differences occur in species composition within plant categories between habitats. The most important difference (in terms of the importance to kangaroos) is in differences in the low-fibre grass leaf and sheath category. The low-fibre grass leaf and sheath category in sheep-affected pasture often contains only *Microlaena*. Small dense patches of *Microlaena* also occur in dense rock slope and low-sight-distance slope. Savanna woodland, rocky slope, low-sight-distance slope and gentle slope on the whole contain similar species in the low-fibre grass leaf and sheath category. Dense woodland probably contains more *Danthonia racemosa* than other habitats. The low-fibre grass leaf present in large boulder slope is mainly *Danthonia richardsonii* which did not appear to be eaten by kangaroos (pers. obs.). The pattern of seasonal change for sampled tussock grasses in savanna woodland on Lana is probably incorrect since it shows the greatest abundance of tussock grasses occurring in winter. No such trend was apparent in the field. This result was probably obtained because tussock grasses in savanna woodland occur as scattered dense clumps as well as scattered individual plants. A chance occurrence of a few quadrats in these dense clumps will bias the results and mask any seasonal trend. The sampling procedure was not designed to cope with such extreme local variability.

On Newholme the greatest biomass occurs in slopes dominated by

Table 3.1 Biomass of each plant category and total biomass present in each habitat type in each season on Lana. Figures in the tables are means ± standard error in units of grams of dry matter/ quarter sq. metre.

(A) SUMMER

HABITAT	No. of quadrats	Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grass	Tussock grasses	Non-grass monocotyledons	Forb	Total Biomass
		PLANT CATEGORY						
Savanna woodland	40	11.62±0.77	8.83±0.41	1.91±0.44	0.46±0.22	1.45±0.27	6.94±0.51	31.21± 1.04
Dense woodland	19	1.20±0.15	4.78±0.33	2.40±0.22	0.13±0.05	0.08±0.02	4.02±0.52	12.62± 0.75
Large boulder slope	10	0.50±0.15	1.09±0.10	1.66±0.44	12.88±2.98	0±0	1.46±0.33	17.59± 2.88
Rocky slope	16	1.65±0.31	3.74±0.40	2.85±0.71	0.03±0.01	0.28±0.14	2.59±0.35	11.14± 1.18
Dense rock slope	11	0.03±0.03	0.43±0.40	0.20±0.16	0.01±0.02	0±0	0.79±0.56	1.46± 0.97
Low-sight-distance slope	6	1.27±0.41	2.97±1.21	2.35±1.47	0.27±0.24	0.18±0.14	3.31±1.48	10.35± 3.38
Gentle slope	35	1.93±0.26	4.92±0.45	3.22±0.57	0.26±0.13	0.06±0.02	3.16±0.33	13.55± 1.14
Sheep-affected pasture	21	5.91±0.56	10.51±0.85	0±0	0.04±0.02	0.03±0.01	4.35±0.41	20.84± 1.15

(B) AUTUMN

HABITAT	No. of quadrats	Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grass	Tussock grasses	Non-grass monocotyledons	Forb	Total Biomass
		PLANT CATEGORY						
Savanna woodland	32	0.09±0.01	2.20±0.12	1.40±0.44	2.11±0.68	0±0	2.22±0.15	8.01±0.86
Dense woodland	16	0.36±0.04	3.31±0.25	1.48±0.16	0.54±0.17	0±0	1.79±0.14	7.47±0.44
Rocky slope	14	0.33±0.06	1.51±0.18	1.97±0.51	0.67±0.18	0±0	1.38±0.15	5.87±0.73
Low-sight-distance slope	7	0.34±0.20	1.43±0.54	4.87±2.21	0.55±0.49	0±0	1.25±0.41	8.47±3.09
Gentle slope	32	0.25±0.03	2.17±0.19	2.5±0.54	0.92±0.34	0.02±0.01	1.97±0.19	7.84±2.05
Sheep-affected pasture	17	0.07±0.02	2.14±0.16	0±0	0±0	0±0	2.04±0.20	4.25±0.25

(C) WINTER

HABITAT	No. of quadrats	PLANT CATEGORY: Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grass	Tussock grasses	Non-grass monocotyledons	Forbs	Total Biomass
Savanna woodland	32	0.02±0.01	1.60±0.09	1.33±0.29	4.51±0.87	0.03±0.01	1.80±0.10	6.50±0.90
Dense woodland	16	0.02±0	2.04±0.17	1.05±0.11	1.72±0.09	0±0	0.88±0.08	4.18±0.27
Rocky slope	15	0±0	0.79±0.10	0.86±0.20	0.08±0.03	0±0	0.97±0.11	2.71±0.29
Low-sight-distance slope	7	0±0	1.39±0.56	2.23±1.74	0.11±0.11	0±0	1.04±0.34	4.77±2.07
Gentle slope	31	0.02±0.01	1.05±0.13	1.59±0.53	0.93±0.25	0±0	1.23±0.11	4.83±0.63
Sheep-affected pasture	15	0.01±0	2.16±0.12	0±0	0±0	0±0	2.12±0.15	4.30±0.22

(D) SPRING

HABITAT	No. of quadrats	PLANT CATEGORY: Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grass	Tussock grasses	Non-grass monocotyledons	Forbs	Total Biomass
Savanna woodland	28	4.91±0.66	5.19±0.30	0.36±0.10	0.02±0.01	1.62±0.44	11.62±0.69	23.72±1.21
Dense woodland	14	3.29±0.32	3.45±0.23	1.77±0.29	1.26±0.37	0±0	6.22±0.41	15.99±0.89
Rocky slope	14	1.99±0.27	2.03±0.24	0.57±0.17	0.05±0.02	0±0	6.07±0.78	10.71±1.11
Low-sight-distance slope	6	2.97±1.45	3.43±1.23	2.07±1.29	0±0	0±0	6.01±2.27	14.48±5.23
Gentle slope	30	2.34±0.24	3.41±0.34	1.92±0.47	0.80±0.26	0±0	9.84±0.76	18.31±1.29
Sheep-affected pasture	11	1.81±0.16	4.06±0.33	0±0	0±0	0.05±0.02	6.26±0.55	12.18±0.94

Table 3.2 Biomass of each plant category and total biomass present in each habitat type in each season on Newholme. Figures in the tables are means $\pm$ standard error in units of grams of dry matter/quarter sq. metre.

(A) SUMMER

HABITAT	No. of quadrats	PLANT CATEGORY: Grass Stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grasses	Tussock grasses	Non-grass monocotyledons	Forb	*Lomandra longifolia* + *Pteridium*	Total Biomass
Microlaena pasture	14	0.42±0.03	6.34±0.42	0±0	0.40± 0.14	0±0	0.98±0.13	0.96±0.62	9.12± 0.88
Eragrostis grassland	4	0.94±0.22	14.65±3.05	1.92±0.94	0± 0	1.44±0.90	1.65±0.34	0±0	20.60± 4.86
Poa-Pennisetum grassland	14	0.92±0.07	7.18±0.45	4.83±0.50	4.99± 1.00	5.30±2.27	2.73±0.34	0±0	25.95± 2.63
Poa sieberana slope	18	0.06±0.01	1.54±0.13	0.17±0.74	32.31± 3.81	0±0	2.01±0.18	0.49±0.22	36.58± 4.07
Poa costiniana slope	11	1.28±0.27	5.56±0.37	1.04±0.07	7.60± 0.98	0.14±0.04	3.82±0.17	0±0	19.44± 1.79
Poa labillardieri slope	3	0.17±0.03	6.85±1.14	0.14±0.08	2.32± 0.74	0±0	4.39±0.86	0±0	13.87± 2.51
Grassy slope	3	0.05±0.01	3.16_0.17	0.01±0	0.48± 0.06	0±0	0.86±0.07	0±0	4.57± 0.24
Cymbopogon slope	6	0.91±0.12	1.98±0.21	0.91±0.30	0± 0	0±0	0.55±0.06	0±0	4.36± 0.50
Dense rock slope	6	0.11±0.02	1.65±0.23	0.03±0.01	0.06± 0.02	0.01±0	0.67±0.15	0±0	2.52± 0.34
Shrub slope	2	0.49±0.22	3.05±1.38	0±0	1.14± 1.08	0±0	1.05±0.47	0±0	5.73± 2.72
Savanna slope	8	0.43±0.06	3.42±0.16	0.09±0.04	0± 0	0±0	0.78±0.11	0±0	4.72± 0.33
Poa grassy woodland	14	0.64±0.04	4.94±0.25	1.53±0.37	2.59± 0.55	0.03±0.01	2.05±0.15	0±0	11.78± 0.66
Acacia woodland	4	0.01±0	2.87±0.17	0±0	0± 0	0±0	1.31±0.09	0±0	4.19± 0.18
Hilltop *Poa* forest	3	0.12±0.05	2.03±0.73	0±0	57.03±13.77	0±0	1.99±0.50	0±0	61.17±13.41
Hilltop *Poa* forest with *Acacia*	3	0.15±0.05	2.03±0.12	0±0	48.03±12.42	0.38±0.20	3.28±0.59	3.58±1.91	57.49±13.19

(B) AUTUMN

HABITAT	No. of quadrats	PLANT CATEGORY: Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grasses	Tussock grasses	Non-grass monocotyledons	Forb	*Lomandra longifolia* + *Pteridium*	Total Biomass
Microlaena pasture	14	0.10±0.02	5.58±0.35	0.03±0.02	0.01± 0.01	0.01±0.01	1.04±0.09	0.33±0.20	7.11± 0.46
Eragrostis grassland	4	0.19±0.12	6.04±1.30	0±0	0± 0	1.57±0.79	0.94±0.09	0±0	8.73± 1.24
Poa-Pennisetum grassland	13	0.08±0.01	6.23±0.34	1.30±0.14	9.82± 2.15	0.87±0.19	2.02±0.06	0±0	20.31± 2.36
Poa sieberana slope	18	0.05±0.01	1.96±0.15	0.24±0.08	26.15± 2.28	0±0	2.59±0.22	0.45±0.21	31.43± 2.43
Poa costiniana slope	11	0.08±0.01	5.51±0.23	0±0	13.38± 1.41	0.38±0.01	3.73±0.42	0±0	22.74± 1.54
Poa labillardieri slope	3	1.68±0.90	6.23±1.13	0.43±0.23	9.83± 1.65	0±0	3.01±0.55	0±0	21.18± 3.66
Grassy slope	3	0±0	2.10±0.12	0±0	0.89± 0.15	0±0	1.62±0.10	0±0	4.61± 0.28
Cymbopogon slope	6	0.55±0.07	2.10±0.18	2.78±0.46	0.13± 0.09	0±0	0.77±0.08	0±0	6.33± 0.74
Dense rock slope	6	0.03±0.01	1.38±0.23	0.11±0.04	0.19± 0.07	0±0	0.95±0.18	0±0	2.66± 0.42
Shrub slope	2	0.03±0.02	2.33±1.10	0±0	2.49± 2.31	0±0	1.52±0.08	0±0	6.37± 3.15
Savanna slope	8	0.18±0.02	2.24±0.13	0±0	0.02± 0.01	0±0	1.59±0.10	0±0	4.03± 0.19
Poa grassy woodland	14	0.31±0.06	3.94±0.23	1.21±0.13	2.35± 0.49	0.04±0.01	1.53±0.13	0±0	9.38± 0.61
Acacia woodland	6	0.01±0	2.70±0.17	0±0	0± 0	0.02±0	0.63±0.05	0±0	3.37± 0.19
Hilltop *Poa* forest	3	0±0	1.91±0.46	0±0	43.15± 7.07	0±0	1.35±0.16	0±0	46.41± 7.15
Hilltop *Poa* forest with *Acacia*	3	0.04±0.02	3.44±0.56	0±0	50.90±14.39	0±0	2.58±0.51	11.85±6.24	68.80±12.29

(C) WINTER

HABITAT	No. of quadrats	PLANT CATEGORY Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grasses	Tussock grasses	Non-grass monocoty-ledons	Forb	*Lomandra longifolia* + *Pteridium*	Total Biomass
Microlaena pasture	14	0±0	2.69±0.19	0±0	0±0	0.05±0.03	1.15±0.10	0.37±0.16	4.27± 0.34
Eragrostis grassland	4	0±0	2.30±0.15	2.03±1.45	0±0	1.08±0.51	0.16±0.07	0±0	5.57± 0.92
Poa-Pennisetum grassland	14	0±0	1.88±0.12	0.22±0.03	6.71±0.98	2.02±0.57	1.18±0.18	0±0	12.02± 1.31
Poa sieberana slope	17	0±0	1.54±0.13	0±0	27.24±2.92	0±0	1.77±0.25	0.48±0.21	31.03± 3.03
Poa costiniana slope	12	0.04±0.01	2.67±0.14	0.05±0.01	7.50±0.70	0.17±0.04	2.69±0.24	0±0	13.12± 0.90
Poa labillardieri slope	3	0±0	1.84±0.38	0±0	5.68±1.28	0±0	0.66±0.13	0±0	8.18± 1.74
Grassy slope	3	0.03±0.01	1.04±0.06	0±0	1.17±0.08	0±0	1.02±0.16	0±0	3.27± 0.20
Cymbopogon slope	6	0±0	0.97±0.01	0.41±0.14	0±0	0±0	0.52±0.05	0±0	1.91± 0.20
Dense rock slope	6	0±0	0.82±0.12	0.01±0	0.31±0.12	0±0	0.28±0.05	0±0	1.42± 0.23
Shrub slope	2	0.64±0.60	0.84±0.71	0.64±0.63	0±0	1.30±1.23	0.20±0.18	0.24±0.21	3.86± 2.53
Savanna slope	7	0±0	1.22±0.58	0±0	0.69±0.10	0±	0.81±0.05	0±0	2.71± 0.14
Poa grassy woodland	13	0±0	1.92±0.09	0.57±0.20	2.07±0.46	0.01±0.01	0.83±0.05	0±0	5.40± 0.49
Acacia woodland	5	0±0	1.58±0.07	0±0	0±0	0±0	0.42±0.04	0±0	1.99± 0.09
Hilltop *Poa* forest	3	0±0	1.16±0.32	0±0	55.64±8.65	0±0	0.71±0.21	0±0	57.52± 8.59
Hilltop *Poa* forest with *Acacia*	3	0±0	1.94±0.31	0±0	31.59±6.70	0±0	3.52±1.00	0±0	37.04± 6.87

(D) SPRING

HABITAT	No. of quadrats	PLANT CATEGORY: Grass stem + infloresence	Grass low-fibre leaf + sheath	High-fibre grasses	Tussock grasses	Non-grass monocotyledons	Forb	*Lomandra longifolia* + *Pteridium*	Total Biomass
Microlaena pasture	14	2.87±0.39	7.49±0.52	0±0	0± 0	0.07±0.02	2.85±0.23	1.63±0.70	14.91± 1.12
Eragrostis grassland	4	0.27±0.17	11.05±2.06	0.50±0.41	0± 0	1.90±0.15	2.44±0.61	0±0	16.16± 2.53
Poa-Pennisetum grassland	13	0.72±0.07	7.03±0.55	2.52±0.30	10.71± 1.34	2.15±0.33	3.94±0.25	0±0	27.06± 1.91
Poa sieberana slope	15	0.25±0.03	2.16±0.18	0.02±0.01	32.81± 3.14	0.02±0.01	3.20±0.30	0.39±0.15	38.84± 3.20
Poa costiniana slope	12	2.70±0.24	4.78±0.30	0±0	7.52± 0.94	0.24±0.07	5.89±0.55	0±0	21.12± 1.34
Poa labillardieri slope	3	2.06±0.34	6.68±1.20	0±0	5.42± 2.44	0.16±0.03	4.07±0.78	0±0	18.40± 3.63
Grassy slope	3	1.28±0.16	3.35±0.18	0±0	0± 0	0±0	1.67±0.16	0±0	6.29± 0.44
Cymbopogon slope	6	0.93±0.11	3.36±0.30	2.01±0.26	0±0	0±0	1.51±0.13	0±0	7.81± 0.71
Dense rock slope	6	0.57±0.16	1.48±0.25	0.01±0.01	0.03±0.01	0±0	1.72±0.28	0±0	3.80±0.63
Shrub slope	2	1.73±1.04	3.73±2.01	0.43±0.40	0±	0±0	1.61±0.73	0±0	7.49± 3.61
Savanna slope	7	2.11±0.23	5.14±0.25	0±0	0.17±0.12	0.16±0.02	2.15±0.08	0±0	9.74± 0.48
Poa grassy woodland	12	3.16±0.31	6.96±0.33	0.42±0.09	1.22±0.37	0.12±0.03	2.08±0.18	0±0	13.96± 0.64
Acacia woodland	5	0.68±0.18	3.17±0.16	0±0	0±	0.03±0.01	0.88±0.05	0±0	4.75± 0.31
Hilltop *Poa* forest	3	0.22±0.11	3.29±0.49	0±0	69.15±11.63	0±0	2.66±0.51	0±0	75.32±10.81
Hilltop *Poa* forest with *Acacia*	3	0.27±0.09	3.43±0.72	0±0	64.80±13.13	0±0	4.07±0.77	0±0	72.56±12.79

Poa tussocks. *Eragrostis* grassland contains the highest biomass of low-fibre grasses in summer and spring. *Microlaena* pasture contains the highest low-fibre grass leaf biomass in winter but not in summer as for sheep-affected pasture on Lana. As on Lana differences occur in the species composition of the low-fibre grass leaf category between habitats. In *Microlaena* pasture *Microlaena* dominates the low-fibre grass leaf category. *Eragrostis* grassland contains more *Eragrostis* and probably more *Sporobolus* than other habitats. *Bothriochloa* tends to be common in most habitats.

Taking into account the area covered by each habitat on the study areas on Lana and Newholme (see Table 5.1), the total pasture biomass is probably greater on Newholme than on Lana. However most of this biomass is in the form of *Poa* tussocks. For the low-fibre grass leaf and sheath category (see Table 3.3) Lana contains more biomass in summer and similar amounts in winter and spring. Low-fibre grass leaf biomass may be somewhat less on Lana than on Newholme in autumn. Some of the low-fibre grass leaf may be less available to kangaroos on Newholme than on Lana. In areas of dense *Poa* tussocks some low-fibre grass leaf occurs amongst the *Poa* tussocks and hence would be difficult for kangaroos to select. This is especially true for *Agropyron scabrum*.

Table 3.3 Biomass of low-fibre grass leaf and sheath (g dry matter/0.25 sq.m.) present on Lana and Newholme each season. Values were calculated by weighting habitat biomass figures according to the area each habitat covered on the study area. Values shown are means ± standard errors.

SEASON	NEWHOLME	LANA
SUMMER	3.85 ± 0.28	7.20 ± 0.27
AUTUMN	3.27 ± 0.17	2.21 ± 0.04
WINTER	1.65 ± 0.04	1.53 ± 0.04
SPRING	4.40 ± 0.23	4.50 ± 0.11

Data on the frequency of occurrence of plant species in the grass stem and infloresence, and forb categories are given in Chapter 4.

3.2.3 Pasture quality

The results of the analysis of pasture samples for nitrogen are shown in Table 3.4, for total fibre in Table 3.5, for organic matter fibre in Table 3.6 and for ash content in Table 3.7. The nitrogen content of plants was negatively correlated with both total fibre (Lana, r = -0.80,

Table 3.4 Nitrogen content (g/100 g dry matter) of selected plants and plant parts on Lana and Newholme

Plant Species	Plant Part	LANA						NEWHOLME					
		2/78	5/78	7/78	12/78	8/79	11/79	3/78	5/78	7/78	12/78	8/79	11/79
GRASSES													
Agropyron scabrum	L		1.83	3.24		2.99		1.68					
" "	(SC) L			4.58									
" "	St + I				1.06						1.29		
" "	St						1.26						
" "	I						1.54						
Aristida ramosa	L + St + I	0.96	0.72	0.72	0.88	0.86		0.91	0.65	0.61	1.00	0.56	
Bothriochloa macera	L	2.88	1.52		1.36			1.60	1.47		1.52		
" "	St	0.94											
Bromus molliformis	L						1.48				1.78		
" "	St + I				0.96						0.88		
" "	St						0.72						
" "	I						1.62						
Bromus unioloides	L								1.43				
Chloris truncata	L	1.50											
Cymbopogon refractus	L							1.40		1.03			
Danthonia longifolia	L			2.08									
Danthonia pallida	L			0.96									
Danthonia racemosa	L		1.68				1.73						
" "	St						0.91						
" "	I						1.28						
Dichelachne micrantha	St + I				0.92								
Digitaria brownii	L	2.18											
Echinopogon nutans	L		2.88			3.20		2.06	1.76	2.12	1.80	2.17	
Eleusine tristachya	L				3.34								
Eragrostis brownii	L												
Eragrostis leptostachya	L	1.40	1.46					1.09	0.84	0.92	0.90	0.96	
Eragrostis phillippica	L	1.63											
Eulalia fulva	L	2.01	1.52										
Festuca pratensis	L	2.90	1.98		2.12	2.13							
Holcus lanatus	L					2.44				3.64			
Imperata cylindrica	L	0.88		0.72	1.07			1.38					
Microlaena stipoides	(SC) L	4.32	4.03	3.92	2.64	3.30		3.62	3.48	3.60	4.22	3.08	
" "	(W) L		1.66					2.24					
" "	(HF) L							2.21		1.69			
" "	(Dr) L							2.00					
" "	(SC) St + I				1.20						1.35		
Panicum effusum	L	2.01			1.36						1.75		
Paspalum dilatum	L				2.00					1.72	1.76		
Pennisetum alopecuroides	L	1.40						1.26					
Phalaris tuberosa	L	4.11	3.56	4.00	2.37	3.21							
Poa costiniana	L			1.56		1.84		1.28		1.34	1.20		
" "	(WC & SL) L					1.33	1.53		0.69	1.04	0.91	0.91	
" "	(WC & G) L										0.59		
" "	(WC & Dr) L											0.58	
Poa labillardieri	L			1.67		1.68		1.12					
" "	(WC) L			0.85		0.96			0.88	1.04	0.86		
Poa sieberana	L							1.22		0.92			
" "	(WC) L								0.64	0.57	0.76	0.80	
Setaria glauca	(SC) L	3.26											
Sorghum leiocladum	L						1.79	1.04					1.60
Sporobolus elongatus	L	1.88	1.84		1.22			1.11	0.78				
" "	St	0.90											
Stipa nervosa	L		1.98										
" "	(WC) L			0.68	0.88	1.20				0.92			
Themeda australis	L		1.13					1.33	1.43		1.24		
Vulpia bromoides	L			3.44		2.45				3.29		3.02(SC)	
" "	St + I				1.02						1.12		
" "	St						0.98						
" "	I						1.60						
OTHER MONOCOTYLEDONS													
Carex fascicularis	L									1.36			
Carex gaudichaudiana	L								1.24	1.28			
Carex inversa	L	1.52	1.02	1.67		1.63		0.99		1.24		0.92	
" "	(Dr) L											0.86	
Cyperus brevifolius	L + St + I	1.80						1.12			1.40		
Fimbristylis dichotoma	L + St	1.33											

Table 3.4 (cont.)

Plant Species	Plant Part	LANA						NEWHOLME					
		2/78	5/78	7/78	12/78	8/79	11/79	3/78	5/78	7/78	12/78	8/79	11/79
Juncus bufonius												1.20	
Juncus polyanthemus		1.76		1.40	0.84	1.06				0.84		0.72	
Lomandra filiformis			1.46			1.28							
Luzula meridionalis	L			2.08						1.66			
Murdannia graminea	L	3.46									2.30		
Schoenus apogon	L + St + I										1.05		
Tricoryne elatior			1.24										
DICOTYLEDONS													
Acaena anserinifolia										1.60			
Desmodium varians	St + L							2.20					
Dichondra repens	L + St		2.00										
Geranium solanderi											1.69		
Glycine clandestina	L + St	1.80											
Halorogis heterophylla									1.32				
Helichrysum apiculatum	L + St + I	1.29											
Hydrocotyl laxiflora											2.04		
Hypochoeris radicata	L	2.54	1.96	2.28	2.24			2.22	1.95	1.72	2.08		
" "	St	1.30											
Medicago sativa	L + St + I	3.30											
Paryonchia brasiliana	L			3.12									
Petrorhagia prolifera					1.00								
Pteridium esculatum										1.24	1.44		
Stellaria pungens	(SC)									1.84			
Trifolium arvense	L + St + I				2.28								
Trifolium campestre	L + St				2.16						2.69		
Trifolium desvauxii	L	3.13		3.60		3.44							
" *glomeratum*	L + St				2.43								
" *repens*	L				3.20			3.97			3.15		
Wahlenbergi sieberi	L + St + I	1.44											

L = leaf
St = stem
I = infloresence

W = sample from woodland
SC = sample from sheep camp
Dr = sample from drainage area
WC = dead and live material included
SL = sample from a slope area
G = sample from grassland area

The above abbreviations also apply to Tables 3.5, 3.6 and 3.7.

Table 3.5. Total fibre content (g/100 g dry matter) of selected plants and plant parts on Lana and Newholme

Plant Species	Plant Part	LANA						NEWHOLME					
		2/78	5/78	7/78	12/78	8/79	11/79	3/78	5/78	7/78	12/78	8/79	11/79
GRASSES													
Agropyron scabrum	L		33.31			29.33							
" "	(SC) L			30.52									
" "	St						43.27						
" "	I						40.13						
" "	St + I										43.56		
Aristida ramosa	L + St + I			39.16	46.83			47.23		44.88	45.39		
Bothriochloa macera	L	25.26			26.22			30.96	31.21		33.27		
" "	St	48.49											
Bromus molliformis	L						37.69				42.96		
" "	St + I				39.01								
Bromus unioloides	L								40.10				
Cymbopogon refractus	L							36.18					
Danthonia racemosa	L		37.57				42.15						
" "	St						43.33						
" "	I						40.40						
Digitaria brownii	L	34.56											
Echinopogon nutans	L									29.28	34.84		
Eragrostis leptostachya	L	37.61	35.52					40.76	37.36	35.95	36.95	33.20	
Eragrostis philippica	L	37.84											
Eulalia fulva	L	34.88											
Festuca pratensis	L		24.70										
Holcus lanatus	L									19.52			
Imperata cylindrica	L	44.78		41.28									
Microlaena stipoides	(SC) L	22.71	21.21	17.87	28.04			25.14	26.78	23.49	24.27		
" "	St + I				36.50						40.45		
Panicum effusum	L	27.34			26.59						31.39		
Pennisetum alopecuroides	L	38.63						44.32					
Phalaris tuberosa	L			15.82									
Poa costiniana	L			38.49				44.75			49.41		
" "	(WC) L					42.92	42.85		46.52	46.11			
" "	(WC & G) L										48.43		
" "	(WC & Dr) L											47.63	
Poa labillardieri	(WC) L		42.29							46.07			
Poa sieberana	(WC) L								47.74	47.44	47.18		
Sorghum leiocladum	L						36.55	40.50					
Sporobolus elongatus	L	36.35	36.04		32.66			39.78	36.89				
" "	St	46.68											
Stipa nervosa	(WC) L			49.01		41.91				42.90			
Themeda australis	L		35.74					38.31	38.54				
Vulpia bromoides	L			24.48		24.84							
" "	(SC) L									24.73		24.99	
" "	St + I				34.91						38.25		
" "	St						45.57						
" "	I						33.39						
OTHER MONOCOTYLEDONS													
Carex fascicularis	L									34.27			
Carex gaudichaudiana	L								35.95	40.29	(Dr)		
Carex inversa	L	34.70	38.49	33.59		32.13				35.32		39.23	
Fimbristylis dichotoma	L + St	38.51											
Juncus bufonius	L											33.38	
Juncus polyanthemus	L			45.32	42.23	35.80				36.77		33.52	
Lomandra filiformis	L					46.19							
Murdannia graminea	L										28.46		
DICOTYLEDONS & OTHERS													
Desmodium varians	St + L							33.73					
Helichrysum apiculatum	L + St + I	37.04											
Hypochoeris radicata	L	29.36						22.40					
" "	St	50.76											
Petrorhagia prolifera	L + St				38.53								
Pteridium esculatum										48.44			
Trifolium arvense	L + St + I				33.04								
Trifolium campestre	L + St				35.47						33.35		
Trifolium desvauxii	L			14.59									
Trifolium glomeratum	L + St				35.65						22.42		
Trifolium repens	L												

Table 3.6. Organic matter fibre content (g/100 g dry matter) of selected plants and part parts on Lana and Newholme.

Plant Species	Plant Part	LANA						NEWHOLME					
		2/78	5/78	7/78	12/78	8/79	11/79	3/78	5/78	7/78	12/78	8/79	11/79
Agropyron scabrum	L		30.93			24.91							
" "	(SC) L			25.66									
" "	St						40.64						
" "	I						37.56						
" "	St + I										39.45		
Aristida ramosa	L + St + I			38.00	40.66			42.46		39.30	40.98		
Bothriochloa macera	L	22.33			22.58			25.25	24.35		27.84		
" "	St	47.82											
Bromus molliformis	L						29.88				25.13		
" "	St + I				38.67								
Bromus unioloides	L								35.19				
Cymbopogon refractus	L							31.36					
Danthonia ramosa	L		33.61				38.02						
" "	St						41.38						
" "	I						37.84						
Digitaria brownii	L	32.34											
Echinopogon nutans	L									25.00	27.13		
Eragrostis leptostachya	L	34.83	32.75					37.33	34.78	33.56	34.23	30.88	
Eragrostis phillippica	L	36.28											
Eulalia fulva	L	31.90											
Festuca pratensis	L		22.11										
Holcus lanatus	L									16.86			
Imperata cylindrica	L	43.12		39.30									
Microlaena stipoides	(SC) L	19.81	18.52	16.94	23.36			20.05	21.64	17.01	20.41		
" "	ST + I				35.02						38.64		
" "	St												
" "	I												
Panicum effusum	L	23.97			23.91						26.26		
Pennisetum alopecuroides	L	34.79						39.49					
Phalaris tuberosa	L	20.47		13.42									
Poa costiniana	L							40.13		39.77			
" "	(WC) L			35.17		37.17	38.55		39.77		40.82		
" "	(WC & G) L										41.76		
" "	(WC & Dr) L											41.37	
Poa labillardieri	(WC) L		38.97							38.12			
Poa sieberana	(WC) L								41.28	40.88	41.17		
Sorghum leiocladum	L						33.60	34.76					
Sporobolus elongatus	L	33.31	33.63		30.75			35.11	33.31				
" "	St	46.13											
Stipa nervosa	(WC) L			43.27		36.87				35.93			
Themeda australis	L		31.08					33.88	33.56				
Vulpia bromoides	L			21.08		20.81							
" "	(SC) L									20.73		21.11	
" "	ST + I				33.19						35.24		
" "	St						43.77						
" "	I						30.43						
OTHER MONOCOTYLEDONS													
Carex fascicularis	L									30.82			
Carex gaudichaudiana	L								31.59	34.75			
Carex inversa	L	32.67	35.70	30.95		28.92				31.30		33.39 (Dr)	
Fimbristylis dichotoma	L + St	34.76											
Juncus bufonius	L											25.52	
Juncus polyanthemus	L			39.54	39.00	35.40				36.09		32.84	
Lomandra filiformis	L					45.96							
Murdannia graminea	L										23.11		
DICOTYLEDONS & OTHERS													
Desmodium varians	St + L							32.30					
Helichrysum apiculatum	L + St + I	36.76											
Hypochoeris radicata	L	28.52						21.57					
" "	St	50.70											
Petrorhagia prolifera	L + St				38.50								
Pteridium esculatum										45.80			
Trifolium arvense	L + St + I				32.96								
Trifolium campestre	L + St				35.44						32.82		
Trifolium desvauxii	L			14.34									
Trifolium glomeratum	L + St				35.50								
Trifolium repens	L										22.18		

Table 3.7. Ash content (g/100 g dry matter) of selected plants and plant parts on Lana and Newholme

Plant Species	Plant Part	LANA						NEWHOLME					
		2/78	5/78	7/78	12/78	8/79	11/79	3/78	5/78	7/78	12/78	8/79	11/79
Agropyron scabrum	L		2.49			4.42							
" "	(SC) L			4.86									
" "	St						2.63						
" "	I						2.57						
" "	St + I										2.86		
Aristida ramosa	L + St + I			1.16	4.20			4.77		5.58	4.41		
Bothriochloa macera	L	2.93			3.65			5.71	6.86		5.43		
" "	St	0.67											
Bromus molliformis	L						7.81						
" "	St + 1				0.25								
Bromus unioloides	L								4.90				
Cymbopogon refractus	L							4.82					
Danthonia ramosa	L		3.96				4.13						
" "	St						1.95						
" "	I						2.56						
Digitaria brownii	L	2.22											
Echinopogon nutans	L									4.28	7.71		
Eragrostis leptostachya	L	2.80	2.77					3.43	2.65	2.39	2.71	2.33	
Eragrostis phillippica	L	1.56											
Eulalia fulva	L	2.98											
Festuca pratensis	L		4.65										
Holcus lanatus	L									2.66			
Imperata cylindrica	L	1.67		1.99									
Microlaena stipoides	SC (L)	2.90	2.69	0.93	3.66			5.09	5.14	6.48	3.86		
" "	St + I				1.48						1.80		
" "	St												
" "	I												
Panicum effusum	L	3.37			2.68						5.14		
Pennisetum alopecuroides	L	3.84						4.83					
Phalaris tuberosa	L	1.73		2.40									
Poa costiniana	L			3.32				4.62			7.65		
" "	(WC) L					5.77	4.30		6.75	6.34			
" "	(WC & G) L										7.22		
" "	(WC & Dr) L											6.26	
Poa labillardieri	(WC) L		3.32							7.95			
Poa sieberana	(WC) L								6.46	6.56	6.02		
Sorghum leiocladum	L						2.95	5.74					
Sporobolus elongatus	L	3.04	2.41		1.91			4.67	3.58				
" "	St	0.55											
Stipa nervosa	(WC) L			5.74		5.04				6.97			
Themeda australis	L		4.98					4.43	2.59				
Vulpia bromoides	L			3.40		4.02							
" "	(SC) L									4.00		3.88	
" "	St + I				1.80						3.01		
" "	St						1.72						
" "	I						3.06						
OTHER MONOCOTYLEDONS													
Carex fascicularis	L									3.44			
Carex gaudichaudiana	L								4.60	5.54			
Carex inversa	L	2.03	2.78	2.64		3.21				4.07		5.84	
Fimbristylis dichotoma	L + St	3.54											
Juncus bufonius	L											7.86	
Juncus polyanthemus	L			3.98	2.27	0.40				0.68		0.68	
Lomandra filiformis	L					0.23							
Murdannia graminea	L										4.17		
DICOTYLEDONS AND OTHERS													
Desmodium varians	St + L							1.43					
Helichrysum apiculatum	L + St + I	0.28											
Hypochoeris radicata	L	0.84						0.83					
" "	St	0.06											
Petrorhagia prolifera	L + St				0.03								
Pteridium esculatum										2.64			
Trifolium arvense	L + St + I				0.06								
Trifolium campestre	L + St				0.04						0.53		
Trifolium desvauxii	L			0.22									
Trifolium glomeratum	L + St				0.15								
Trifolium repens	L										0.24		

$df = 66$, $p < 0.001$; Newholme, $r = -0.81$, $df = 56$, $p < 0.001$) and organic matter fibre (Lana, $r = -0.79$, $df = 66$, $p < 0.001$; Newholme, $r = -0.82$, $df = 56$, $p < 0.001$; see Fig. 3.1†). For the regression of total fibre against nitrogen content of plants there was no difference in either slope or intercept for the two study areas. However the intercepts of the regression lines for organic matter fibre against nitrogen content were significantly different (analysis of covariance, $F(1,122) = 6.84$, $p < 0.001$). Thus for a given nitrogen content a plant on Lana will contain more organic matter fibre. Hence a greater percentage of the total fibre of Newholme plants consists of ash and a greater percentage of the total fibre of Lana plants consists of organically-derived fibre (i.e. lignin, cellulose). Ash residues from the plant samples could have contained silica and/or other minerals. The extent of uptake and mineralization of silica differs among plant types (e.g. grasses have a higher silica content than legumes). In order to test whether differences in the proportions of different plant types led to the differences found above, the proportions of different types of plants and plant parts included in the analysis of both nitrogen and fibre were compared (Table 3.8). The only major difference is in the greater proportion of tussock grasses for Newholme. When these are excluded from the analysis the intercepts are still significantly different ($F(1,105) = 8.3$, $p < 0.01$). It thus appears that the difference between the two study areas is a real one. Without direct measurements of the silica content of plants from Lana and Newholme it is not possible to tell whether silica or other minerals are responsible for the higher ash content for a given level of nitrogen in plant species on Newholme. It is unlikely that any of the ash was derived from soil contaminants since each sample was thoroughly sorted before analysis. If the majority of ash in the Newholme plants is in fact silica it could affect the digestibility of the plants. Van Soest and Jones (1968) have shown that silica can be a major factor limiting the nutritive value of forages.

In order to compare the quality of plants on Newholme and Lana, the same species and plant parts which had been analysed in the same season were compared using a Wilcoxon matched-pairs signed-ranks test (Siegel, 1956). Nitrogen content of plants is significantly higher on Lana ($N = 46$, $p < 0.01$). When all plants are included there is no difference between Lana and Newholme in total fibre or organic matter fibre. However if only grass species (and *Carex inversa*) are included in the

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† The relationship between the logarithm of total fibre and organic matter fibre, and nitrogen was also investigated but did not lead to a significant increase in the explained variation.

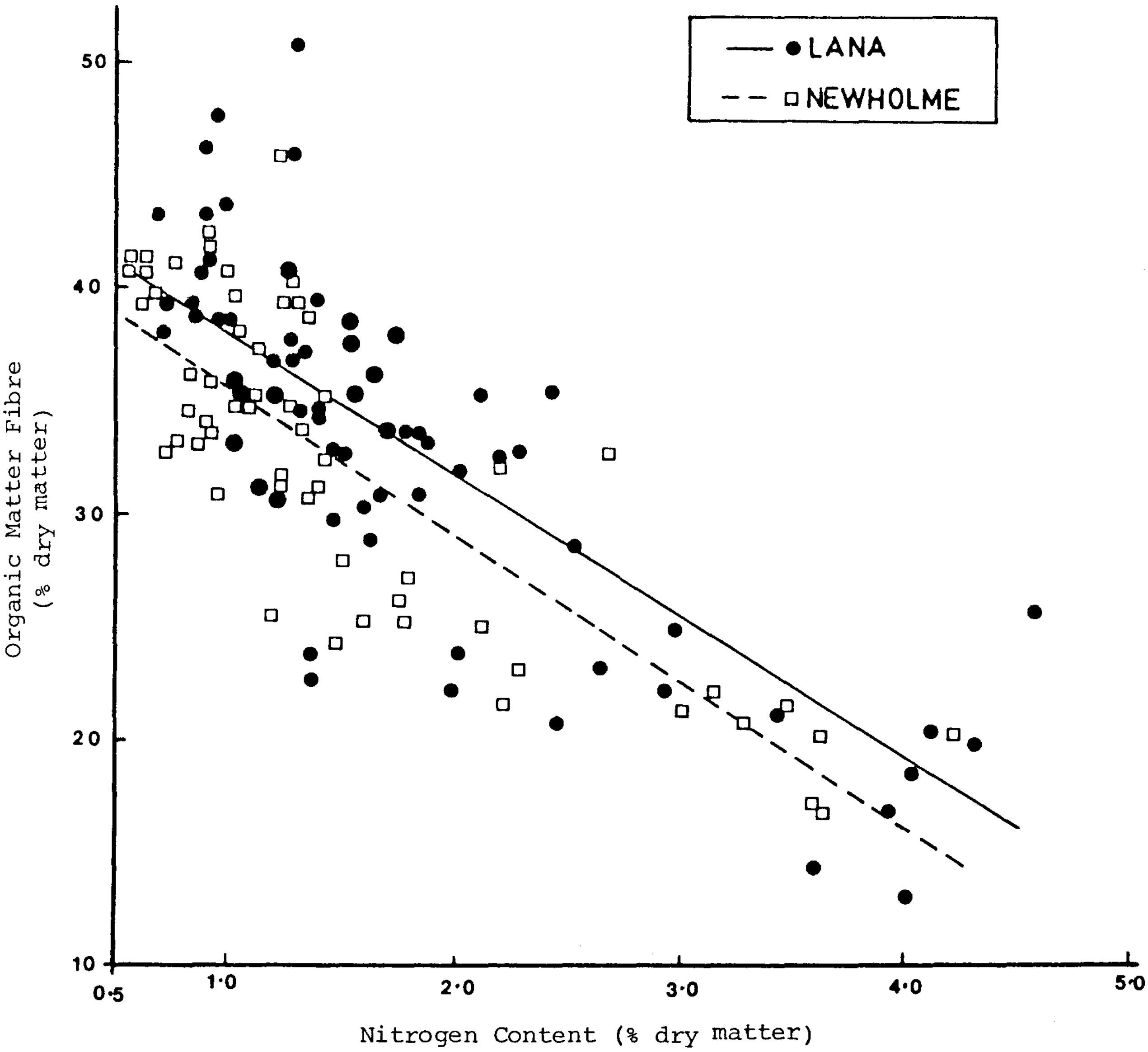


Fig. 3.1. Relationship between organic matter fibre content and nitrogen content for plants on Newholme and Lana.

Newholme: Y = -6.6X + 42.5
(r = -0.82, p < 0.001)

Lana: Y = -6.6X + 44.8
(r = -0.79, p < 0.001)

where X = Nitrogen content
and Y = Organic matter fibre content.

Table 3.8 The percentage of samples from each plant category included in the analysis of the relationship between nitrogen and fibre content. The values in brackets represent the numbers in each sample.

PLANT CATEGORY	STUDY AREA LANA %		NEWHOLME %	
Low-fibre grass leaf and sheath (including *Carex inversa*)	46	(31)	43	(25)
Grass stem + infloresence	7	(5)	5	(3)
Grass Infloresence	6	(4)	0	(0)
Tussock grasses	9	(6)	19	(11)
High-Fibre grasses	7	(5)	9	(5)
Non-grass Monocotyledons	13	(9)	16	(9)
Legumes (i.e. *Trifolium* spp. and *Desmodium* spp.)	6	(4)	5	(3)
Other Forbs	6	(4)	3	(2)

analysis, Newholme plants contain significantly more total fibre ($N = 20$, $p < 0.01$) and more organic matter fibre ($N = 20$, $p < 0.05$). Newholme plants also contain significantly more ash ($N = 23$, $p < 0.01$). Although sample sizes were small, some differences in nitrogen content of plants were found between consecutive seasons. On Lana plant nitrogen was higher in summer than in autumn ($N = 10$, $p < 0.05$) or spring ($N = 10$, $p < 0.01$). No differences were found between autumn and winter or winter and spring. On Newholme the only significant difference was a higher plant nitrogen content in summer compared to autumn ($N = 8$, $p < 0.01$). There was no difference between the winter samples collected in 1978 and 1979 on either Lana or Newholme.

From an examination of Tables 3.4 to 3.7 it can be seen that plant species and plant parts differ in quality. Plants included in the high-fibre grass and tussock grass categories have a higher fibre and lower nitrogen content than other grass species (see Table 3.9). In the few cases where differences in the quality of the same species in different habitats was investigated some differences were found. The major differences were found in the comparison of plants in sheep camps to those outside sheep camps. The plants in sheep camps had a much higher nitrogen and lower fibre content. Sheep camp species on Lana were generally of a higher quality than those in sheep camps on Newholme. One of the two grass species which has been introduced onto Lana in sown pasture areas (i.e. *Phalaris tuberosa*) was of a similar quality to those species found in sheep camps.

Table 3.9 Comparison of the nitrogen and fibre content of plant species included in the high-fibre, low-fibre and tussock grass categories. Both nitrogen and fibre content are expressed as a percentage of dry matter. Figures are means ± standard error of a variety of species in different seasons. Figures in brackets are the number of samples included.

Quality Measure	Property	GRASS CATEGORY High-fibre	Low-fibre	Tussock
Nitrogen content	Lana	0.92±0.07 (10)	2.43±0.14 (47)	1.35±0.12 (12)
	Newholme	0.98±0.11 (9)	1.95±0.15 (38)	0.91±0.05 (20)
Total fibre content	Lana	42.14±1.60 (5)	30.48±1.28 (28)	42.91±1.39 (6)
	Newholme	43.60±1.92 (5)	32.85±1.32 (25)	46.74±0.54 (11)

3.3 Discussion

On both study areas changes in total biomass and in the proportions of different plant categories have been shown to occur over the course of a year. Newholme contains a higher total biomass of pasture plants but the greater proportion of it is high-fibre tussock grasses. In summer the biomass of low-fibre grass leaf is much higher on Lana. In winter and spring the low-fibre grass leaf biomass is similar on the two areas. Low-fibre grass leaf biomass may be higher on Newholme in autumn. This may, however, be a result of the effects of the unusually wet conditions at this time on the low-fibre grass leaf biomass on Lana (see Chapters 4 and 7). Pasture species on Lana are in general of a higher quality (i.e. they contain more nitrogen, less fibre and less ash (i.e. silica?)). Grasses present in sheep camp areas are also of a higher quality on Lana. The effects of these differences in biomass and quality of pasture between seasons and between study areas on the condition of the two kangaroo species will be examined in detail in Chapter 7.

Only biomass was measured in the present study. However productivity of pasture is also an important factor determining the carrying capacity of an area. Dramatic increases in pasture production have been shown to occur when native pastures similar to those found on the present study areas have superphosphate applied (e.g. Robinson and Lazenby, 1976; Whalley *et al.*, 1978; Simpson and Robinson, 1967). Introduced grasses (e.g. *Phalaris tuberosa*) have also been shown to have a greater productivity than native species during winter on fertilized pastures (Robinson, 1976). Since Lana has had annual applications of superphosphate as well as some areas sown to introduced grasses, whereas Newholme has not, it is likely that productivity of the pasture will be greater on Lana than on Newholme. Productivity on sheep camps is also likely to be higher than on normal pasture (Vieirea, 1980) due to transfer of nutrients (in the form of faeces and urine) to these areas by sheep (Hilder and Mottershead, 1963; Hilder, 1964).

When deciding on how to divide up the pasture into groups which might be relatively homogeneous in terms of quality and palatability to kangaroos, I had to rely on guesswork based on the findings of previous dietary studies of kangaroos. With the value of hindsight, after having examined in detail the diet of the two kangaroo species on the study areas, it is possible to make suggestions for the improvement of the classification of pasture into homogeneous categories (bearing in mind that the limiting factor is the time involved in sorting). The grass stem category would be best divided into two categories i.e. (1) high-fibre stems which are not utilized to any greater extent (e.g. *Bothriochloa*, *Sporobolus*, *Cymbopogon*) and (2) stems of a lower fibre content which are utilized to some extent (e.g. *Microlaena*, *Danthonia racemosa*, *Vulpia*). Infloresence could also be divided from stem but this would cause a large increase in sorting time. The non-grass monocotyledons would be best divided into two groups, the first containing the species which are abundant in summer but mostly die out during winter (e.g. *Cyperus brevifolius*, *Fimbristylis*) and a second group containing species which are present all year and most of which are utilized during winter (e.g. *Juncus*, *Lomandra filiformis*). *Lomandra filiformis* would best be classified with the non-grass monocotyledon group rather than with the forbs as was done. The legumes could be separated from the forb category as these seem to be utilized by kangaroos to a greater extent than other species in this category (especially during spring)(see Chapter 4).

If kangaroos are selecting their diet on the basis of the quality of plants (i.e. nitrogen and fibre content) then they should be feeding mostly upon low-fibre grass leaf (especially species from sheep camp areas) and a variety of forb species such as *Trifolium* spp. and *Hypochoeris*. On the other hand if kangaroos are selecting their diet on the basis of the quantity of plants available then on Newholme tussock grasses should make up the majority of the diet in all seasons. On Lana during summer grass stem, grass leaf and forbs should make up a large proportion of the diet with the importance of grass stem decreasing and the importance of tussock grasses increasing during winter. Kangaroo dietary selection will be examined in the next chapter.

CHAPTER 4

DIET

4.1 Introduction

The feeding strategy adopted by a herbivore will be important in determining many aspects of the animal's ecology. The well known migration of wildebeest *Connochaetes taurinus* in parts of Africa is a result of this species' need to feed in areas with a high proportion of grass leaf of adequate quality (e.g. Bell, 1971). In contrast, impala *Aepyceros melampus* can remain within a fixed home range all year despite seasonal changes in food supply. Their feeding strategy is based on seasonal changes in habitat use, feeding upon plants that form a large proportion of the plant community, selection of plant species and plant parts when available in sufficient quantities and use of abundant low quality forage during periods of reduced availability of high quality food (Jarman and Gwynne, unpubl.). Similar contrasts occur between kangaroo species. Red kangaroos undertake long movements in search of high quality food whereas euros remain within a fixed home range and tolerate changes in the quality of food available (Newsome, 1975).

Differences in feeding strategies may also be important in ecological separation of sympatric species. Species inhabiting the same area may differ in the habitats in which they feed (e.g. Child and Von Richter, 1969; Batcheler, 1960). There are, however, many examples of sympatric herbivores which feed in the same area yet maintain ecological separation. Species may, for example, feed on different plant species. Thus one species may be a browser and another a grazer (e.g. Estes, 1967). In periods of superabundance of food herbivores may overlap considerably in the species of plants eaten without competition occurring. For example, Jarman (1971) found that the diets of herbivores in woodland around Lake Kariba, Rhodesia overlapped considerably during the wet season but as the dry season began the species' diets became more distinct. Differential use of plant parts has also been shown to be important in ecological separation of grazing ungulates in African savanna (Gwynne and Bell, 1968).

Studies on the diets of the large kangaroos have found them to be almost exclusively grazers (e.g. Storr, 1968; Chippendale, 1968; Griffiths and Barker, 1966; Low *et al.*, 1971; Kirkpatrick, 1965a;

Ealey and Main, 1967; Griffiths *et al.*, 1974). Most studies have found a high proportion of grass in the diet with a variable dicotyledon component depending on seasonal conditions and pasture composition. Although few studies have quantified use of plant parts many authors (e.g. Ellis *et al.*, 1977; Griffiths and Barker, 1966; Chippendale, 1968; Prince, 1976; Storr, 1968) have commented on the heavy use of grass seed head when available. Studies on the red kangaroo and euro (e.g. Bailey *et al.*, 1971; Ellis *et al.*, 1977) have shown these species to be selective in their use of the pasture. Kirkpatrick (1965a), however, considered eastern grey kangaroo to be non-selective feeders. Investigation of the deit of sympatric macropods (e.g. Griffiths and Barker, 1966; Ellis *et al.*, 1977; Storr, 1968) have found that species do in general have differences in the plant species content of their diet, the extent of the overlap increasing during periods of reduced food abundance.

Both kangaroos in the present study remain in restricted home ranges and do not undertake long movements in search of food. The feeding strategies of both species must therefore cope with periods of reduction in the abundance of good quality food. A study of the species and plant parts that composed the diet was undertaken in order to assess: (1) the effects of seasonal changes and differences between study areas in food abundance and quality on the composition of the diet; (2) the influence which seasonal changes in the plant species and plant parts eaten had in determining changes in habitat use; (3) the role of selection of different plant species and plant parts in the ecological separation of the grey kangaroo and wallaroo; and (4) the effects of changes in quality of plant species and plant parts eaten on the condition of the kangaroos.

4.1.1 Techniques Used in Dietary Analysis

Three main techniques have been used for studying the plants eaten by herbivores. These are:

(1) Direct observation. In this method an observer records the plant species eaten by an animal at specific time intervals or each time a plant is seen to be fed upon (e.g. Jarman, 1971; Deschamps *et al.*, 1979).

(2) Pasture analysis before and after grazing (e.g. Smith and Julander, 1953). and

(3) Analysis of plant species composition in the stomach, oesophagus or faeces.

Of these only the third was applicable to the conditions present in this study. Oesphageal fistulation of animals was not feasible. Analysis of stomach contents is to be preferred to faecal analysis because of the lower probability of differential digestion of plant species (e.g. Slater and Jones, 1971; Martin, 1954; Stewart, 1967).

Various techniques have been developed for estimating the quantities of plant species present in stomach samples. Only micro-techniques were relevant to the present study as kangaroos chew their food into small particles. All techniques utilize epidermal characteristics to differentiate between plant species. These techniques can be divided into two groups based on whether or not plant fragments are ground before quantification. Techniques where plant fragments are not ground depend on estimation of the area of fragments present in the sample. This can be done by direct area estimates of plant fragments occurring on transect lines across a prepared slide of a random sample of plant fragments from the stomach or by using species occurrence at point quadrats. The point quadrat method is to be preferred as it is less time consuming and produces better results (Stewart, 1967). It is possible to use area of epidermis to weight ratios for each plant species to enable comparisons of the plant species composition of the diet to be based on weights and not simply area of epidermis (Storr, 1961).

The studies of herbivore diets using grinding have justified its use in terms of reducing all plant fragments to a uniform size. Sparks and Malechek (1968) recorded species occurrence, after grinding, in microscope fields. The relative frequencies of occurrence were then converted to densities. They found that relative density was directly correlated with dry weight percentages for the grass and forb combinations they used as samples. However this technique was still only estimating epidermal area since all particles were of the same size and the density of particles was measured. I believe their study showed a correlation between relative density of particles and dry weight percentage only because the weight to epidermal area ratios were similar for the species used to test their method. In a study of kangaroo diets utilizing grinding of plant fragments before analysis, Griffiths and Barker (1966) found that each species had to be corrected by an identifiability factor to correct for differences in the percentages of particles identifiable for different species. This identifiability factor may be related to the epidermal to weight ratio for different species. If a species is thicker there will be more particles without epidermis attached and hence more particles which are unidentifiable. In a later study, Griffiths *et al.* (1974) found that this identifiability factor changed for the same species over different seasons.

In my opinion techniques using grinding are equivalent to those not using grinding in the sense that both techniques must apply correction factors to account for differences between species in the epidermal area to weight ratio. However studies on macropods utilizing non-grinding techniques have proved far superior to those using grinding techniques in terms of the identifiability of epidermal fragments. Grinding reduces the size of the epidermal fragments and thus makes it much harder to identify individual fragments. For the present study it was decided to utilize a technique which did not involve grinding.

4.2 Methods

4.2.1 General Methods

When a sample of kangaroos was shot a sample of the stomach contents was obtained in order to examine the plant species and plant part composition of the diet. Ten grey kangaroo and ten wallaroo were obtained on Lana in February, May, August and late November 1978 and in August 1979. The winter sample was repeated to assess the effects of an unusually wet winter on the diet and condition of the kangaroos. Animals were shot after dark, five individuals of each species being collected on the first night and the others being collected two nights later. The animals were taken back to a laboratroy at the University of New England (one hour's drive from Lana) where the stomachs were opened and a sample was taken from the fore and mid-stomach regions. Small samples were taken along the length of the fore and mid-stomach to make up the total sample as little mixing occurs in kangaroo stomachs (Dellow, 1979) and thus species composition could differ along the length of the stomach. Samples were placed in glass bottles and preserved in formal acetic alcohol.

On Newholme it was not possible to shoot all the kangaroos at night because of the rugged terrain in which they were found. Samples of kangaroos also had to be restricted to certain areas where it was possible to get near enough to be able to shoot them. Grey kangaroo could be shot at night in grassland and woodland which occurred to the south-west of the study area. All grey kangaroo sampled here except one were obtained by spotlighting at night. Animals not shot at night were obtained in the period before darkness, when kangaroos were actively feeding, by stalking on foot. Grey kangaroo found on the northern slopes of Mt. Duval were hard to stalk and only a few could be obtained. Most wallaroo had to be shot while feeding in sheep camps, however some were obtained while feeding in *Poa* slopes. Animals shot on Newholme were either taken bodily to the shearing shed on Newholme and then processed or only samples (in this case whole stomachs) were taken from the animals, placed in plastic bags and then taken to the shearing shed and processed. Samples of shot kangaroos on Newholme were obtained in March and August 1978 and August 1979.

4.2.2 Preparation of Stomach Samples and Quantification of Stomach Contents

Each individual stomach sample was poured into a beaker and thoroughly mixed, then a further subsample was obtained. Each sub-sample was placed into a large plastic centrifuge tube and after centrifuging the formal acetic alcohol was drained off. Subsamples were then washed several times in 70% alcohol (centrifuging off the alcohol each time). Safranin stain (1% stain in 50% alcohol) was added in excess and the subsamples were left for a week. The safranin solution was then removed by washing over a sieve (100 μm). The stained stomach plant fragments were then stored in 70% alcohol.

In order to quantify the plant species composition of stomachs a subsample from the sample of stained plant fragments was poured into a large glass petri dish which had a grid pattern of lines etched on its surface. Plant fragments occurring on grid line intersections were placed on a slide in a drop of glycerol. Fifty particles were selected and then a new subsample was taken and fifty more particles were selected. Only epidermal fragments were counted. Any particle selected which did not have epidermis attached was excluded and another particle selected to take its place. The results for each individual kangaroo were expressed as a direct percentage of occurrence of particles in the sample of 100 identified fragments. This grid intersection technique should provide a quantitative comparison of the area of epidermis of each plant species and plant part present in the stomach of the kangaroo sampled.

The plant species and plant parts were identified from epidermis obtained from known species. Reference epidermal slides were obtained by the acid digestion process of Storr (1961). Epidermal slides of grass leaf, sheath (both sheath attached to stem and not attached to stem i.e. in leaf tufts on the ground), stem and seed head, and of leaf and stem (non-woody species) of non-grass species were obtained. Epidermal slides from the flowering heads of only the abundant non-grass species were prepared. The epidermal fragments obtained from known species were stained using safranin as outlined above. Epidermis from known plants and plant parts were photographed to form a reference collection.

The following features were used to distinguish the epidermis of different species and plant parts:

(1) shape and arrangement of cells
(2) abundance, position and types of hairs present
(3) abundance, position and type of silica cells
(4) abundance, position and type of stomata
(5) presence of papillae
(6) degree of staining of cell boundaries and nuclei.

All leaves of grass species could be distinguished from the reference epidermal slides. However when only small pieces were present in the stomach samples, a fragment could sometimes only be placed into a group of species. Some grass species had different epidermal patterns on sheath occurring on stem compared to sheath occurring on leaf tufts, however in some species the two types of sheath had identical epidermal patterns. A lot of grass stems could not be identified as to species although it was still possible to categorize them as grass stem. In some genera of non-grass monocotyledons (e.g. *Juncus*) and in large numbers of dicotyledons, species could only be separated into groups with similar epidermis and not into individual species. Examples of epidermal features on different plant species and plant parts are shown in Fig.4.1.

4.3 Results

A complete list of plant species and plant parts and the amounts of each identified in each kangaroo stomach is given in Appendix II. A summary of these results is shown in Table 4.1. In this table only the more abundant species in each category are shown and some species with similar seasonal occurrences are grouped. The high-fibre grass category in the grass leaf section contains *Aristida* stem and sheath as well as leaf for reasons explained in Chapter 3. High-fibre grass and tussock grass categories have also had the sheath for each species added to the leaf category to maintain the homogeneity of these groups

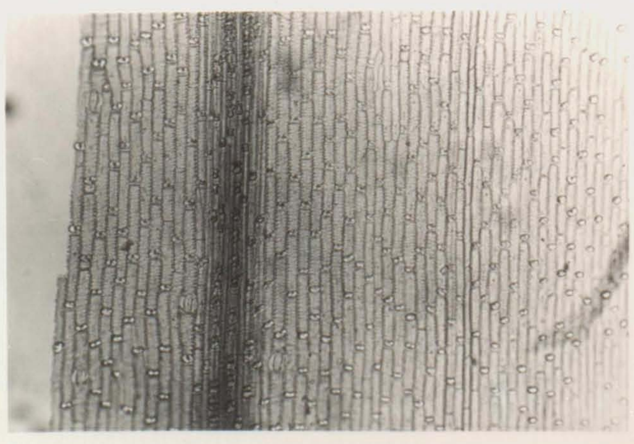
Fig. 4.1. Examples of epidermal features on different plant species and plant parts.

Eragrostis leptostachya
leaf (adaxial surface)

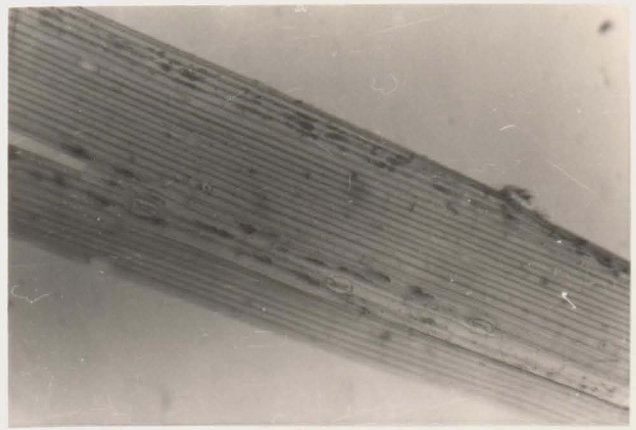
Eragrostis leptostachya
leaf (abaxial surface)

Bromus molliformis
leaf

Poa labillardieri
leaf

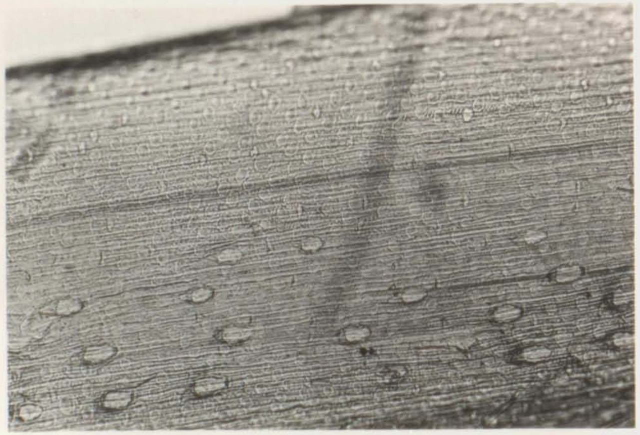


Danthonia tenuior
sheath (on leaf tuft)

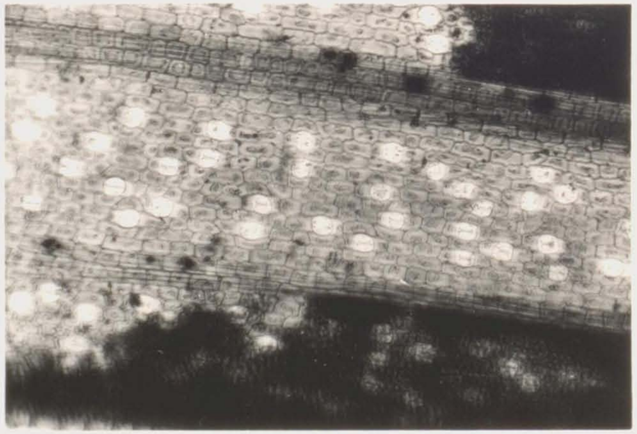


Anthoxanthum odoratum
stem

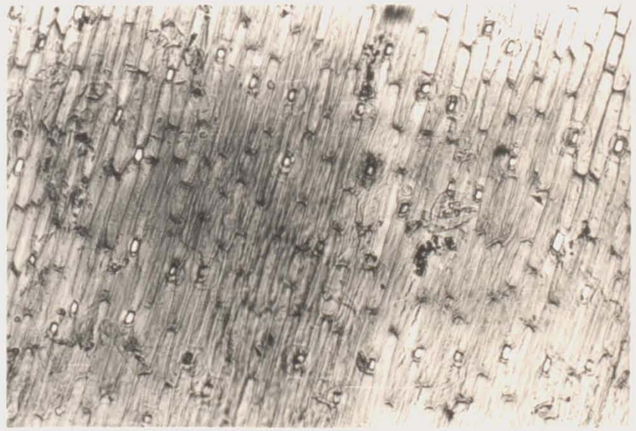
Fig. 4.1. (cont.)



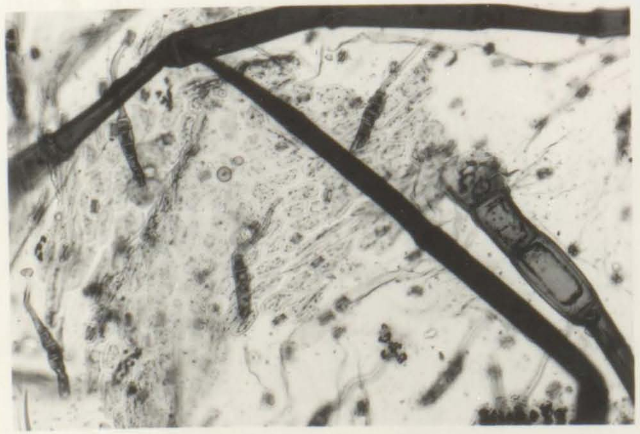
Vulpia bromoides
infloresence



Juncus australis
(high fibre species)

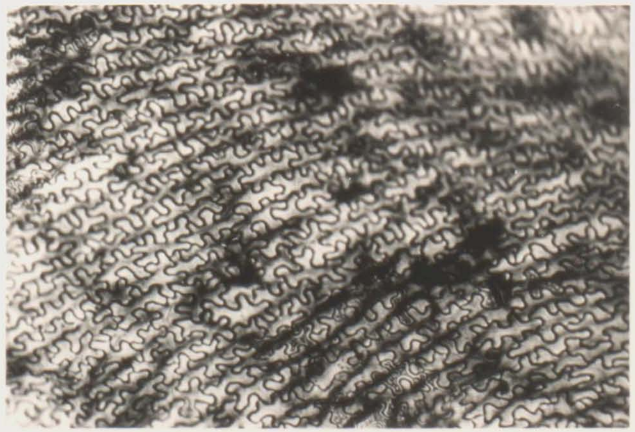


Tricoryne elatior
stem



Solengyne belloides
leaf

Desmodium varians
leaf



Pteridium esculentum
leaf

Table 4.1 Plant parts and plant species found in the stomachs of kangaroos. One hundred fragments were identified for each stomach. Values in the table represent mean percentage occurrence in all stomachs examined for each kangaroo species each season on each property. *Aristida* stem was included with the high-fibre grass category in the grass leaf section for reasons given in the text. Values in brackets are the number of species in the category.

Juncus H.F. = *Juncus* spp. with a high fibre content

Sheath on leaf = sheath in leaf tufts

Sheath on stem = sheath attached to stem

(A) GREY KANGAROO LANA

Species and Plant Part	% of identified fragments				
	Feb. 1978	May 1978	Aug. 1978	Nov. 1978	Aug. 1979
MONOCOTYLEDONS					
GRASS					
Leaf					
Agropyron + *Holcus*	0.3	9.4	2.1	0.9	2.3
High Fibre Grass	0	0.5	1.9	0.8	1.0
Bothriochloa macera	22.2	3.4	0.6	5.5	1.4
Bromus + *Vulpia*	0	1.0	19.2	1.1	20.9
Danthonia racemosa + *tenuior*	2.4	11.2	8.2	5.1	16.4
Digitaria and *Eulalia*	12.8	0.2	0.2	5.4	0.1
Eragrostis (3 spp) + *Sporobolus*	22.0	11.9	2.2	27.4	2.1
Microlaena stipoides	7.4	2.6	2.7	6.0	2.0
Phalaris + *Festuca*	0	7.8	5.8	0.6	6.5
Tussock grasses	0	24.3	17.7	0	8.9
Other spp + unidentified leaf	10.2(6)	10.7(6)	5.3(7)	7.1(7)	4.6(6)
TOTAL LEAF	77.3	83.0	65.9	59.9	66.2
Sheath					
On leaf	5.7	2.4	4.0	0.7	2.4
On stem	2.9	0.3	0.6	1.7	0.1
On either leaf or sheath	3.8	3.9	4.6	3.7	5.9
TOTAL SHEATH	12.4	6.5	9.2	6.1	8.4
Unidentified leaf or sheath	1.7	1.6	1.0	0.8	0.8
TOTAL LEAF AND SHEATH	91.4	91.2	76.1	66.8	75.4
Stem					
Danthonia racemosa + *tenuior*	0.2	0	0	1.3	0
Microlaena stipoides	0.1	0	0.6	0.9	0
Vulpia bromoides	0	0	0	0.5	0.1
Other spp + unidentified	2.3(5)	1.0(2)	0.8(2)	4.5(4)	1.2(3)
TOTAL STEM	2.6	1.0	1.4	7.2	1.3
Infloresence					
Agropyron + *Bromus*	0	0	0	1.7	0
Danthonia racemosa + *teniuor*	0.2	0	0	1.2	0
Microlaena stipoides	0.3	0	0.2	1.4	0
Vulpia bromoides	0	0	0	3.5	0.1
Other spp + unidentified	3.0(5)	0.3(0)	0.3(1)	8.6(5)	0.3(1)
TOTAL INFLORESENCE	3.5	0.3	0.5	16.4	0.4
Unidentified grass	0.8	0.6	0.1	0.9	0.4
TOTAL GRASS	98.3	93.1	78.1	91.3	77.5
OTHER MONOCOTYLEDONS					
Carex inversa	0	3.1	4.8	0.3	6.0
Juncus H.F.	0	0	7.4	0	4.6
Lomondra filiformis	0	0.4	0.2	0	3.2
Other spp	0.4(2)	1.6(4)	3.2(6)	0.4(1)	1.8(2)
TOTAL MONOCOTYLEDONS	98.7	98.2	93.7	92.0	93.1
DICOTYLEDONS					
Desmodium (2 spp) + *Glycine*	0	0	0.3	0.2	0
Hypochoeris radicata	0.4	0.5	0.3	1.4	0.5
Trifolium (6 spp) + *Medicago*	0	0	1.9	3.1	2.4
Other spp	0.4(1)	1.2(0)	3.7(5)	3.1(1)	4.0(2)
TOTAL DICOTYLEDONS	0.8	1.7	6.2	7.8	6.9
UNIDENTIFIED	0.5	0.1	0.1	0.2	0
TOTAL	100%	100%	100%	100%	100%
No. of identified fragments	1000	1000	1000	1000	1000
No. of kangaroos in sample	10	10	10	10	10

Table 4.1 (cont.)

(B) WALLAROO LANA

Species and Plant Part	% of identified fragments				
	Feb. 1978	May 1978	Aug. 1978	Nov. 1978	Aug. 1979
MONOCOTYLEDONS					
GRASS					
Leaf					
Agropyron + *Holcus*	0.6	10.3	8.8	0.6	3.4
High Fibre Grass	0.1	4.9	0.7	0	2.5
Bothriochloa macera	20.2	3.1	1.2	6.1	0.9
Bromus + *Vulpia*	0.1	6.4	13.3	1.5	26.8
Danthonia racemosa + *tenuior*	1.9	7.6	9.4	3.0	15.5
Digitaria + *Eulalia*	10.5	0.1	0.5	2.9	0
Eragrostis (3 spp) + *Sporobolus*	6.7	5.1	2.0	2.1	0.9
Microlaena stipoides	16.3	6.6	6.5	21.1	5.2
Phalaris + *Festuca*	0.8	11.5	10.1	4.1	7.2
Tussock grasses	0.5	11.1	19.6	0	4.9
Other spp. + unidentified	15.3(6)	11.1(7)	3.7(5)	4.6(4)	4.5(6)
TOTAL LEAF	73.0	77.8	75.8	46.0	71.8
Sheath					
On leaf	5.7	1.5	2.7	1.7	2.3
On stem	3.3	0.2	0.6	3.1	0.1
On either leaf or sheath	5.0	2.5	3.8	2.8	4.3
TOTAL SHEATH	14.0	4.2	7.1	7.6	6.7
Unidentified leaf or sheath	1.7	0.5	1.0	0.6	0.7
TOTAL LEAF AND SHEATH	88.7	82.5	83.9	54.2	79.2
Stem					
Danthonia racemosa + *tenuior*	0.1	0	0	0.8	0.1
Microlaena stipoides	0.8	0.5	0	1.2	0
Vulpia bromoides	0.1	0	0	1.6	0
Other spp. + unidentified	1.5(4)	2.7(3)	0.7(2)	1.4(2)	1.5(2)
TOTAL STEM	2.5	3.2	0.7	5.0	1.6
Infloresence					
Agropyron + *Bromus*	0.1	0	0	2.3	0.1
Danthonia racemosa + *tenuior*	0.2	0.1	0	0.6	0
Microlaena stipoides	1.6	0.4	0.3	2.5	0
Vulpia bromoides	0	0	0	5.8	0.1
Other spp. + unidentified	3.1(2)	0.5(2)	0	5.8(4)	0.1(0)
TOTAL INFLORESENCE	5.0	1.0	0.3	17.0	0.3
Unidentified grass	0.5	0.3	0.6	0.6	0.1
TOTAL GRASS	96.7	87.0	85.5	76.8	81.2

(B) WALLAROO LANA (cont.)

Species and plant part	% of identified fragments Feb. 1978	May 1978	Aug. 1978	Nov. 1978	Aug. 1979
<u>OTHER MONOCOTYLEDONS</u>					
Carex inversa	0	7.5	6.5	0	6.1
Juncus H.F.	0	0	0.2	0	0.1
Lomandra filiformis	0	0.4	0.7	0	0.6
Other spp. + unidentified	0.4(2)	1.4(4)	2.1)3)	0.1(1)	1.1(1)
TOTAL MONOCOTYLEDONS	97.1	96.3	95.0	76.9	89.1
<u>DICOTYLEDONS</u>					
Desmodium (2 spp) + *Glycine*	0.9	0.2	0	0.4	0.1
Hypochoeris radicata	0.4	0.9	0.4	0.5	0.4
Trifolium (5 spp) + *Medicago*	0.1	0.7	0.3	15.5	2.8
Other spp. + unidentified	1.1(1)	1.8(3)	4.2(4)	6.5(1)	7.5(5)
TOTAL DICOTYLEDONS	2.5	3.6	4.9	22.9	10.8
<u>UNIDENTIFIED</u>	0.4	0.1	0.1	0.2	0.1
TOTAL	100%	100%	100%	100%	100%
No. of identified fragments	1000	1000	1000	1000	1000
No. of kangaroos in sample	10	10	10	10	10

Table 4.1 (cont.)

(C) GREY KANGAROO NEWHOLME

Species and Plant Part	% of identified fragments		
	Mar. 1978	Aug. 1978	Aug. 1979
MONOCOTYLEDONS			
GRASS			
Leaf			
Agropyron + *Alopecurus* + *Echinopogon*	0.3	9.5	8.7
High Fibre Leaf	2.9	0	0.8
Bothriochloa macera	14.5	0.5	1.0
Bromus molliformis + *Poa annua* + *Vulpia bromoides*	0	0.7	2.7
Danthonia racemosa	3.7	8.1	16.3
Eragrostis (2 spp) + *Sporobolus*	24.8	3.9	8.2
Microlaena stipoides	13.0	14.2	5.9
Tussock grasses	3.7	41.5	42.4
Other species + unidentified	5.1(7)	3.6(2)	2.6(5)
TOTAL LEAF	68.0	82.0	88.6
Sheath			
On leaf	6.8	0.9	0.7
On stem	1.6	0	0.2
On either leaf or stem	1.9	4.9	3.0
TOTAL SHEATH	10.3	5.8	3.9
Unidentified leaf or sheath	0.6	0.3	0
TOTAL LEAF AND SHEATH	78.9	88.1	92.5
Stem			
Microlaena stipoides	1.2	0.2	0
Other spp + unidentified	3.0(6)	1.2(3)	0.2(1)
TOTAL STEM	4.2	1.4	0.2
Infloresence			
Microlaena stipoides	3.3	0	0.1
Other spp + unidentified	3.8(6)	0	0.1(0)
TOTAL INFLORESENCE	7.1	0	0.2
Unidentified grass	0.5	0	0.3
TOTAL GRASS	90.7	89.5	93.2
OTHER MONOCOTYLEDONS			
Carex inversa	2.7	2.7	2.0
Juncus H.F.	0	0.5	0.6
Lomondra filiformis	0	0.2	0.6
Other spp. + unidentified	1.4(4)	5.2(5)	2.5(4)
TOTAL MONOCOTYLEDONS	94.8	98.1	98.9
DICOTYLEDONS			
Desmodium + *Glycine*	0	0	0
Hypochoeris radicata	4.0	0.4	0.4
Trifolium spp.	0.2	0	0
Other spp. + unidentified	1.0(2)	1.5(0)	0.7(0)
UNIDENTIFIED	0	0	0
TOTAL	100%	100%	100%
No. of identified fragments	600	600	900
No. of kangaroos in sample	6	6	9

Table 4.1 (cont.)

(D) WALLAROO NEWHOLME

Species and Plant Part	% of identified fragments		
	Mar. 1978	Aug. 1978	Aug. 1979
MONOCOTYLEDONS			
GRASS			
Leaf			
Agropyron + *Alopecurus* + *Echinopogon*	1.2	1.3	2.4
High Fibre Leaf	0.7	2.7	0.8
Bothriochloa macera	21.2	0	0.4
Bromus molliformis + *Poa annua* + *Vulpia bromoides*	0.2	17.5	14.2
Danthonia racemosa	3.8	3.3	3.6
Eragrostis (2 spp) + *Sporobolus*	1.8	0	0.2
Microlaena stipoides	27.5	6.0	13.4
Tussock grasses	6.4	54.3	42.8
Other spp. + unidentified	3.9(5)	2.7(3)	4.2(4)
TOTAL LEAF	66.9	87.8	82.0
Sheath			
On leaf	10.7	0.4	1.8
On stem	1.2	0	0
On leaf or stem	1.4	2.9	3.6
TOTAL SHEATH	13.3	3.3	5.4
Unidentified leaf or sheath	0.1	0.1	0.6
TOTAL LEAF AND SHEATH	80.3	91.2	88.0
Stem			
Microlaena stipoides	2.2	0.2	0
Other spp. + unidentified	0.5(2)	0.3(2)	1.2(3)
TOTAL STEM	2.7	0.5	1.2
Infloresence			
Microlaena stipoides	6.7	0	0
Other spp. + unidentified	2.2(7)	0.8(0)	0.4(0)
TOTAL INFLORESENCE	8.9	0.8	0.4
Unidentified grass	0.5	0.6	0.2
TOTAL GRASS	92.4	93.1	89.8
OTHER MONOCOTYLEDONS			
Carex inversa	3.5	1.6	2.2
Juncus H.F.	0	0	0.2
Lomandra filiformis	0	0.6	0
Other species + unidentified	1.0(1)	1.0(1)	0
TOTAL MONOCOTYLEDONS	96.9	96.3	92.2
DICOTYLEDONS			
Desmodium + *Glycine*	1.0	0.2	0.2
Hypochoeris radicata	0.2	0.1	0.8
Trifolium spp.	0.5	0.3	1.0
Other spp. + unidentified	1.4(1)	3.0(6)	5.0(7)
TOTAL DICOTYLEDONS			
MUSHROOM ?	0	0	0.4
UNIDENTIFIED	0	0.1	0.4
TOTAL	100%	100%	100%
No. of identified fragments	600	700	500
No. of kangaroos in sample	6	7	5

and to separate them from sheath of low-fibre grasses. As can be seen from Appendix II, very little sheath from tussock grass and high-fibre grass species was found in the stomach samples.

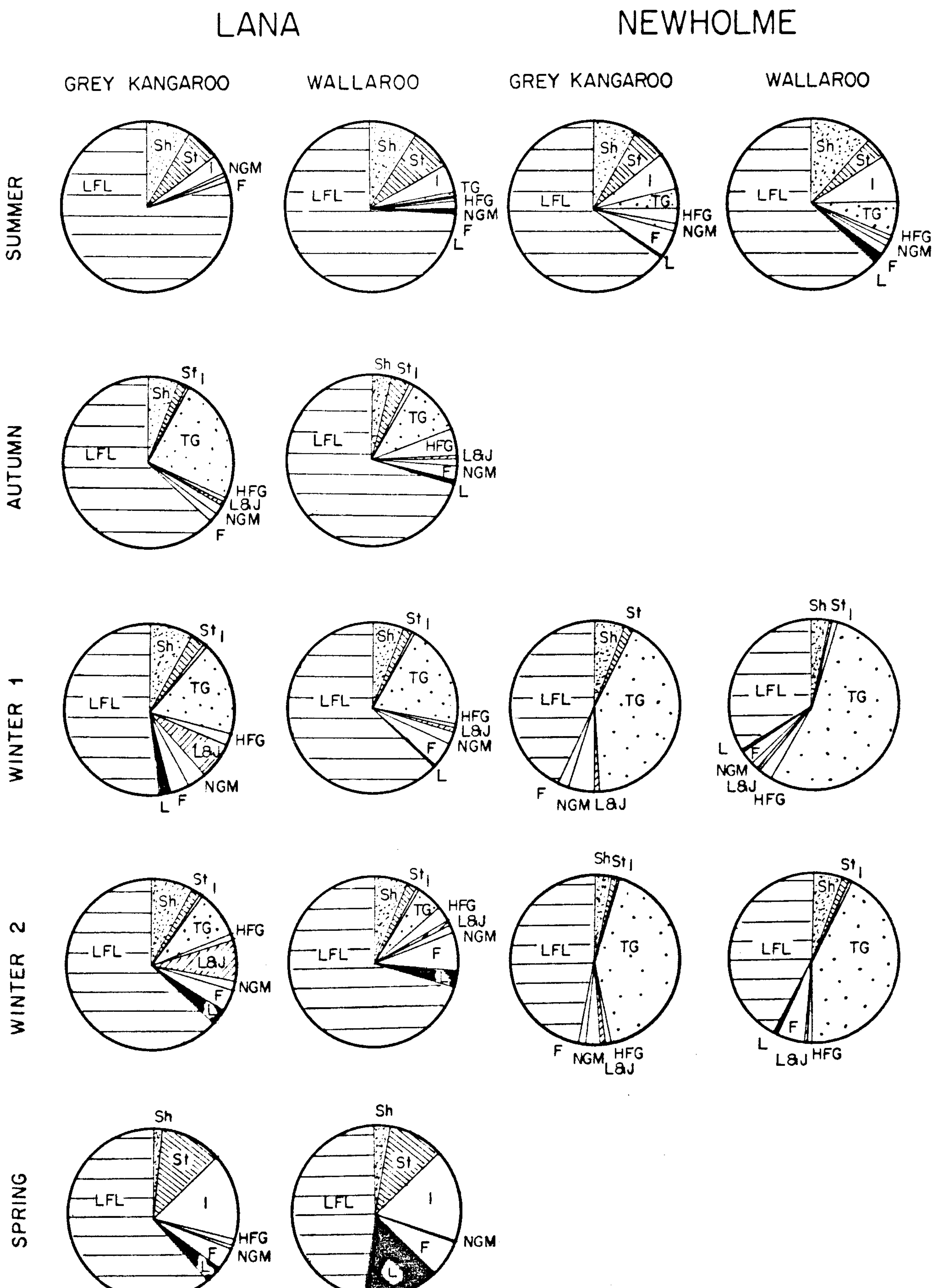
For both kangaroo species on both study areas, seasonal changes in most plant species and plant parts in the diet reflect seasonal changes in their abundance. For example, *Bathriochloa*, *Eulalia* and *Digitaria* (warm season annuals) are eaten most in summer and very little in winter. *Vulpia* and *Bromus molliformis* leaf (cool season annuals) are eaten most in winter. The stem and infloresence of *Microlaena*, *Danthonia* and *Vulpia* are eaten in spring when they are abundant. However not all plant species or plant parts are eaten when they are most abundant or simply because they are abundant. *Bothriochloa* stem and leaf are very abundant during summer but only leaf is eaten to any great extent. The major exception to the selection of species when most abundant is for species in the cool season perennial category. These species remain green all year but are eaten mainly during autumn and winter. Species in this category from the low-fibre leaf species (e.g. *Danthonia racemosa*) are eaten to a small extent in summer and their importance in the diet increases during winter. Low quality species (i.e. tussock grasses) in this category are not eaten to any great extent in summer or spring but their proportion in the diet increases greatly in autumn and winter especially on Newholme. Some other species not in the cool season perennial category do not conform to the pattern of selection of species when most abundant. An example of this from the low-fibre grass leaf category is *Phalaris tuberosa* and from the non-grass monocotyledon category is *Juncus* (high fibre species). These species, although probably more abundant in summer, are more prominent in the winter due to dieback of a great percentage of other species' biomass.

Seasonal changes in different plant categories found in the diet are shown in Fig.4.2. The plant categories were formed by grouping plant species and plant parts of similar quality. Although, for example, low-fibre grass leaf contained species differing in fibre content and hence quality, these species as a whole contained less fibre than species in the high-fibre grass category. Similarly tussock grass species were of a higher fibre content than species in the low-fibre grass leaf category. For both kangaroo species on both properties in all seasons, with one exception (i.e. wallaroo on Newholme, winter 1978), low-fibre grass leaf is the most abundant plant category in the diet. The proportion of low-fibre grass leaf in the diet is greatest in summer and lowest in winter for the grey kangaroo and lowest in spring for the wallaroo. Only

Fig.4.2. Proportions of different plant categories in the diet of grey kangaroo and wallaroo on Lana and Newholme for each season.

LFL	Low-fibre grass leaf
Sh	Grass sheath (on leaf tuft)
St	Grass stem (including sheath on stem and a proportion of the sheath (on leaf or stem) category)
I	Grass infloresence
TG	Tussock grasses
HFG	High-fibre grasses
L&J	*Lomandra filiformis* and *Juncus* (high fibre spp.)
NGM	Non-grass monocotyledons
F	Non-legume forbs
L	Legumes

Data on which this figure is based are given in Appendix III.


LANA
NEWHOLME
GREY KANGAROO
WALLAROO
GREY KANGAROO
WALLAROO
SUMMER
AUTUMN
WINTER 1
WINTER 2
SPRING
LFL
Sh
St
I
TG
HFG
NGM
F
L
L&J

minor changes occur over the seasons in the proportion of sheath (on leaf tufts) in comparison to low-fibre grass leaf present in the diet. The proportion of sheath in comparison to low-fibre grass leaf is lowest for the grey kangaroo and wallaroo during spring. Grass stem and infloresence is greatest in the diet during spring, less so in summer and only of minor importance in autumn and winter. As noted previously the proportion of tussock grass in the diet increases markedly during autumn and winter. High-fibre grasses, although of minor importance all year, increase slightly in the diet during autumn and winter. The pattern of occurrence for *Lomandra filiformis* and *Juncus* (high-fibre species) and other non-grass monocotyledons in the diet is similar to high-fibre grass occurrence. The importance of forbs in the diet is usually low (note however wallaroo on Lana in spring), although they may increase somewhat in winter and spring.

4.3.1 Comparison of the Two Winter Dietary Samples

For the grey kangaroo on Newholme there appears to be little difference in the proportions of plant categories in the diet between the two winter samples. There may be minor differences in the low-fibre grass leaf and sheath proportions but the total low-fibre grass leaf and sheath proportions are similar (winter 1 = 49.3; winter 2 = 50.4). Within the low-fibre grass leaf category there is an increase in the proportion of *Danthonia racemosa* and a drop in the proportion of *Microlaena stipoides* in winter 2 compared to winter 1 (Table 4.1). However this is probably because two grey kangaroo were sampled in *Microlaena* pasture in winter 1 and only one in winter 2. When the kangaroos shot while feeding in *Microlaena* pasture are excluded there is no significant difference (using a t-test) between the mean proportion of *Danthonia racemosa* or *Microlaena* found in stomach samples between winters.

For the grey kangaroo on Lana there appears to be a greater proportion of low-fibre grass leaf and a lower proportion of tussock grasses in winter 2 compared to winter 1. The higher proportion of low-fibre grass leaf is due mainly to an increase in the proportion of *Danthonia racemosa* ($t = 4.18$, $df = 18$, $p < 0.01$).

For the wallaroo on Lana there is a decrease in the tussock grass and an increase in the low-fibre grass leaf and forb component of the diet in winter 2 compared to winter 1. For the low-fibre grass leaf category the main increases in winter 2 are in *Bromus molliformis*, *Danthonia racemosa* and *Vulpia bromoides*.

For the wallaroo on Newholme although there is an increase in

Microlaena leaf and a decrease in tussock grasses in the diet in winter 2 compared to winter 1, this is probably due to more animals being shot while feeding in *Microlaena* pasture during winter 2 (four out of five) than during winter 1 (four out of seven).

4.3.2 Comparison of the Diets of the Kangaroo Species

A diversity index for plant species and plant part occurrence in the diet was calculated using the Shannon-Wiener diversity index (MacArthur and MacArthur, 1961). The diversity index for the diet increases as the numbers of plant species and plant parts increase and as the abundances of different plant species and plant parts become more equitable. Mean diversity indices are shown in Table 4.2 along with the significance of differences in the indices between seasons, kangaroo species and properties. A similarity index for the comparison of the diets of the two kangaroos was calculated by summing the percentage of each plant species and plant part which was common to the diets of the two species in the same season on the same property. The results are given in Table 4.3 along with the plant species and plant parts which made the greatest contribution to the similarity index.

Both species had significantly more diverse diets during winter and overall on Lana than on Newholme. On Lana there is no difference between diversity indices for the diet of the grey kangaroo and wallaroo for any season. The similarity between the diets of the grey kangaroo and wallaroo on Lana only increases slightly during winter compared to summer. The season of the lowest similarity is spring. An examination of the occurrence of plant categories in the diet of the two kangaroos (Fig. 4.2) shows little difference in summer, although in the low-fibre grass leaf category *Eragrostis* and *Sporobolus* are more important and *Microlaena* less important in the grey kangaroo compared to the wallaroo. In autumn wallaroo diets contain a lower proportion of tussock grasses and a slightly higher proportion of high-fibre grasses and low-fibre grass leaf. Since these differences are small another sample would have to be taken in autumn to check the significance of these. During winter wallaroo have a higher proportion of low-fibre grass leaf and a lower proportion of tussock grasses in the diet than have grey kangaroo. Wallaroo also have a lower proportion of *Lomandra filiformis* and *Juncus* (high fibre species) in the diet during winter. The greatest differences in the occurrence of plant categories in the diet of the two species are in spring. Wallaroo have 13.6% less low-fibre grass leaf and 12.6% more legumes in their diet compared to grey kangaroo . Both species increase dramatically the stem and infloresence component of the diet during spring. There are also major

Table 4.2 Diversity indices for grey kangaroo and wallaroo diets for each season on Lana and Newholme. Values are means ± standard error. Values in brackets are the number of kangaroos in each sample. The significance of differences between species on each property, between properties for each species and between seasons for each species on both properties is given below the table.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Summer	3.61±0.14 (10)	3.67±0.17 (10)	3.83±0.10 (6)	3.32±0.14 (6)
Autumn	3.88±0.08 (10)	4.00±0.16 (10)	-	-
Winter 1	3.72±0.18 (10)	3.44±0.24 (10)	2.99±0.11 (6)	2.63±0.24 (7)
Winter 2	3.74±0.08 (10)	3.60±0.17 (10)	2.79±0.14 (9)	3.00±0.11 (5)
Spring	4.26±0.14 (10)	4.02±0.18 (9)	-	-
Overall	3.84±0.06	3.74±0.08	3.14±0.12	2.96±0.12

GREY KANGAROO TO WALLAROO

LANA overall	NS	NEWHOLME overall	NS
S	NS	S	*
A	NS	W1	NS
W1	NS	W2	NS
W2	NS		
SP	NS		

LANA TO NEWHOLME

WALLAROO overall†	***	GREY KANGAROO overall†	***
S	NS	S	NS
W1	*	W1	**
W2	***	W2	***

SEASONAL COMPARISON

LANA WALLAROO		LANA GREY KANGAROO	
S-A	NS	S-A	NS
A-W1	NS (p = 0.07)	A-W1	NS
A-W2	*	A-W2	NS
W1-SP	NS (p = 0.08)	W1-SP	*
W2-SP	*	W2-SP	**
SP-S	NS	SP-S	**
W1-W2	NS	W1-W2	NS

NEWHOLME WALLAROO		NEWHOLME GREY KANGAROO	
S-W1	*	S-W1	***
S-W2	NS	S-W2	***
W1-W2	NS	W1-W2	NS

† used only S, W1 and W2 for the comparison

* = $p < 0.05$		S = Summer
** = $p < 0.01$		A = Autumn
*** = $p < 0.001$		W1 = Winter 1
		W2 = Winter 2
		SP = Spring

Table 4.3 Similarity indices for the diets of grey kangaroo and wallaroo on Lana and Newholme for each season along with the plant species which contribute the most to the similarity of the diets.

	Season	Similarity Index (%)	Plant Species Contributing the Most to the Similarity Index
LANA	Summer	62.3	*Bothriochloa macera* leaf (20.2)
	Autumn	60.0	*Agropyron scabrum* leaf (8.7) *Danthonia racemosa* leaf (7.1)
	Winter 1	64.5	*Poa costianana* leaf (12.6) *Vulpia bromoides* leaf (8.7) *Danthonia racemosa* leaf (7.2)
	Winter 2	67.1	*Danthonia racemosa* leaf (15.3) *Vulpia bromoides* leaf (13.1)
	Spring	48.8	*Microlaena stipoides* leaf (6.0) *Bothriochloa macera* leaf (5.5) *Vulpia bromoides* infloresence (3.5)
NEWHOLME	Summer	55.2	*Bothriochloa macera* leaf (14.5) *Microlaena stipoides* leaf (13.0)
	Winter 1	56.3	*Poa costianana* leaf (26.6) *Poa sieberana* leaf (10.2) *Microlaena stipoides* leaf (6.0)
	Winter 2	60.7	*Poa costianana* leaf (39.4) *Microlaena stipoides* leaf (5.9)

differences between the two kangaroos in the species abundances within the low-fibre grass leaf category. In the grey kangaroo, *Eragrostis* and *Sporobolus* account for 46% of the low-fibre grass leaf and *Microlaena* only 10%. In the wallaroo *Microlaena* makes up 46% and *Eragrostis* and *Sporobolus* make up 5% of the low-fibre grass leaf. When the proportions of plant categories in the diet of the wallaroo and grey kangaroo are compared statistically for each season (grouping similar categories when frequencies are small to enable statistical comparison) only in spring are the diets significantly different ($\chi^2 = 9.05$, df = 3, $p < 0.05$).

On Newholme the differences between the diets of the two kangaroos in summer are similar to those found on Lana. The proportions of plant categories in the diet are similar, although there may be minor differences in the sheath (from leaf tufts) and forb categories. Within the low-fibre grass leaf category the wallaroo diets contain more *Microlaena* and far less *Eragrostis* and *Sporobolus* than the grey kangaroo. The greater sheath (from leaf tufts) in wallaroo stomachs is probably a result of the greater intake of *Microlaena* sheath when feeding in sheep camps. Here grass is short and so the grasses are probably grazed closer to the ground and hence more sheath is eaten. On Lana in both winters low-fibre grass leaf proportions in the diet were greater for the wallaroo whereas on Newholme the grey kangaroo diets contain more low-fibre grass leaf in both winters. In winter 1 tussock grasses make up a higher proportion of the wallaroo diets but in winter 2 the two kangaroos have similar proportions of tussock grasses in the diet. As on Lana, the non-grass monocotyledons appear to be slightly more important in grey kangaroo diets than in wallaroo diets during the winter. Forbs are slightly more abundant in wallaroo diets than in grey kangaroo's in both winters on Newholme. Statistical comparisons of the proportions of plant categories in the diet of grey kangaroo and wallaroo on Newholme showed no significant differences for any season.

On Newholme although the diets of the two species have over 55% of the plant species and plant parts in common in all seasons (Table 4.3), the similarity of the two kangaroo species' diets is slightly lower than on Lana. The similarity of the diets of the two kangaroos on Newholme is greatest in winter 2 as on Lana. The mean diversity index for the grey kangaroo's diet is significantly greater than for the wallaroo in summer on Newholme.

4.3.3 Comparison of the Diet of Kangaroos on Lana and Newholme

A comparison of the diets on the two study areas was based on a comparison of the proportions of plant categories in the diet as differences between species' occurrences in categories may have been due to differences in the relative abundances of species and have had little ecological significance. Differences in plant species' abundances within plant categories will be important if these species differ markedly in quality.

For the grey kangaroo there are significant differences in the proportions of plant categories in the diet between Lana and Newholme for all seasonal comparisons (summer, $\chi^2 = 12.03$; df = 3, $p < 0.01$; winter 1, $\chi^2 = 11.04$, df = 3, $p < 0.05$; winter 2, $\chi^2 = 32.0$, df = 3, $p < 0.001$). In summer there is a lower low-fibre grass leaf content and a higher proportion of most other components in the diet of grey kangaroo on Newholme. In both winters there is a higher proportion of tussock grasses and a lower proportion of low-fibre grass leaf in the diet of grey kangaroo on Newholme. These differences are more marked in winter 2 than winter 1 due to an increase in the low-fibre grass leaf and a drop in the tussock grass content of the diet of grey kangaroo on Lana in winter 2 compared to winter 1. The mean diversity index (Table 4.2) for the diet of grey kangaroo on Lana is not significantly different from Newholme during summer but is significantly higher on Lana for both winter samples.

For the wallaroo in summer there is no significant difference in the proportions of different plant categories in the diet between Lana and Newholme. For the two winter samples the proportions of plant categories in the diet are significantly different between the two areas (winter 1, $\chi^2 = 28.5$, df = 3, $p < 0.001$; winter 2, $\chi^2 = 36.0$, df = 3, $p < 0.001$). On Lana during winter the proportion of tussock grass is lower and the proportion of low-fibre grass leaf is higher than on Newholme. These differences are more marked in winter 2 than in winter 1. The mean diversity indices for wallaroo diets on Newholme and Lana are not significantly different in summer but are significantly different in both winters (Table 4.2).

The main difference between properties in the species occurrences of low-fibre grasses is the lack of some of the warm season annual species (e.g. *Eulalia*, *Digitaria*) on Newholme and the reduced importance of cool season annuals (e.g. *Vulpia*, *Bromus molliformis*). *Eulalia* and *Digitaria* are both rare on Newholme whereas they are common to abundant on Lana during the summer. The cool season annuals are abundant in most habitats on Lana during winter whereas on Newholme they are mainly confined to sheep camps.

4.3.4 Sex Differences in Diet

Although differences in the diet are just as likely to occur within different age and reproductive classes of the same sex as between sexes, sample sizes only allowed a comparison of diets between sexes.

(A) Grey kangaroo

A comparison of plant categories found in the diet of male and female grey kangaroo for each season is given in Table 4.4 for Lana and Table 4.5 for Newholme. Similar plant categories with small frequencies had to be grouped for statistical analysis. On Newholme in winter 1 no males were sampled. For Lana in summer, autumn, winter 2 and spring and for Newholme in summer and winter 2 there were no significant differences between males and females. However for the winter 1 sample on Lana males and females differed significantly in the proportions of plant categories present in the diet ($\chi^2 = 22.6$, df = 5, $p < 0.001$). Males had a higher proportion of tussock grasses and less low-fibre grass leaf (especially *Vulpia*) in their diet compared to females. However two of the three males in this sample were shot in an area of savanna woodland where there were abundant *Poa* tussocks present. When the females are compared to the male who was not feeding in an area of dense *Poa* tussocks when shot there are still significant differences between sexes ($\chi^2 = 17.3$, df = 5, $p < 0.01$). If this male is compared to each female individually the proportion of *Vulpia* in the diet is the same as one of the females and lower than the others and the proportion of tussock grasses in the diet is lower than one of the females (male = 23%; female = 26%) and higher than the others.

(B) Wallaroo

The proportion of each plant category in the diets of male and female wallaroo for each season is given in Table 4.6 for Lana and Table 4.7 for Newholme. There are significant differences between male and female diets on Lana during winter 1 ($\chi^2 = 28.1$, df = 4, $p < 0.001$) and spring ($\chi^2 = 12.5$, df = 3, $p < 0.01$) and on Newholme in summer ($\chi^2 = 9.6$, df = 3, $p < 0.05$) and in winter 1 ($\chi^2 = 11.8$, df = 2, $p < 0.01$). For winter 1 on Lana, males have a higher proportion of tussock grasses in their diet. However three of the four males were shot while feeding in an area of abundant tussock grasses. If the one

Table 4.4 Proportions of plant categories found in the stomachs of male and female grey kangaroo on Lana for each season.

(A) SUMMER

Sex	No. in sample	PLANT CATEGORY *Microlaena* leaf	*Bothriochloa* leaf	Other low-* fibre grass leaf	Grass sheath + unidentified grass	Others
♀	6	8.8	18.3	54.2	12.5	6.2
♂	4	5.3	28.0	38.0	18.5	10.3

* including *Carex inversa*

(B) AUTUMN

Sex	No. in sample	PLANT CATEGORY Low-fibre* grass leaf	Grass sheath + unidentified grass	Tussock grasses + High-fibre grass	Others
♀	7	62.0	8.9	25.1	4.0
♂	3	59.7	8.3	24.3	7.7

(C) WINTER 1

Sex	No. in Sample	PLANT CATEGORY *Vulpia* leaf	Other low-* fibre grass leaf	Grass sheath + unidentified grass	Tussock grasses	High-fibre grass + grass stem + infloresence + *Juncus* H.F. + *Lomondra filiformis*	Others
♀	7	21.6	37.1	10.0	11.0	9.7	10.6
All ♂♂	3	7.7	26.0	9.0	35.0	15.3	7.0
♂ not in *Poa* area	1	5.0	35.0	9.0	23.0	18.0	10.0

(D) WINTER 2

Sex	No. in sample	PLANT CATEGORY *Vulpia* leaf	Other low-* fibre grass leaf	Grass sheath + unidentified grass	Tussock grasses	High-fibre grass + grass stem + infloresence + *Juncus* H.F. + *Lomondra filiformis*	Others
♀	6	18.8	40.0	9.4	10.3	14.3	7.2
♂	4	17.2	50.3	9.7	7.0	4.8	11.0

(E) SPRING

Sex	No. in sample	PLANT CATEGORY Low-fibre grass leaf	Grass sheath + unidentified grass	Grass stem + infloresence	Others
♀	4	61.5	5.0	25.5	8.0
♂	6	58	9.7	22.3	10.0

Table 4.5 Proportions of plant categories found in the stomachs of male and female grey kangaroo on Newholme for summer and winter.

(A) SUMMER*

		PLANT CATEGORY					
Sex	No. in sample	*Brothiochloa* leaf	*Microlaena* leaf	Other low-fibre grass leaf	Grass sheath	Grass stem + infloresence	Others
♀	2	12.0	10.0	34.5	10.5	14.5	18.5
♂	3	11.7	14.3	40.0	14.0	12.0	8.0

* one individual was left out of the analysis as it was shot on Mt. Duval in a separate area to the others in this sample.

(B) WINTER 2†

		PLANT CATEGORY		
Sex	No. in sample	Low-fibre grass leaf	Tussock grasses	Others
♀	6	47.0	42.0	11.0
♂	2	38.0	53.5	8.5

† the female shot in a sheep camp was excluded

Table 4.6 Proportions of plant categories found in the stomachs of male and female wallaroo on Lana for each season.

(A) SUMMER

Sex	No. in sample	*Microlaena* leaf	*Bothiochloa* leaf	Other low-fibre grass leaf	Grass sheath + unidentified grass	Others
				PLANT CATEGORY		
♀	6	17.0	23.0	34.8	13.3	11.9
♂	4	15.3	16.0	37.5	20.5	10.7

(B) AUTUMN

Sex	No. in sample	Low-fibre grass leaf	Tussock grasses	High-fibre grass + grass stem + infloresence	Others
			PLANT CATEGORY		
♀	4	67.0	14.2	6.2	12.6
♂	6	70.9	9.3	11.0	8.8

(C) WINTER 1

Sex	No. in sample	*Vulpia* leaf	Other low-fibre grass leaf	Grass sheath + unidentified grass	Tussock grasses	Others
				PLANT CATEGORY		
♀	6	11.2	63.2	8.5	7.5	9.6
♂	4	5.0	38.5	8.5	38.3	9.7

(D) WINTER 2

Sex	No. in sample	*Vulpia* leaf	Other low-fibre grass leaf	Grass sheath + unidentified grass	Tussock Grass + Grass stem + infloresence + high-fibre grasses + *Lomondra filiformis* + *Juncus* H.F.	Others
				PLANT CATEGORY		
♀	8	11.9	58.7	7.6	8.9	12.9
♂	2	18.0	52.0	6.5	15.0	8.5

(E) SPRING

Sex	No. in sample	Low-fibre grass leaf	Grass sheath + unidentified grass	Grass stem + infloresence	Others
			PLANT CATEGORY		
♀	5	47.4	5.0	28.8	18.8
♂	4	44.3	13.5	13.2	29.0

Table 4.7 Proportions of plant categories found in the stomachs of male and female wallaroo on Newholme for summer and winter.

(A) SUMMER

		PLANT CATEGORY			
Sex	No. in sample	Low-fibre grass leaf	Grass sheath + unidentified grass	Tussock grasses + high-fibre grass	Others
♀	3	54.0	19.7	7.3	19.0
♂	3	72.4	8.0	7.6	12.0

(B) WINTER 1

		PLANT CATEGORY		
Sex	No. in sample	Low-fibre grass leaf	Tussock grasses	Others
♀	4	42.0	45.8	12.2
♂	3	19.7	65.7	14.6

(C) WINTER 2

		PLANT CATEGORY				
Sex	No. in sample	*Microlaena* leaf	Other low-fibre grass leaf	Grass sheath + unidentified grass	Tussock grasses	Others
♀	2	15.0	32.0	5.0	35.5	12.5
All ♂♂	3	12.4	21.3	7.0	50.3	9.0
♂†	2	18.0	24.0	8.0	41.0	9.0

† excluding the male sampled in *Poa costiniana* slope

male shot in sown pasture is compared to the female also shot in this pasture, the female has a higher proportion of tussock grass in the diet (male = 0% tussock and 78% low-fibre grass leaf; female = 10% tussock and 80% low-fibre grass leaf). For the Lana spring sample males have a higher proportion of grass sheath and forbs (mainly legumes) and a lower proportion of grass stem and infloresence in their diet in comparison to females. However three of the four males were shot in the same area and three females (and no males) were shot in sown pasture so that differences in diet due to differences in the composition of the pasture where the sexes were feeding cannot be ruled out as a possibility. For Newholme the differences between the sexes in summer and winter 1 may also be due to differences in the habitats where animals were feeding when shot. In winter 1 male diets contained more tussock grasses and less low-fibre grass leaf but all four females were shot in sheep camps and all three males were shot in *Poa* slopes. In summer males had more low-fibre grass leaf and less grass sheath, stem and infloresence in their diet than females. However, more females were shot in sheep camps than males. The one male shot in *Microlaena* pasture was in a drainage area near savanna slope where he had probably been feeding as his stomach contained a lot of *Bothriochloa macera* which is rare in *Microlaena*-dominated drainage areas. The females in the sheep camps were eating *Microlaena* stem, infloresence and sheath as well as leaf which would account for the sex differences in diet for this season.

4.3.5 Diet Selectivity

(A) Lana

Since habitats differed in pasture biomass and composition (see Chapter 3) and kangaroos had specific habitat preferences (see Chapter 5) it was necessary to weight each habitat's contribution to calculate a pasture biomass which represented an estimate of biomass available to the kangaroos from which they could select their diet. Densities of kangaroos in each habitat obtained the year before the dietary study was undertaken were used as indices of the use of each habitat. To obtain a weighting for pasture biomass in each habitat, the density of kangaroos present in each habitat during feeding periods (in the same month as the diet was examined) was multiplied by the area of that habitat present on the study area. For the grey kangaroo only the biomass of sheep-affected pasture occurring in savanna woodland

and gentle slope areas was used in the calculation as grey kangaroo did not use sheep camp areas on rocky slope. For the wallaroo, since they did not utilize savanna woodland away from rocky hills, the percentage of area covered by savanna woodland on transects was used as a weighting instead of the area of savanna woodland on the study area. Since transects were done around the rocky hills this will give a better index to the area of savanna woodland available to wallaroo for feeding. For the wallaroo, large boulder slope and dense rock slope were not included in the pasture biomass calculations as the density of wallaroo present in these habitats was thought to far exceed their value as feeding areas. Very little feeding is thought to have taken place in these two habitats (see Chapter 5).

The proportions of plant categories found in the stomachs of individual kangaroos were used as replicates to test whether kangaroos were selecting a plant category from the pasture. The value of t (for a t-test) was calculated for each plant category using the formula:

$$t = (\bar{X} \text{ stomachs} - \bar{X} \text{ pasture biomass}) \div \frac{SD}{\sqrt{N}}$$

where SD = standard deviation of the proportion of a plant category in the stomach samples

N = number of kangaroos in a sample.

The percentages of each plant category in the diet and in the pasture were transformed (arcsine) for the statistical analysis. When examining dietary selection the plant categories in the diet were grouped to match the plant categories separated in the pasture analysis. No pasture sample was taken in winter 2 and so selection could not be examined for this sample.

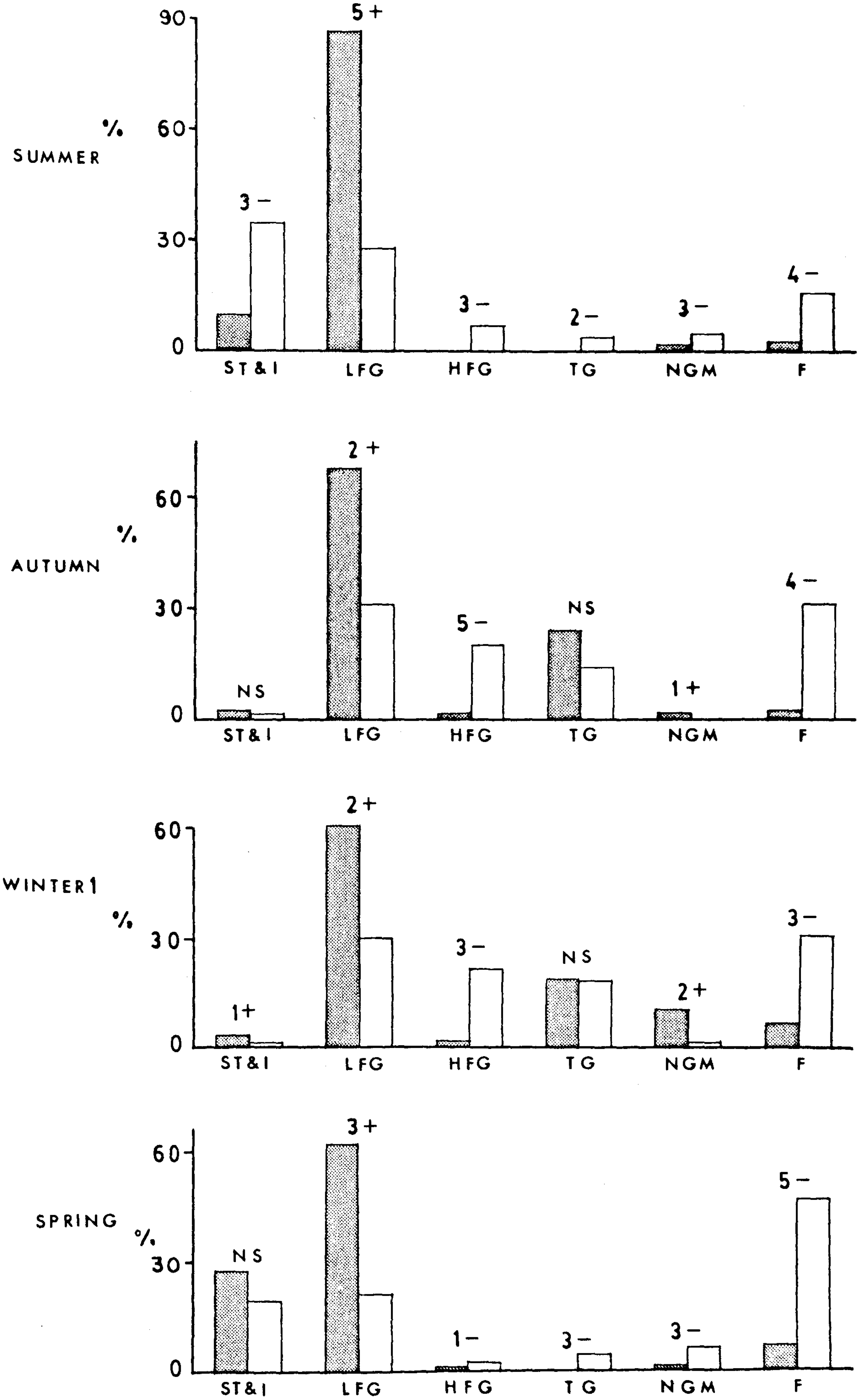
The majority of the weighting for pasture biomass available to the grey kangaroo came from savanna woodland in all seasons (70.5% (winter) to 90.3% (spring)). A comparison of the proportion of plant categories in the pasture and in the diet of grey kangaroo on Lana for each season is given in Fig. 4.3. The grass stem and infloresence category was selected to a small degree by grey kangaroo during winter when it was least abundant. In spring grass stem and infloresence was not selected for or against. In summer, however, there was heavy selection against grass stem and infloresence. Low-fibre grass leaf and sheath was selected by grey kangaroo during all seasons. Selection for low-fibre grass leaf and sheath was most intense during summer and least intense during autumn and winter. High-fibre grasses were selected against during all seasons. Tussock grasses were selected against during summer and

Fig. 4.3 Comparison of the proportion of each plant category present in the pasture and in the diet of grey kangaroo for each season on Lana. Values for the proportions of plant categories in the diet are means. See text for explanation of how the proportions of the plant categories in the pasture were calculated and for the method of investigation of dietary selection. +, - or NS above each histogram represents the degree of selection. Degree of selection is based on value of t in t-test e.g. 1+ = selection significant and $t < 5.0$, 2+ = $5.1 < t < 10.0$, 3+ = $10.1 < t < 15.0$, 4+ = $15.1 < t < 20.0$, 5+ = $t > 20.1$; + indicates selection, - indicates avoidance, NS indicates no selection or avoidance occurs for a plant category.

% in diet

% in pasture

St & I = Grass stem and infloresence
LFG = Low-fibre grass leaf and sheath
HFG = High-fibre grass
TG = Tussock grass
NGM = Non-grass monocotyledons
F = Forbs


SUMMER
%
90
60
30
0
5+
3−
3−
2−
3−
4−
ST&I
LFG
HFG
TG
NGM
F
AUTUMN
%
60
30
0
2+
NS
5−
NS
1+
4−
ST&I
LFG
HFG
TG
NGM
F
WINTER 1
%
60
30
0
2+
1+
3−
NS
2+
3−
ST&I
LFG
HFG
TG
NGM
F
SPRING
%
60
30
0
3+
NS
1−
3−
3−
5−
ST&I
LFG
HFG
TG
NGM
F

spring but during autumn and winter the proportion in the diet did not differ significantly from the proportion found in the pasture. The non-grass monocotyledons were selected against during spring and summer when this category consisted of abundant lower fibre species (e.g. *Fimbristylis*, *Cyperus brevifolius*) as well as the higher fibre species (e.g. *Juncus*). During autumn and winter when high-fibre species make up a greater proportion of this category some selection for this category occurs. Forbs are avoided during all seasons.

For the wallaroo savanna woodland made up the greatest contribution to the weighting for the pasture biomass calculation (38.4% (winter) to 62.1% (spring)), however the size of the contribution was a lot less than for the grey kangaroo. All other habitats but especially gentle slope and sheep-affected pasture increased in importance in the pasture biomass weightings compared to the grey kangaroo. A comparison of the proportions of plant categories in the pasture and in the diet of the wallaroo on Lana for each season is given in Fig.4.4. Grass stem and infloresence was selected by wallaroo only during spring when this category consisted mostly of cool season annuals such as *Vulpia* and *Bromus molliformis* but also a lot of *Danthonia racemosa*. During summer stem and infloresence was also abundant in the pasture but it was avoided. The stem and infloresence species present during summer were mainly warm season annuals with the most abundant being *Bothriochloa* which was more fibrous than the species present during spring. In autumn and winter very little grass stem or infloresence was present and there was no selection for or against this plant category. There was selection for low fibre grass leaf and sheath in all seasons and, as with the grey kangaroo, selection was most intense during summer. High-fibre grass was selected against in all seasons. The pattern of selection of tussock grasses was the same as that for the grey kangaroo, i.e. selection against during summer and spring and no selection for or against during autumn and winter. Non-grass monocotyledons were selected against during summer and spring and selected for during winter. Forbs were selected against during all seasons but least of all during winter. The degree of selection against forbs by the wallaroo was lower than that by the grey kangaroo in all seasons but during spring the difference between the two kangaroo species was greatest.

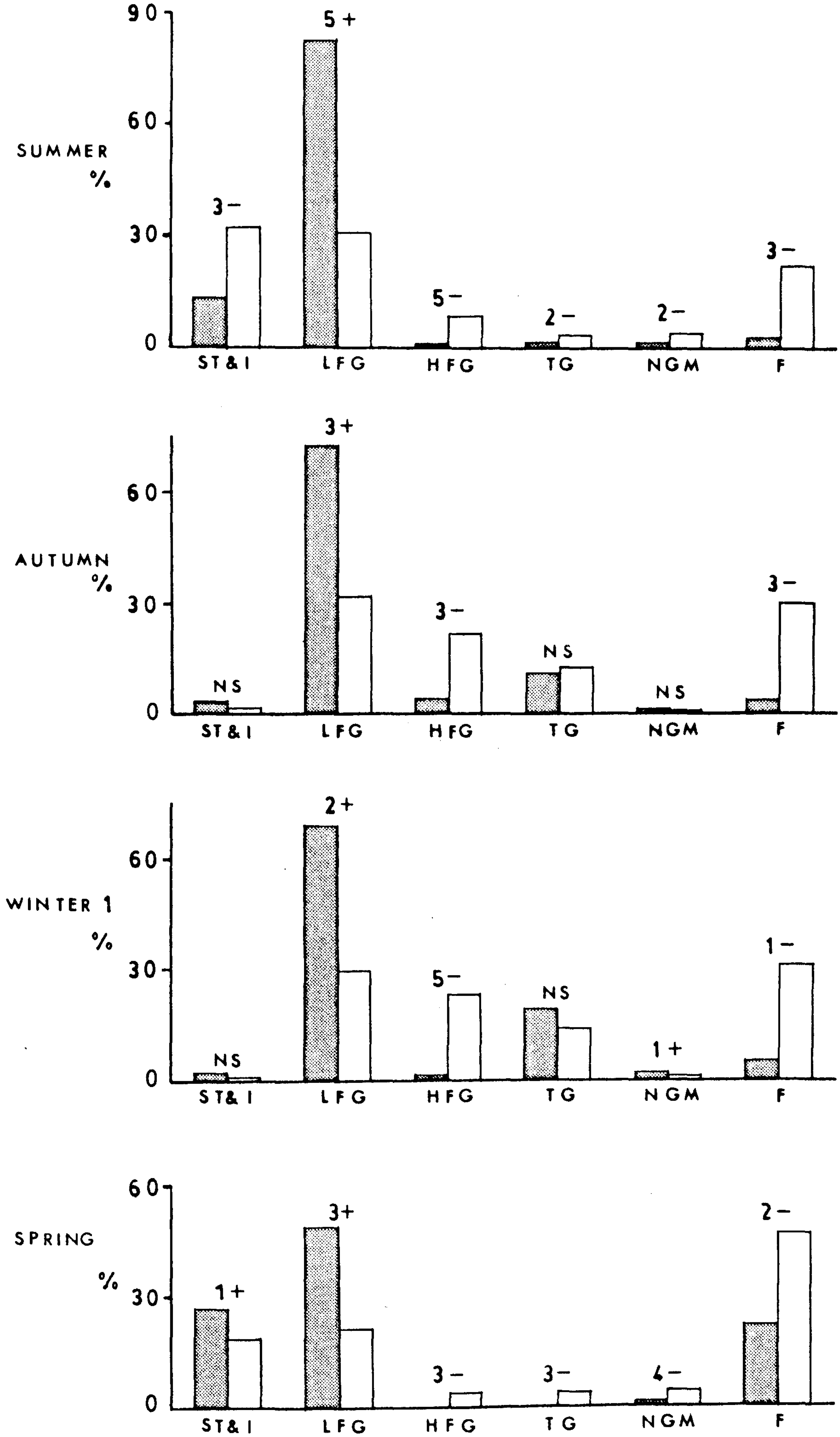
No biomass data were collected for plant species occurrence within plant categories, however data on the frequency of occurrence of plant species in quadrats were collected for the grass stem and infloresence and forb categories. The frequency of occurrence of

Fig. 4.4 Comparison of the proportion of each plant category present in the pasture and in the diet of wallaroo for each season on Lana. Values for the proportions of plant categories in the diet are means. See text for explanation of how the proportions were calculated and for the method of investigation of dietary selection. +, - or NS above each histogram represents the degree of selection. Degree of selection symbols same as in Fig. 4.3

▒ % in diet

☐ % in pasture

St & I	= Grass stem and infloresence
LFG	= Low-fibre grass leaf and sheath
HFG	= High-fibre grass
TG	= Non-grass monocotyledons
F	= Forbs


90
60
30
0
SUMMER
%
5+
3-
5-
2-
2-
3-
ST&I
LFG
HFG
TG
NGM
F
60
30
0
AUTUMN
%
3+
NS
3-
NS
NS
3-
ST&I
LFG
HFG
TG
NGM
F
60
30
0
WINTER 1
%
2+
NS
5-
NS
1+
1-
ST&I
LFG
HFG
TG
NGM
F
60
30
0
SPRING
%
3+
1+
3-
3-
4-
2-
ST&I
LFG
HFG
TG
NGM
F

plant species did not differ markedly between most habitats. The exception to this was sheep-affected pasture where plant species differed markedly from other habitats. However no special weighting was given to each habitat, as was done for the plant categories. Habitats were simply weighted according to the number of quadrats sampled in each habitat. The results for the grass stem and infloresence category is shown in Table 4.8 for each season. For both kangaroo species in all seasons there is little correspondence between the frequency of occurrence of species in the pasture and the frequency of occurrence in the diet. There also appears to be differential use of the stem and infloresence of the same plant species. Some species in the diet are only, or mostly, represented by infloresence and not by stem. Differences in the identifiability of stem in relation to infloresence of some species may have contributed to this but this cannot account for the differences in all species. The results of the forb species comparison is shown in Table 4.9 for each season. For the grey kangaroo the forb species in the diet tend to be the most abundant species present in the pasture. The occurrence of forb species in the diet of the wallaroo appears to be more independent of the abundance of the forb species in the pasture. Since wallaroo feed a lot in sheep camps, the differences in the forb species composition in sheep camp compared to other habitats may be influencing these results to a certain extent.

(B) Newholme

Since most grey kangaroo and wallaroo were shot in only a few of the habitats present on Newholme it was not possible to weight each habitat's biomass according to the degree of usage by kangaroos. It was also usually the case that kangaroos that had been shot feeding in one habitat had not spent all their time feeding there. The stomachs of grey kangaroo shot in *Eragrostis* grassland, for example, could contain *Poa* tussock grasses even though there were no *Poa* tussocks in this habitat. Since the time spent feeding in different habitat types was not known, no weighting could be given to habitats in order to examine dietary selection. There were three wallaroo which were judged, from the plant species composition of their stomachs, to have fed only in one habitat before being shot. A comparison of the proportion of each plant category present in the diet and in the pasture in which they fed for these three wallaroo is shown in Table 4.10. All three individuals were in the winter 1 sample. It was not possible to compare the diet with the pasture statistically because of the small sample of kangaroos. It appears that, (1) selection for

Table 4.8 Comparison of the frequency of occurrence of plant species in the grass stem + infloresence category found in pasture and in the diet of the grey kangaroo and wallaroo for each season on Lana. The species with the largest frequency is given the value of 100 for each of pasture and grey kangaroo and wallaroo diets. Other species were given values as a proportion of the 100 based on their relative frequency of occurrence in proportion to the largest value in each category.

(A) SUMMER

Plant Species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Agropyron	20	0	
Bothriochloa	100	12 (all I[A])	4
Chloris	12	9 (all I)	0
Danthonia	26	12 (50% I)	11 (66% I)
Digitaria	32	3	48 (85% I)
Eragrostis	43	12 (50% I)	4 (all I)
Eulalia	1	3	4
Microlaena	17	12 (75% I)	89 (66% I)
Panicum	64	9 (all I)	4 (all I)
Sporobolus	46	12	7
Vulpia	0	0	4
Sum of Rest	46 (9 spp)	100†	100†
Actual frequency of most abundant species	48%*	3%[x]	2.7%[x]

† unidentified as to species.

* expressed as percentage of occurrence in all quadrats sampled.

x expressed as percentage of identified plant fragments in stomachs.

A; I= infloresence, % of particles which are infloresence is noted when they make up a large proportion of the diet sample.

(B) AUTUMN

Plant Species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Agropyron	26	0	0
Bothriochloa	100	0	0
Danthonia	48	0	4
Eragrostis	52	13	13
Microlaena	48	0	39
Panicum	48	0	26
Sporobolus	13	13	0
Sum of Rest	43	100†	100†
Actual frequency of most abundant species	19%*	1.5%[x]	2.3%[x]

Table 4.8 (cont.)

(C) WINTER

Plant species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Cynodon	0	25	0
Danthonia	50	0	0
Dichelachne	100	0	0
Eleusine	100	0	0
Microlaena	100	100	60
Sporobolus	0	13	20
Stipa	0	0	20
Sum of Rest	0	100	100
Actual frequency of most abundant species	1.7%*	0.8%^{x}	0.5%^{x}

(D) SPRING

Plant species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Agropyron	59	15 (all I)	22 (all I)
Aira	13	0	0
Bothriochloa	43	3	1
Bromus	34	7 (86% I)	11 (88% I)
Danthonia	100	26 (48% I)	20 (43% I)
Dichelachne	53	0	0
Digitaria	7	0	0
Echinopogon	9	1	0
Eragrostis	10	2	0
Festuca	0	0	3
Microlaena	29	24 (60% I)	50 (68% I)
Panicum	13	4 (all I)	11 (all I)
Phalaris	0	5	1
Poa	18	0	0
Sporobolus	10	14 (64% I)	1
Vulpia	56	41 (88% I)	100 (78% I)
Sum of Rest	30 (8 app)	100†	78†
Actual frequency of most abundant species	66%*	9.7%^{x}	6.4%^{x}

Table 4.9 Comparison of the frequency of occurrence of plant species in the forb category found in pasture and in the diet of the grey kangaroo and wallaroo for each season on Lana. Relative frequencies calculated as in Table 4.8.

(A) SUMMER

Plant species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Cheilanthus	28	0	0
Chenopodium	11	0	0
Desmodium	37	0	30
Dichondra	48	0	0
Geranium	14	0	0
Glycine	75	0	60
Halorogis	14	0	0
Helichrysum	18	0	0
Hydrocotyle	13	0	0
Hypochoeris	96	100	40
Paryonchia	18	0	0
Trifolium	38	0	10
Wahlenbergia	17	0†	10†
Sum of Rest	100 (24 spp)	100	100
Actual frequency of most abundant species	45%	0.4%	1.0%

† unidentified as to species

(B) AUTUMN

Plant species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Cheilanthus	35	0	0
Desmodium	32	0	0
Dichondra	50	0	0
Geranium	10	0	0
Glycine	25	0	15
Halorogis	12	0	0
Helichrysum	18	0	0
Hydrocotyle	52	0	0
Hypochoeris	100	42	69
Indigophora	0	0	8
Paryonchia	30	0	0
Poterium	17	0	0
Sheep Camp Succulent	0	0	23
Stellaria	2	0	8
Trifolium	55	0	54
Wahlenbergia	23	0†	0†
Sum of Rest	83	100	100
Actual frequency of most abundant species	51%	1.2%	1.3%

Table 4.9 (cont.)

(C) WINTER

Plant species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Acetosella	15	0	3
Alternanthera	0	3	0
Cerastium	1	0	3
Cheilanthus	22	3	0
Desmodium	17	6	0
Dichondra	47	0	0
Erodium	0	6	3
Geranium	9	0	0
Glycine	0	3	0
Hydrocotyle	28	0	0
Hypericum	15	0	0
Hypochoeris	67	10	10
Kohlrauschia	31	0	0
Lagenophora	0	3	0
Lepidium	0	3	0
Paryonchia	23	0	0
Poterium	13	0	0
Trifolium	100	61	8
Wahlenbergia	31	0	0
Sum of rest	72 (21 spp)	100†	100†
Actual frequency of most abundant species	43%[B]	3.1%	3.9%

B. Frequency of the most abundant species in the genus.

(D) SPRING

Plant species	Pasture	Grey Kangaroo Diet	Wallaroo Diet
Acetosella	11	0	0
Cheilanthus	13	0	0
Desmodium	11	3	2
Dichondra	36	0	0
Geranium	13	0	0
Glycine	38	3	2
Halorogis	8	0	0
Helichrysum	8	0	0
Hydrocotyle	27	0	0
Hypochoeris	55	45	3
Oxalis	10	0	0
Petrorhagia	54	6	0
Plantago	6	0	0
Senecio	0	0	2
Trifolium	100	100	100
Wahlenbergia	16	0	0
Sum of Rest	51 (28 spp)	94†	41†
Actual frequency of most abundant species	65%[C]	3.1%	17.2%

C *Hypochoeris* was the most frequent species as opposed to group of species in the same genus (i.e. *Trifolium*).

Table 4.10 Comparison of the proportions of each plant category present in the pasture and in the diet of wallaroo on Newholme in winter 1978. Only those individuals believed to have feed in one habitat were included.

Habitat in which feeding		Grass stem + infloresence	Low-fibre leaf + sheath	High-fibre grass	Tussock grasses	Non-grass monocotyledons	Forb
Poa sieberana slope	% in diet†	2.0	22.5	9.5[A]	57.5	2.0	4.5
	% in pasture	0	5.0	0	89.2	0	5.8
Poa costiniana slope	% in diet*	0	18.0	0	82.0	0	0
	% in pasture	0.3	20.3	0.4	57.2	1.3	20.5

† mean of two individuals

* only one individual in the sample

A The stomach of one of the individuals contained 19% *Imperata cylindrica*. This individual was probably feeding in one of the large dense clumps of this blady grass which occur scattered through the habitat.

low-fibre grass leaf and sheath may be occurring in one habitat and not in another, (2) selection for tussock grass occurs in one habitat and against it in the other habitat, and (3) selection against forbs is occurring in one habitat and not in another. The results are thus ambiguous and no conclusions can be reached from these data. It should be noted however that differences will occur within a habitat and the pasture biomass data represent the mean of samples taken all over that habitat whereas the kangaroos were probably feeding in specific areas which may have differed somewhat from the mean pasture biomass values for that habitat. A larger sample of kangaroos feeding exclusively in a habitat and from different areas of that habitat would have to be obtained before valid comparisons could be made.

4.4 Discussion

Some of the previous studies on macropod diets have concentrated on the occurrence and seasonal change of plant categories in the diet rather than changes in plant species and plant parts (e.g. Ellis *et al.*, 1977). Their plant categories were based on groups which were recognizable by epidermal patterns rather than plant categories based on groups of species and plant parts which would be of similar quality and palatability to the kangaroos. In part this was due to the grinding of plant fragments in the stomach which made the task of identifying plant species' epidermal patterns much harder. However even though many workers have commented on the seasonal occurrence of grass seed heads no attempts were made to quantify their occurrence except for the study of Bailey *et al.* (1971) which examined plant part occurrence in the mouth contents of shot kangaroos. None of the reports of kangaroo dietary studies commented on the preparation of reference epidermal slides of grass infloresence (or sheath). If in fact these studies recognized grass seed head epidermis as such for example, why were they not included in the results? If grass infloresence was not recognized it was probably classified as unidentified grass or even as unidentified. Dietary studies should not just aim to produce a quantified list of plant species eaten by a herbivore. The importance of single species dietary studies lies in their investigation of the relationship between changes in the environmental conditions and changes in the composition and quality of the diet and the effects of these changes on the population being studied. Since plant parts can differ in their quality, an examination of changes in the plant parts eaten can be just as important as, or more important than, the documentation of changes in the species of plant eaten when examining the feeding strategy of an animal. Studies on the diet of sympatric herbivore species in Australia (e.g. Griffiths and Barker, 1966) have been able to show differences in the plant species composition of the diet between species. There are cases however, reported from Africa, where differences in the diet between sympatric herbivores are based on selection of plant parts and not plant species (e.g. Gwynne and Bell, 1968).

Although the wallaroo and grey kangaroo have a major portion of the plant species and plant parts common to both their diets in all seasons, differences between the feeding strategies of the two species do exist. In summer the similarity of the diet of the two species is greatest. Both kangaroos eat a lot of *Bothriochloa*, *Digitaria* and *Eulalia* (summer annual species). It is unlikely that any competition for these grasses occurs as they are probably superabundant. Large quantities of these grasses die (due to cool weather) before they can be eaten. Both kangaroos select against the abundant stem present during summer. The main difference between the grey kangaroo and wallaroo during summer is the proportion of *Microlaena stipoides* and *Eragrostis/Sporobolus* in the diets. The wallaroo's diet contains more *Microlaena* and less *Eragrostis/Sporobolus* than the grey kangaroo's. *Microlaena* is most abundant and of highest quality in sheep-affected pasture. Wallaroo feed in these areas extensively (see Chapter 5), whereas grey kangaroo utilize savanna woodland to a greater extent. The differences between the proportions of these grasses in the diet is probably a result of the differences in habitat use.

Both kangaroos avoid eating high-fibre grasses. However during autumn and winter the proportion of tussock grasses (also of high-fibre content) in the diet increases. The quality of the diet is probably poorest during late autumn since most warm season annuals have died off and the cool season annuals have not yet begun to grow (see Table 7.1). The proportion of tussock grasses present in the diet of both kangaroos is higher in autumn than in winter 2. The increase in tussock grass use in winter 1 was probably related to the unusually wet conditions prevailing during that season. Judging from the increased use made of *Danthonia racemosa* in winter 2 compared to winter 1 the main effect of these wet conditions may have been either to increase decomposition or to reduce growth rates for *Danthonia racemosa* during winter 1. Unfortunately no pasture biomass data were collected in winter 2 so it is not possible to compare the grass leaf biomass present in the two winters. The potential for competition between the two kangaroos would be greatest during winter when plant biomass is reduced and the similarity of the diets is greatest. Wallaroo have a slightly lower proportion of tussock grasses and high-fibre non-grass monocotyledons (i.e. *Juncus* and *Lomandra filiformis*) and a slightly higher proportion of *Microlaena* in their diets during autumn and winter than do grey kangaroo . This is again probably related to their higher use of sheep-affected pasture compared to grey kangaroo. The effects of the greater use of sheep-affected pasture by wallaroo on the differences in the diet of the two kangaroos appears to be greatest during spring. Wallaroo diets contain far more *Microlaena* in comparison to grey kangaroo during this season. *Eragrostis/Sporobolus* leaf takes on the equivalent importance of *Microlaena* in the diet of the grey kangaroo during spring. Forbs, especially legumes, were also a major component of the spring diet of wallaroo and not grey kangaroo. *Microlaena* and legumes contained the highest protein content of plants available in spring (see Table 3.4).

The main difference in the diets of kangaroos on Lana and Newholme was in the much higher proportion of tussock grasses eaten in winter (especially winter 2) on Newholme. Tussock grasses make up a much higher proportion of the pasture biomass on Newholme and during winter, when low-fibre grasses become scarce, kangaroos are probably forced to accept large proportions of tussock grass in their diet. The quality of plant species is also lower on Newholme (see Table 3.4). Comparisons between the quality of the diets of kangaroos on Newholme and Lana are given in Tables 7.1, 7.3 and 7.4.

Both kangaroo diets contained large proportions of grass. Dietary studies of other kangaroos have also found this to be the case. Studies on red kangaroo have found from 21% to 97% of the diet to be composed of grass (Bailey *et al.*, 1971; Ellis *et al.*, 1977; Low *et al.*, 1973; Griffiths and Barker, 1966; Storr, 1968; Chippendale, 1968). Euro diets contained between 52% to 96% grass (Ealey, 1967c; Storr, 1968; Ellis *et al.*, 1977). Studies on the eastern grey kangaroo have found between 64% to 89% grass in the diet (Griffiths and Barker, 1966; Griffiths *et al.*, 1974; Kirkpatrick, 1965a). In the present study the grass content of the diet of the grey kangaroo ranged from 77% to 98% and for the wallaroo from 77% to 97%.

The higher grass content of kangaroo diets in the present study is probably a reflection of the higher proportion of grass in the pasture in this study in comparison to the semi-arid areas where most other studies took place.

Measurement of nitrogen content of plants in some of the above studies has shown that nitrogen content of dicotyledons is generally higher than in grasses. Hence kangaroos did not appear to select plants primarily for their nitrogen content. In the present study the grey kangaroo appears also not to be selecting for plant nitrogen. Although a large range of dicotyledon species were not analysed for nitrogen it appears that dicotyledons have levels of nitrogen similar to grasses (see Table 3.4). *Hypocheirus radicata*, although present in the diets, was not eaten to an extent which matched its abundance in relation to grasses, yet its nitrogen content in all seasons was high. Grey kangaroo densities are also usually higher in savanna woodland than in sheep-affected pasture (see Chapter 5) where grass nitrogen content is highest. Wallaroo appear to be more selective for nitrogen than are grey kangaroo . Although forbs are not eaten a great deal, within grasses wallaroo prefer species with a high nitrogen content. Wallaroo feed extensively in sheep camps on these high quality grasses. Their intake of legumes, which have a high nitrogen content, increases dramatically in spring when these plants are abundant; in contrast the grey kangaroo did not increase its intake of legumes in spring.

Bailey *et al.* (1971) have investigated plant part use by the red kangaroo. They found that grass stem was utilized to the same extent as grass leaf. Bailey's study was carried out during dry conditions which could perhaps be likened to winter conditions in the present study when both kangaroo species did not select against stem. During summer, in the present study, there was selection against stem and against grass species containing a high fibre content in preference for low-fibre grass leaf and sheath. Dellow (1979) has noted selection by eastern grey kangaroo and wallaroo against the stem component of a lucerne diet fed to animals in laboratory cages.

The only study on the dietary selectivity of *Macropus robustus* was carried out by Ellis *et al.* (1977) on a different subspecies to that in the present study. They found euros (*Macropus robustus erubescens*) to be highly selective for grass even when present at low levels. In the present study, wallaroos (*Macropus robustus robustus*) were also found to be highly selective for low-fibre grass leaf and sheath.

The only published study to date on dietary selectivity by the eastern grey kangaroo was carried out in an area of similar rainfall and pasture condition to the present study areas, although seasonal changes in temperature in the present study areas would have been greater. However the study by Kirkpatrick (1965a) reached conclusions directly opposite to those of the present study. To quote Kirkpatrick "... grey kangaroos were essentially non-selective ... high use of *Aristida* (included in the high fibre grass category in the present study) ... grass seed heads and stems commonly eaten even when young leafy growth abundantly available." Kirkpatrick quantified species occurrence in the pasture by a frequency rating based on a point quadrat analysis. Only species occurence was noted and plant parts were not differentiated. Diet of the grey kangaroo was assessed using the frequency of occurrence of identifiable plant remains in the mouths of shot kangaroos. The frequency of occurrence of pasture species was assessed during one month whereas data on the diet of kangaroos were collected over a twelve month period. Kirkpatrick commented that he believed the relative abundances of the major pasture components varied little throughout the year. However,even if this were true,the abundance of stem in relation to other grass plant parts will definitely vary seasonally. The methods used in Kirkpatrick's study differ from those of the present study. I utilized the weight of plant categories present as an index to their abundance. I believe that since individuals of different plant species can have large differences in biomass that weight is a better index to availability. Even if frequency of occurrence had been used to assess plant species abundance I still believe that the kangaroos would have been shown to be selecting from the pasture. For example, the pasture cover on Newholme although slightly less during winter would not have dropped sufficiently to increase the frequency of occurrence of tussock grasses in the pasture by ten times, yet the proportion of tussock grasses in the diet of both kangaroos increased over ten fold in winter compared to summer. It is possible that, since Kirkpatrick's study was done in an area of unimproved pasture (Kirkpatrick, pers. comm.), selection may not occur on unimproved pasture but may occur on improved pasture. Since diet selectivity could not be quantitatively examined on Newholme it is not possible to say positively that selection was occurring on unimproved pasture in the present study. However, for reasons just given, I believe that kangaroos were selecting on Newholme.

Two factors may be responsible for Kirkpatrick not being able to show selection by the grey kangaroo in his study. Firstly, pasture composition was assessed during one month whereas diet was examined over the period of a year. If changes did occur over the year the comparison between diet and pasture composition would be invalid. Secondly, Kirkpatrick's method of diet investigation may not be very accurate. He relied on the identification of "identifiable plant remains" in the mouth. It is possible that dicotyledons will be more identifiable than grass leaf. Also low-fibre grass leaf may be chewed rapidly in comparison to high-fibre grass species. Thus grass stem and high-fibre species such as *Aristida* may remain in the mouth and remain recognizable for longer periods than low-fibre species. This would increase their chance of being recorded in the mouths of shot kangaroos relative to low-fibre grass leaf.

A short term study of the diet of the eastern grey kangaroo in a sown pasture paddock on Lana using mouth contents analysis found *Imperata cylindrica* to be selected (Eltringham, 1974). *Imperata* is a high-fibre species which the present study has shown to be avoided by the grey kangaroo. In Eltringham's study mouth contents analysis also appears to be overestimating use of high-fibre species.

When the diet of males and females were compared the effects of differential selection and differential habitat use could not be separated. On Newholme when differences existed they were probably due to differences in the relative proportions of the sexes sampled in sheep camps. On Lana differences were probably related to the proportion of sexes shot in areas of abundant *Poa* tussocks. Although wallaroo sex and age classes were shown not to differ in their habitat usage during feeding period (see Chapter 9), it is possible that differences exist in their usage of pasture within habitats. It is not possible to say conclusively whether males and females did prefer different pasture types or whether the abundance of one sex shot in dense *Poa* tussock stands was due to sampling variation. A much larger sample would be needed before any conclusions could be reached on differences in dietary selectivity between the sexes. It is possible on theoretical grounds that differences between sex and age classes could occur. Adult males are larger than adult females and their metabolic rate will be lower than adult females. Since the abundance of good quality food is reduced in winter, females may need to keep feeding on higher quality food to satisfy their requirements whereas males can utilize the more abundant lower quality food. Lactation in females will also increase their energy demands in relation to males. Wallaroo males probably also fight less in winter (Osazuwa, 1978), thus reducing their requirements at this time in comparison to other seasons.

Newsome (1980) has shown small differences to exist between the diet of male and female red kangaroo in certain seasons. However Johnson (1979) and Jarman and Denny (1977) have both shown that differences occur in the habitat use of different sex and reproductive classes in red kangaroos. It is thus possible that differences in where the sexes were feeding rather than differences in selectivity could account for Newsome's result, especially since the differences were so minor.

Differences in pasture use within areas has not been previously taken into account in dietary studies of macropods. For example, Bailey *et al.* (1971) studied red kangaroo diets in sandhill habitat. Denny (1979) has found that differences exist in the density of red kangaroos in interdune and dune areas. Thus in Bailey's study the extent to which the selection for plant species is due to selection of plants per se or to selection of feeding areas is uncertain.

Most of the studies on dietary selection of kangaroos, although only examining selection of grasses as a whole, have still found selection for these. In the present study where grasses were divided into categories based on different parts of the grass plant and different species of different quality it was shown that only good quality grass leaf is consistently selected. The proportion of grass leaf of good quality in the diet of the grey kangaroo and wallaroo is greatest during summer when it is most abundant in the pasture. As good quality grass leaf becomes scarcer during the colder months of the year, the kangaroos intake of the more abundant lower quality grasses increases. On Lana, an area with improved pasture, both species can maintain a higher intake of good quality grass leaf during all seasons, but especially during winter, compared to Newholme, an area with a higher proportion of low quality grasses. Studies on the diet of sympatric macropod species, although not examining plant part use, have found differences between species based on differences in the plant species eaten. Use of plant parts was examined in this study but no difference in the use of these was found between the two kangaroos. Although the grey kangaroo and wallaroo had many plant species and plant parts common to their diets there were major differences in the proportions of a few plant species in the diet of each kangaroo on both study areas.