CHAPTER 5

HABITAT USE

5.1 Introduction

Habitat use by the grey kangaroo and wallaroo was investigated at different times of day for the twelve months of the year on Lana and Newholme. The occurrence of kangaroos was quantified in relation to various factors thought to be of ecological importance. The habitat types recognized on each study area together with their distinguishing features have been described in Chapter 2.

5.1.1 Factors influencing habitat use by kangaroos

Kangaroos have a crepuscular activity pattern (Kaufmann, 1974a; Coulson, 1978; Osazuwa, 1978). From late afternoon to an hour or two after dawn, kangaroos spend the majority of their time feeding. After this feeding period kangaroos move from preferred feeding areas to areas preferred for sheltering (Kaufmann, 1974a; Osazuwa, 1978; pers. obs.). During the shelting period animals move around less and are found lying down or resting in a crouched or semi-erect position more. Little feeding occurs during these sheltering periods (Kaufmann, 1974a; pers. obs.). Thus the influence of environmental factors on the distribution of kangaroos may change depending on whether kangaroos are feeding or sheltering.

Red kangaroo can move long distances in search of food (Bailey, 1971). Habitat use studies on the red kangaroo (e.g., Frith, 1964; Newsome, 1965a,b; Bailey, 1971) have been broad-scale surveys designed to assess the influence of food and shelter on distribution. Emphasis has been placed on comparing the distribution of red kangaroo during favourable and unfavourable (e.g. drought) conditions. These studies have shown that the number of red kangaroo in an area depends on the availability of green herbage and shelter. Kangaroos do not move far into areas without shelter even if food is abundant. In areas where shelter is present the distribution of kangaroos is determined by the abundance of short green grass. Extensive movements may occur in response to the changing distribution of green herbage. During drought, when green grass is scarce, red kangaroo probably need to stay within reach of water (Newsome, 1975), thus limiting their use of habitat isolated from water supplies. A recent study by Johnson (1979) has indicated that differences in habitat use may exist between red kangaroo sex and age classes. He found that females with young-at-foot or large pouch young were found more often in areas with the greenest pasture than were other females. The distribution of large adult males was similar to the pattern found for females with large pouch young or young-at-foot.

Euros usually occur in association with rocky outcrops and ranges. These areas provide important heat refuges. Russell (1969) studied the relationship between the use of different types of shelter by euros and air temperature. She found that at high temperatures more animals were found in shelters among rocky outcrops, which provided almost complete protection from solar radiation, than among tree-shrub shelters, which did not afford the same degree of protection. The increased availability of water since the advent of European man is thought to have reduced the euro's dependance on rocky heat refuges and allowed them to disperse into areas where adequate drought fodder is available (Newsome, 1975). During periods of adequate rain many euros disperse outwards from heat refuges but return as the country dries out (Ealey, 1967b).

The range of the euro overlaps extensively with that of the red kangaroo, however the habitats utilized for feeding are usually quite different. Thus, both Storr (1968) and Ealey (1962) found that red kangaroo preferred "soft country" where herbs and grasses predominate whereas euros confined themselves to areas where spinifex (*Triodia* spp.) is dominant.

Frith and Calaby (1969) stated that where the distribution of red and grey kangaroo overlap these two species occupy essentially different habitats and that these are determined on the basis of availability of food. They found that red kangaroo were most numerous in more open vegetation whereas grey kangaroo were most numerous in denser vegetation. Caughley (1964a) has studied the habitat preferences of the red and grey kangaroo in an area of sympatry in south-west Queensland. He found that the density of grey kangaroo , but not red kangaroo , was correlated with the density of vegetation. Eastern grey kangaroo and western grey kangaroo also appear to have differences in habitat preferences in areas of sympatry (Kirsch and Poole, 1972; Coulson, 1978).

The density and height of undergrowth and the abundance of food have been shown to be important in influencing the distribution of feeding eastern grey kangaroo (Taylor, 1980). In coastal lowland habitat of south-east Queensland it was found that grey kangaroo only utilized habitats with open undergrowth for feeding and in these habitats the density of kangaroos was correlated with the abundance of food present.

Since, in the present study areas, both grey kangaroo and wallaroo are sedentary and occupy limited home ranges (see sections 9.1 and 9.2), large scale movements in response to changing seasonal conditions will probably not occur. It is likely that kangaroos will respond to changes in environmental conditions by altering their distribution within their home range area. Since both kangaroos changed their activity pattern over the period of a day, it was necessary to measure habitat use during periods when they were feeding as well as periodswhen they were sheltering. Kangaroos might well react differently to the same environmental factors during feeding and sheltering periods. For example, the distribution of food would probably be less important in determining habitat use during sheltering periods than during feeding periods. Kangaroo distribution was examined in relation to tree cover, shrub density, size and density of rocks, slope and abundance of food. These factors were chosen (on the basis of what was known of the ecology of the two species and the findings from studies on other kangaroo species) as being the most likely to influence distribution on the two study areas.

5.2 Methods

To quantify the habitat preferences of the grey kangaroo and wallaroo, fixed transects to be walked were set out on Lana and Newholme. Transects were placed so as to sample all habitats present on the study areas. Habitats which occupied only a small area but which received a high usage from either species were oversampled on the basis of area present. On Lana savanna woodland away from rocky hills was not originally included on the transects. Subsequently an additional transect was added which sampled this habitat. The results for this transect are presented separately. Four transects were sampled on Lana (with an additional transect later added) and five on Newholme. Each transect was normally walked four times during each monthly sample; once during early morning (within one and a half hours of dawn), twice during the day (between 10-12 a.m. and between 12-3 p.m.) and once during late afternoon (within one and a half hours of dusk). For one month in every three, the day transects were not walked as faecal pellet counts were carried out during this time.

Results from these counts were not analysed as I was not confident about species recognition of pellets and because the relationship between the pattern of activity of a kangaroo and the dropping of faecal pellets was not known. The transects were done at various times when it was expected that kangaroos would be actively feeding (early morning and late afternoon) and when sheltering (day transects). The length of transects was limited by the time that kangaroos stayed actively feeding during early morning and late afternoon. Transects were sampled in October and November 1976 and January to September and December, 1977. The additional transect on Lana was sampled in October, November and December, 1977 and Freburary, May and July, 1978. Because of mechanical problems with the motor bike used to get to the transects, in October on Lana one early morning transect was substituted for a late afternoon transect and on Newholme one early morning transect was not walked.

Many studies have shown that the probability of sighting an animal decreases as the distance from the observer increases. For this reason reviewers of the methods used for direct estimation of animal density have recommended that curves relating the frequency of sighting of animals to their perpendicular distance from the transect line be used to estimate density (e.g. Eberhardt, 1968; Robinette, 1974). However in the present study it was thought that the construction of probability of sighting curves would not be feasible for the following reasons:

(1) The transects sampled rough terrain which does not lend itself to straight-line transects that are desirable for accurate measurements of perpendicular distances.

(2) It was not feasible to place transects so that the same habitat was sampled on both sides of the transect and for the whole distance to which kangaroos were visible. Some parts of the transects had different habitats on each side. In other places the habitat changed along the line of viewing.

(3) Visibility profiles would not have been uniform throughout a habitat. In rocky slope habitat, for example, visibility could be reduced to 10 metres in some places because of the presence of a large rock whereas in other parts visibility could be over 50 metres.

(4) Large samples are required to estimate the probability of sighting curves for each habitat. Too few animals were

seen in some habitats to allow the calculation of sighting curves.

(5) Fog decreased visibility on some winter mornings. The number of sightings on one transect would not be enough to calculate probability of sighting curves for just one foggy morning.

The method used in the present study to estimate density was similar to that used by Lamprey (1964). Visibility profiles of each transect were constructed. Distances to which it was thought that all kangaroos present could be seen were measured along the length of the transects. Distances from the transect were measured each time the visibility changed rather than at fixed intervals (cf. Lamprey, 1964). Distances were measured with a calibrated range finder. The area of each habitat type present on the transects was calculated from the distances measured. When transects were walked in fog the changes in visibility were noted and the areas of habitats seen changed accordingly.

Most profile distances used were well within the maximal sighting-probability plateau for large mammals in savanna habitats. There were no significant changes in vegetation density between seasons and hence the same profile distances could be used all year (except when fog was present). The lengths of the transects were: on Lana; 3.4 km, 3.5 km, 3.5 km, 2.8 km and 3.2 km; on Newholme; 4.1 km, 3.0 km, 1.9 km, 2.7 km, and 2.4 km.

5.3 Results

The area of each habitat as a proportion of the total study area and as a proportion of the area sampled on transects is given in Table 5.1 for Lana and Newholme. Habitats occupying the greatest areas were sampled the most. However important feeding or sheltering areas such as sheep-affected pasture, *Microlaena* pasture and dense rock slope were purposely oversampled in relation to their area present on the study areas. Approximately 22% of the Lana study area and 17% of the Newholme study area were sampled.

The density of kangaroos on Lana and Newholme is given in Table 5.2. The density figures are estimates from transect counts. The density figures for wallaroo are averages for all late afternoon transects. The densities for grey kangaroo are averages for all early morning and late afternoon transects. These times were used to calculate an estimate of density because kangaroos were most likely to be feeding and in

Table 5.1 Comparison of the proportional area of each habitat on Lana and Newholme and on the transects. Area of habitats on the study areas were estimated from aerial photographs. No allowance was made for the effects of slope on the estimates of area from aerial photographs.

(A) LANA

Habitat		Proportional area on study area (%)	Proportional area on transects (%)
Savanna woodland	(SAV)	59.99	48.51
Dense woodland	(DW)	8.07	7.31
Imperata woodland	(IW)	5.36	0
Large boulder slope	(LBS)	4.12	4.48
Rocky slope	(RS)	8.49	10.46
Small dense rock slope (top)	(SDRt)	0.20	0.57
Small dense rock slope (base)	(SDRb)	0.11	0.80
Dense medium rock slope	(DMR)	0.74	0.69
Low-sight-distance slope	(LSD)	2.36	2.31
Gentle slope	(GS)	7.44	15.84
Sheep-affected pasture	(SAP)	3.12	9.03
TOTAL AREA	(ha)	≃995	225.1

(B) NEWHOLME

Habitat		Proportional area on study area (%)	Proportional area on transects (%)
Microlaena pasture	(MP)	1.02	3.16
Eragrostis grassland	(EG)	3.50	1.68
Poa-Pennisetum grassland	(PPG)	9.80	5.41
Poa sieberana slope	(PS)	30.11	27.09
Poa costiniana slope	(PC)	7.16	5.87
Poa labillardieri slope	(PL)	3.53	2.12
Grassy slope	(GrS)	5.31	6.51
Cymbopogon slope	(CS)	2.34	4.03
Shrub slope	(ShS)	1.23	2.85
Savanna slope	(SvS)	8.19	6.40
Dense rock slope	(DRS)	0.61	3.48
Poa grassy woodland	(PGW)	11.57	19.99
Acacia woodland	(AcW)	8.40	6.80
Poa forest	(PF)	6.70	2.99
Poa forest with *Acacia*	(PFAc)	1.25	1.62
TOTAL AREA	(ha)	≃970	170.1

open areas at these times (see sections 5.3.1 and 5.3.2). Because large areas sampled on the transects were not suitable for use by grey kangaroo , only areas utilized by this species were included for the density estimates. The density of wallaroo is 7.4 times higher on Lana than on Newholme.

Table 5.2 The density (number/hectare) of grey kangaroo and wallaroo in their occupied habitats on Lana and Newholme. Values are means ± standard error of monthly estimates.

	Lana	Newholme
Wallaroo	0.545±0.039	0.075±0.014
Grey kangaroo	0.307±0.012*	0.145±0.012

* population regularly culled

The density of grey kangaroo is 2.1 times higher on Lana than on Newholme. However grey kangaroo were regularly culled on Lana but not on Newholme. Hence the differences in the potential carrying capacity of the two properties would probably be greater than the differences in density suggest.

5.3.1 Habitat use by kangaroos on Lana

(a) Grey kangaroo

The average density of grey kangaroo in each habitat on Lana during early morning and late afternoon is shown in Fig. 5.1. When the density in each habitat was compared between early morning and late afternoon only savanna woodland had a significantly greater density during late afternoon ($p < 0.01$). However an analysis of variance showed no significant difference between the pattern of habitat use during early morning and late afternoon (i.e. habitat × time interaction was non-significant). The results for early morning and late afternoon were therefore grouped when examining grey kangaroo habitat preferences for feeding. Table 5.3 shows the average density of grey kangaroo in each habitat on Lana during feeding periods (i.e. early morning and late afternoon). The highest density of grey kangaroo occurs in savanna woodland. The density of grey kangaroo in sheep-affected pasture is not significantly different from the density in savanna woodland. Large boulder slope, low-sight-distance slope and dense rock slope habitats are used very little if at all. Grey kangaroo thus utilize the woodlands and gentle slopes and tend to avoid the steeper rocky slopes.

A comparison of the density of grey kangaroo within habitats

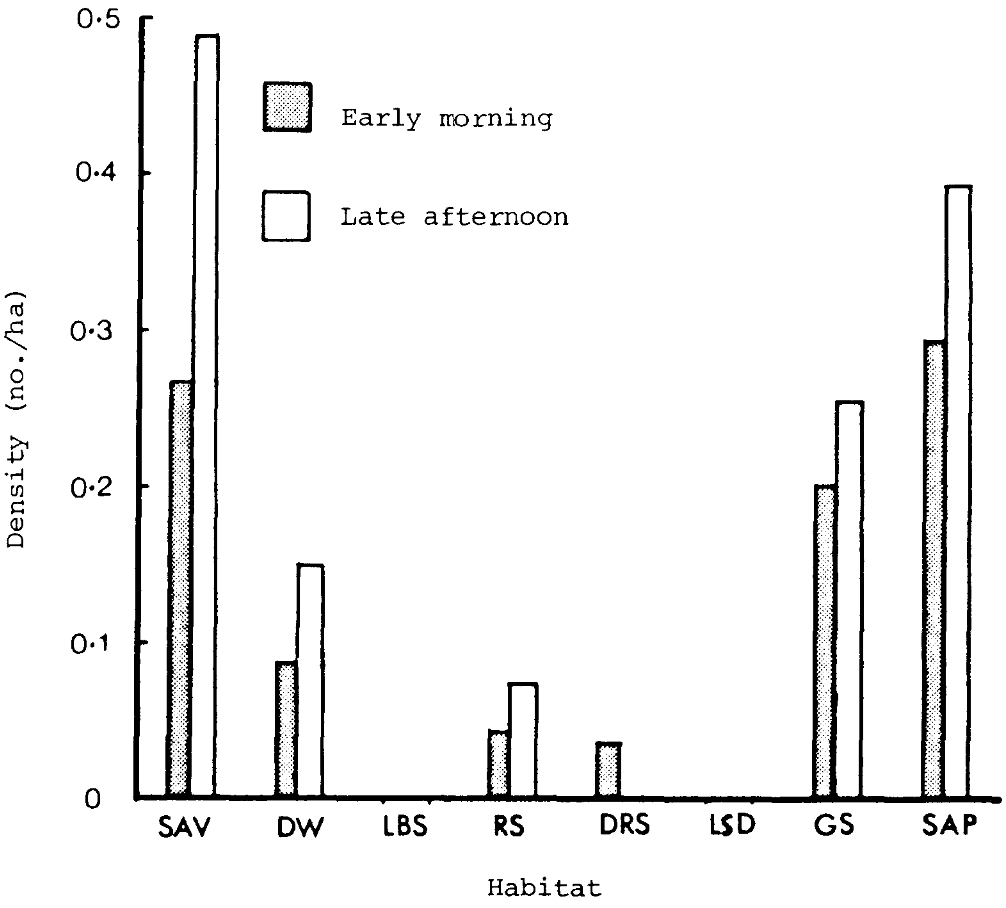

Fig. 5.1. Comparison of the density of grey kangaroo in each habitat on Lana during early morning and late afternoon.

Table 5.3 Average density (no./ha) of grey kangaroo in each habitat on Lana during feeding periods. Density values are means ± standard error.

Habitat	Density
Savanna woodland	0.380 ± 0.020
Dense woodland	0.120 ± 0.031
Large boulder slope	0 ± 0
Rocky slope	0.058 ± 0.015
Dense rock slope	0.018 ± 0.012
Low-sight-distance slope	0 ± 0
Gentle slope	0.229 ± 0.030
Sheep-affected pasture	0.338 ± 0.076

during feeding periods is given in Table 5.4. In savanna woodland, sown pasture areas receive a significantly higher usage than native pastures. Non-rocky areas in savanna woodland and dense woodland receive greater usage than rocky areas. Grey kangaroo do not discriminate between gentle slope areas on the basis of the presence of adjoining steeper slope.

Table 5.4 The density of grey kangaroo in each subhabitat on Lana during feeding periods and the significance of the differences between subhabitat usage. Density values are means ± standard error.

Habitat	Subhabitat	Density (number/ha)	Comparison of subhabitat use
Savanna Woodland	1. Rocky areas	0.086±0.042	1 *** 2
	2. Non-rocky areas (normal pasture)	0.370±0.025	2 * 3
	3. Sown pasture areas	0.790±0.180	
Dense Woodland	1. Rocky areas	0.041±0.033	1 * 2
	2. Non-rocky areas	0.150±0.042	
Gentle Slope	1. Steeper slope or shrubs above	0.253±0.049	1 NS 2
	2. No steeper slope or shrubs above	0.209±0.044	
Sheep-affected Pasture	1. in woodland, *Microlaena*-dominated pasture	0.592±0.252	1 NS 2
	2. in woodland, other grass spp. pasture	0.456±0.093	1 ** 3
	3. in woodland, forb-dominated pasture	0.109±0.073	2 ** 3
	4. on slope, *Microlaena*-dominated pasture	0.039±0.039	4 * 5 1 * 4
	5. on slope, other grass spp. pasture	0.158±0.158	2 NS 5

NS = not significantly different
* = $p < 0.05$
** = $p < 0.01$
*** = $0 < 0.001$

For sheep-affected pasture, areas with the same pasture type present are used to a greater extent if in woodland than if on slope. In woodland areas different grass-dominated pasture types do not differ significantly in their usage but these areas are used significantly more than forb-dominated pasture. On slope areas *Microlaena*-dominated pasture is used significantly less than pasture dominated by other grass species.

The average density of grey kangaroo in each habitat on Lana during feeding and sheltering periods is shown in Fig. 5.2. The average density for savanna woodland and sheep-affected pasture is significantly less ($p < 0.001$ and $p < 0.01$ respectively) during sheltering periods. The

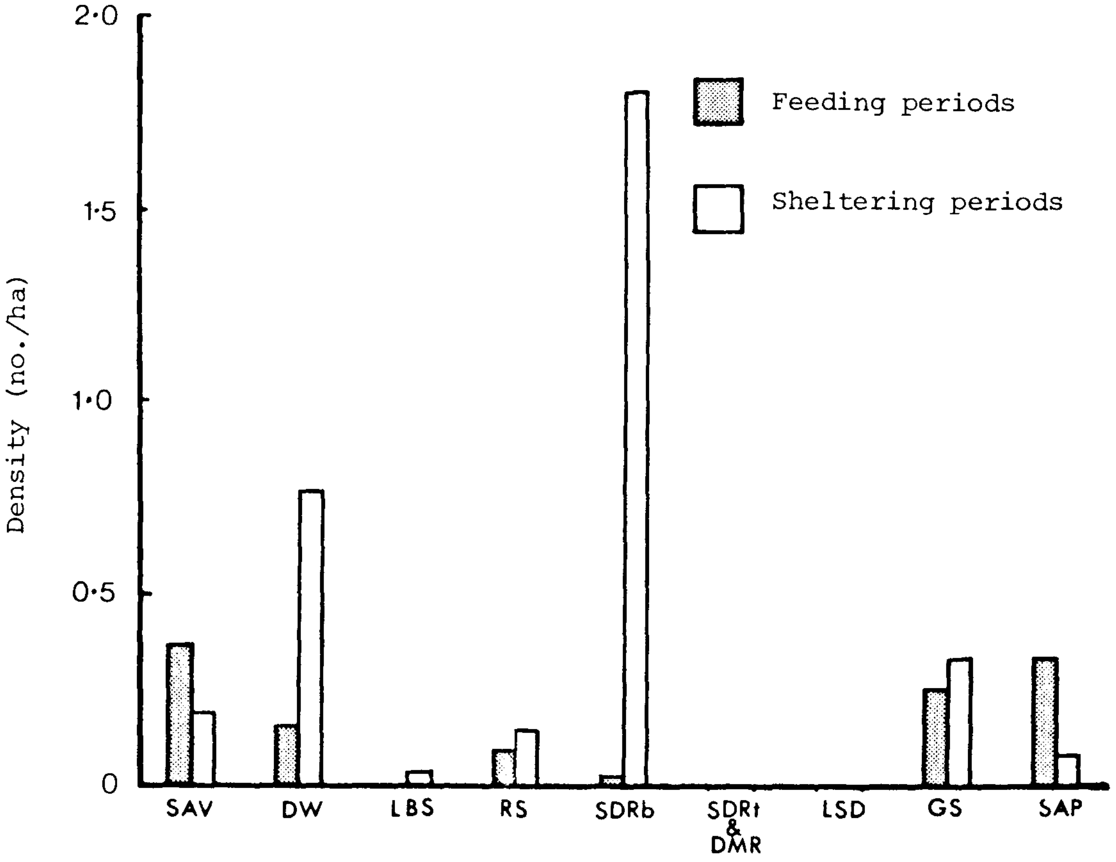

Fig. 5.2. Comparison of the density of grey kangaroo in each habitat on Lana during feeding and sheltering periods.

Table 5.5 Average density (no./ha) of grey kangaroo in each habitat on Lana during sheltering periods. Density values are means ± standard error.

Habitat	Density
Savanna woodland	0.170 ± 0.025
Dense woodland	0.945 ± 0.225
Large boulder slope	0.043 ± 0.029
Rocky slope	0.162 ± 0.037
Small dense rock slope at base of hills	1.810 ± 0.569
Dense rock slope at top of hills (SDRt + DMR)	0 ± 0
Low-sight-distance slope	0.072 ± 0.072
Gentle slope	0.335 ± 0.046

density for small dense rock slope at the base of hills and dense woodland is significantly greater during sheltering periods than during feeding periods ($p < 0.05$ and $p < 0.01$ respectively). Other habitats have similar densities during the two periods. An analysis of variance showed that the pattern of habitat use by grey kangaroo on Lana was significantly different between feeding and sheltering periods ($F(1,8) = 9.6$, $p < 0.001$). Only months in which both feeding and sheltering use were determined were used in the comparison of these periods.

As little feeding takes place during the day, it was expected that differences in pasture composition would not be very important in influencing kangaroo distribution at these times. Areas of sheep-affected pasture were thus classified according to their slope, rock and tree density and each area placed into its appropriate structural habitat type. For example, sheep-affected pasture in gentle slope was placed into the gentle slope habitat.

The density of grey kangaroo in each habitat during sheltering periods is shown in Table 5.5. Dense woodland and small dense rock slope at the base of hills (SDRb) received the greatest use of all habitats during sheltering periods. The grey kangaroo seen in large boulder slope were on the very bottom of this slope next to dense woodland. The grey kangaroo in large boulder slope were moving through this habitat when seen and were not resting here. Thus with the exception of SDRb there appears to be a minor increase in the use of steeper slopes during sheltering periods. Since SDRb makes up a very small percentage of the study area, the major shift in numbers of grey kangaroo in sheltering periods compared to feeding periods is from savanna woodland to dense woodland.

A comparison of the density of grey kangaroo within habitats during sheltering periods is given in Table 5.6. Grey kangaroo utilize non-rocky areas significantly more than rocky areas in dense woodland but use both these areas to the same extent in savanna woodland. Gentle slope areas with and without adjoining steeper slopes are utilized by grey kangaroo to the same extent.

Thus at all times grey kangaroo avoid steep slope areas and prefer woodland areas without rock to those with abundant rock. The presence of adjacent rocky hills does not influence the grey kangaroo's use of a habitat. During feeding periods grey kangaroo are most abundant in savanna woodland especially in areas of sown pasture whereas dense woodland is the preferred sheltering habitat.

Table 5.6 The density of grey kangaroo in each subhabitat on Lana during sheltering periods and the significance of the differences between subhabitat usage. Density values are means ± standard error.

Habitat	Subhabitat	Density (number/ha)	Comparison of subhabitat use
Savanna Woodland	1. Rocky areas	0.257±0.108	1 NS 2
	2. Non-rocky areas (normal and sown pasture)	0.165±0.027	
Dense Woodland	1. Rocky areas	0.113±0.044	1 ** 2
	2. Non-rocky areas	1.351±0.322	
Gentle Slope	1. Steeper slope or shrubs above	0.432±0.091	1 NS 2
	2. No steeper slope or shrubs above	0.259±0.067	

NS = not significantly different
* = $p < 0.05$
** = $p < 0.01$

(b) Wallaroo

The average density of wallaroo in each habitat on Lana during early morning and late afternoon is shown in Fig. 5.3. The density of wallaroo is greater during early morning in rocky slope ($p < 0.05$) and less during early morning for savanna woodland ($p < 0.01$), large boulder slope ($p < 0.05$) and sheep-affected pasture ($p < 0.05$). It is not significantly different between the two periods for other habitats. An analysis of variance showed that the pattern of use of habitats was significantly different between early morning and late afternoon ($F(1,7) = 4.5$, $p < 0.001$). In a study of wallaroo in an area near the present study areas, Osazuwa (1978) found that a greater proportion of time is spent feeding during late afternoon compared with early morning. Savanna woodland and sheep-affected pasture were utilized to a greater extent during late afternoon. These habitats contained the greatest quality and quantity of grass species favoured as food by the wallaroo (see Chapters 3 and 4). Hence it was assumed that the pattern of habitat use shown by wallaroo during late afternoon best reflected the preferences of wallaroo for feeding habitat.

The average density of wallaroo in each habitat on Lana for late afternoon periods is shown in Table 5.7. The highest density of wallaroo was found in sheep-affected pasture. It is considered that the density of wallaroo in gentle slope, dense rock slope and large boulder slope overestimates the value of these habitats as feeding areas and that the density of wallaroo in savanna woodland underestimates this

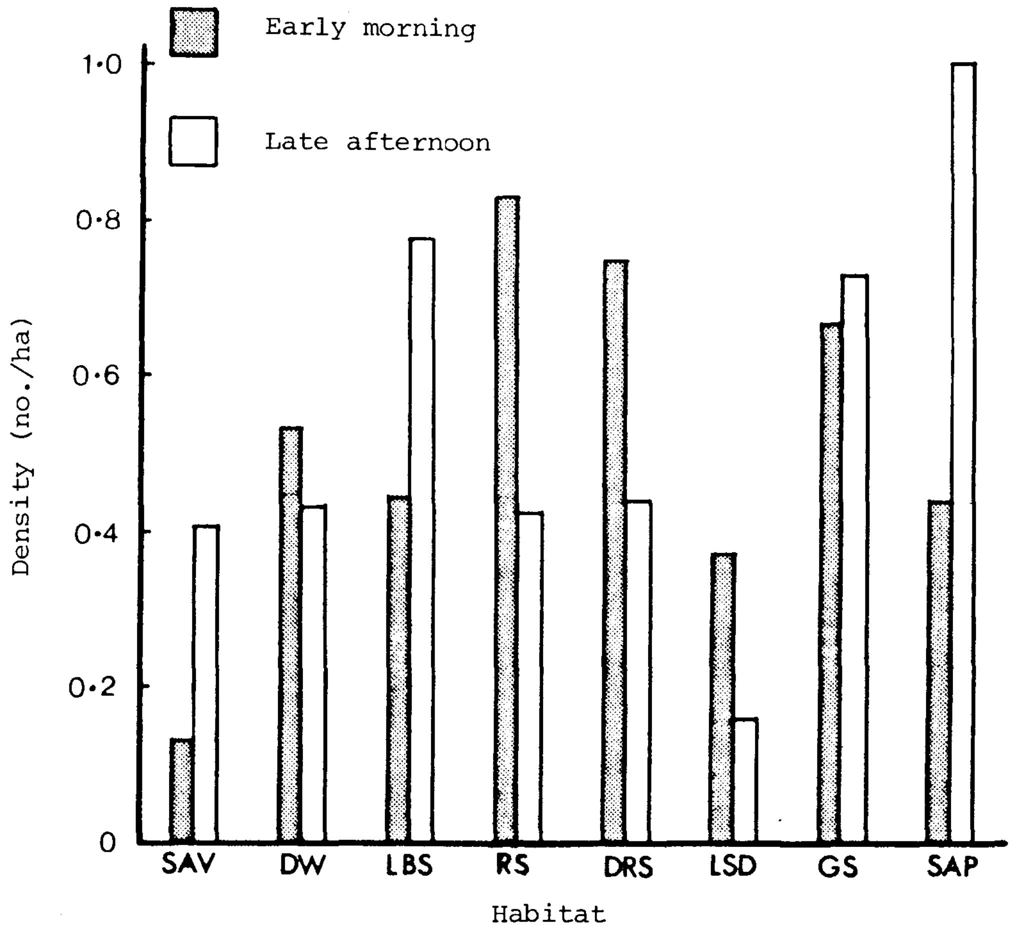

Fig. 5.3. Comparison of the density of wallaroo in each habitat on Lana during early morning and late afternoon.

Table 5.7 Average density (no./ha) of wallaroo in each habitat on Lana during late afternoon periods (= feeding periods). Density values are means ± standard error.

Habitat	Density
Savanna woodland	0.404 ± 0.059
Dense woodland	0.430 ± 0.096
Large boulder slope	0.780 ± 0.099
Rocky slope	0.426 ± 0.099
Dense rock slope	0.440 ± 0.171
Low-sight-distance slope	0.160 ± 0.097
Gentle slope	0.736 ± 0.074
Sheep-affected pasture	1.070 ± 0.196

habitat's value as a feeding area. There are few palatable grasses in large boulder slope and wallaroo were never observed feeding here. A number of the wallaroo seen in large boulder slope may have fled up into this habitat as I approached. When disturbed near this habitat wallaroo tended to funnel up into natural pathways between large boulders on large boulder slope. A few of these pathways were used on a transect to enter and leave this habitat. Hence some of the wallaroo seen here may have fled up into this habitat from surrounding areas. Also some individuals may have been present in this habitat because they had not yet moved into feeding areas. Wallaroo had a tendency to congregate in gentle slope, near where it joined savanna woodland, prior to entering or leaving woodland areas. Any disturbance would also cause them to flee from savanna woodland to gentle slope (or rocky slope) where they would sometimes wait before returning to savanna woodland. Dense rock slope areas were present above a few highly favoured sheep-affected pasture sites. Wallaroo also tended to congregate on the edge of these dense rock slope areas before feeding in sheep-affected pasture. For these reasons savanna woodland will be underestimated and gentle slope, dense rock slope and large boulder slope will be overestimated as feeding habitat for wallaroo. However this may emphasise the wallaroo's need for sheltering habitat to be present near feeding areas.

A comparison of the density of wallaroo within habitats during feeding periods is given in Table 5.8. Rocky areas are preferred to non-rocky areas in savanna woodland but in dense woodland these two areas receive the same usage. Sown pasture areas are favoured to native pasture areas. Wallaroo use of gentle slope with adjoining steeper slope is greater than use of gentle slope with no adjoining steeper slope. For sheep-affected pasture, both on slope and in woodland, *Microlaena*-dominated pasture is preferred to pasture dominated by other grass species. Grass-dominated pasture is preferred to forb-dominated pasture. Although the density of wallaroo in slope areas compared with woodland areas is greater for both *Microlaena*-dominated pasture and pasture dominated by other grass species, the differences are not significant.

Table 5.8 The density of wallaroo in each subhabitat on Lana during feeding periods and the significance of the differences between subhabitat usage. Density values are means ± standard error.

Habitat	Subhabitat	Density (animals/ha)	Comparison of subhabitat use
Savanna Woodland	1. Rocky areas	0.983±0.148	1 *** 2
	2. Non-rocky areas (normal pasture)	0.321±0.057	2 ** 3
	3. Sown pasture areas	1.362±0.286	
Dense Woodland	1. Rocky areas	0.432±0.109	1 NS 2
	2. Non-rocky areas	0.369±0.094	
Gentle Slope	1. steeper slope or shrubs above	0.976±0.156	1 * 2
	2. No steeper slope or shrubs above	0.513±0.085	
Sheep-affected Pasture	1. in woodland, *Microlaena*-dominated pasture	1.955±0.464	1 ** 2 1 ** 3
	2. in woodland, other grass spp. pasture	0.487±0.160	2 NS 3
	3. in woodland, forb-dominated pasture	0.289±0.172	4 * 5 1 NS 4
	4. on slope, *Microlaena*-dominated pasture	2.749±0.643	2 NS 5
	5. on slope, other grass spp. pasture	0.790±0.401	

NS = not significantly different
* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

The density of wallaroo in each habitat during feeding (= late afternoon) and sheltering periods is given in Fig. 5.4. The density of wallaroo in savanna woodland, sheep-affected pasture and gentle slope is less in sheltering periods than in feeding periods ($p < 0.001$, $p < 0.001$ and $p < 0.01$ respectively). Wallaroo density is greater in sheltering periods than in feeding periods in small dense rock slope at the top of hills, dense medium rock slope and low-sight-distance slope (all $p < 0.001$). The pattern of habitat use by wallaroo during the two periods is significantly different ($F(1,9) = 22.9$, $p < 0.001$).

The density of wallaroo in each habitat during sheltering periods is given in Table 5.9. There is a trend of decreasing density from the top of rocky hills (e.g. SDRt, DMR, LSD) down the slope and out into savanna woodland. A comparison of wallaroo density within habitats during sheltering periods is given in Table 5.10. Rocky areas are preferred to non-rocky areas in savanna woodland but in dense woodland these two areas receive the same usage. Use of gentle slope

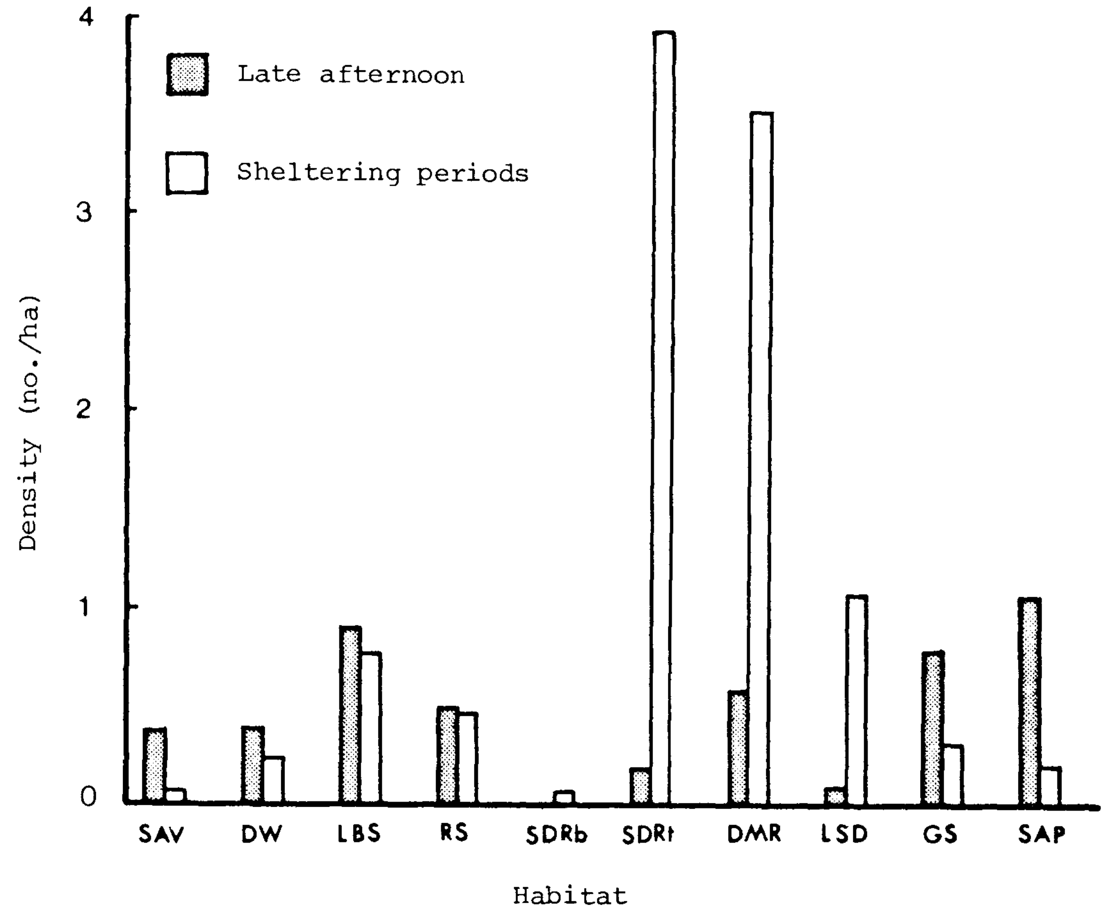

Fig. 5.4. Comparison of the density of wallaroo in each habitat on Lana during late afternoon and sheltering periods.

Table 5.9 Average density (no./ha) of wallaroo in each habitat on Lana during sheltering periods. Density values are means ± standard error.

Habitat	Density
Savanna woodland	0.065 ± 0.009
Dense woodland	0.214 ± 0.033
Large boulder slope	0.768 ± 0.120
Rocky slope	0.497 ± 0.053
Small dense rock slope at base of hills	0.070 ± 0.070
Small dense rock slope at top of hills	3.922 ± 0.807
Dense medium rock slope	3.522 ± 0.628
Low-sight-distance slope	1.070 ± 0.171
Gentle slope	0.320 ± 0.067

areas with and without adjoining steeper slopes is not significantly different.

Table 5.10 The density of wallaroo in each subhabitat on Lana during sheltering periods and the significance of the differences between subhabitat usage. Density values are means ± standard error.

Habitat	Subhabitat	Density (animals/ha)	Comparison of subhabitat use
Savanna Woodland	1. Rocky areas	0.495±0.169	1 * 2
	2. Non-rocky areas (normal and sown pasture)	0.040±0.007	
Dense Woodland	1. Rocky areas	0.338±0.088	1 NS 2
	2. Non-rocky areas	0.154±0.043	
Gentle Slope	1. Steeper slope or shrubs above	0.462±0.140	1 NS 2
	2. No steeper slope or shrubs above	0.207±0.048	

Thus, during feeding periods wallaroo are most abundant in areas with high quality pasture (i.e. sheep-affected pasture and sown pasture areas in savanna woodland). However use of areas for feeding is influenced by the presence of adjoining sheltering habitat. During sheltering periods wallaroo are most abundant around the tops of rocky hills.

(c) Comparison of habitat use by grey kangaroo and wallaroo on Lana

The pattern of habitat use for the two kangaroo species during feeding periods (i.e. for grey kangaroo during early morning and late afternoon and for wallaroo during late afternoon) is significantly different ($F(1,7) = 5.4$, $p < 0.001$) (Fig. 5.5). The density of wallaroo is not significantly different from grey kangaroo density for savanna woodland but for all other habitats wallaroo density is significantly greater than grey kangaroo density (DW, $p < 0.01$; LBS, $p < 0.001$; RS, $p < 0.01$; DRS, $p < 0.05$; GS, $p < 0.01$; SAP, $p < 0.01$). Differences also exist in the species' preferences for different subhabitats. Grey kangaroo generally prefer areas without frequent rock whereas the opposite is true for wallaroo . Wallaroo prefer gentle slope with adjoining steeper slope whereas grey kangaroo utilize both subhabitats to the same extent. Wallaroo have a higher usage of *Microlaena* pasture than other-grass-species pasture in sheep-affected pasture

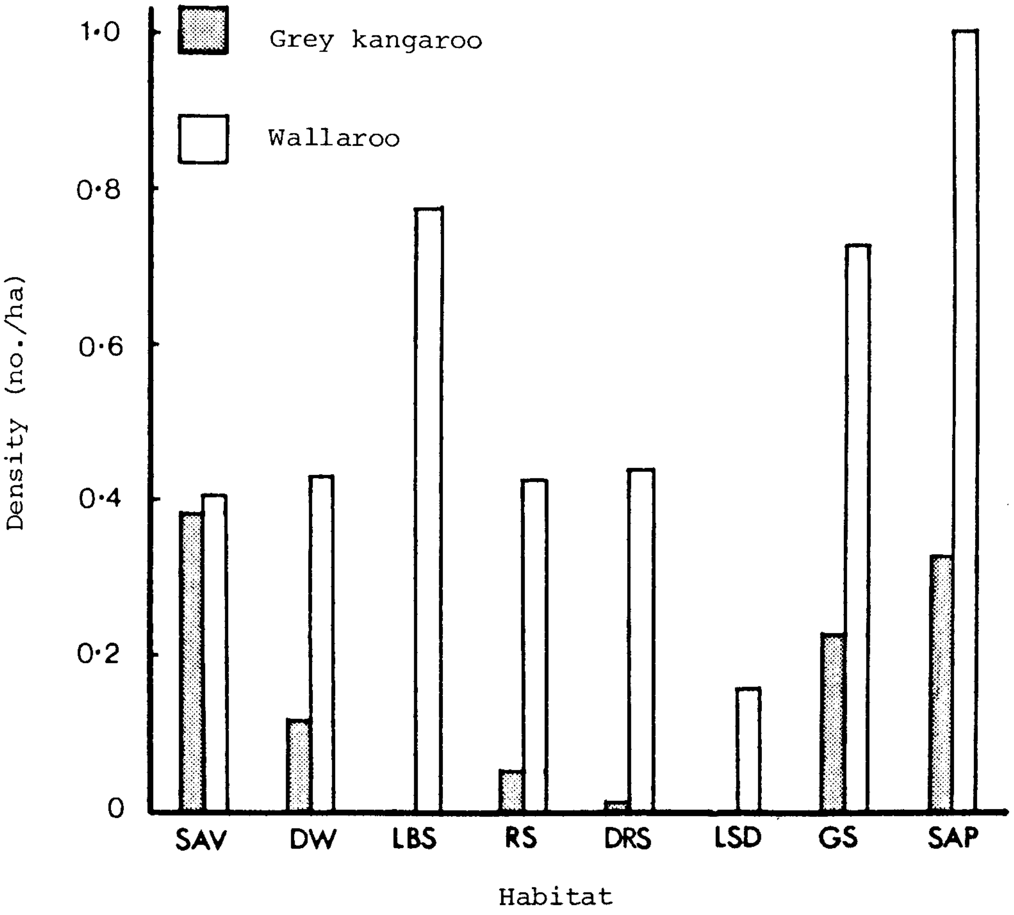

Fig. 5.5. Comparison of the density of grey kangaroo and wallaroo in each habitat on Lana during feeding periods.

Table 5.11 The percentage of the grey kangaroo and wallaroo population present in each habitat on Lana during feeding periods.

	Habitat							
	SAV	DW	LBS	RS	DRS	LSD	GS	SAP
Grey kangaroo	84.3	3.6	0	1.8	0.1	0	6.3	3.9
Wallaroo	43.2	9.9	9.1	10.3	1.3	1.1	15.6	9.5

areas whereas grey kangaroo use both of these pasture types to the same extent. Grey kangaroo make greater use of *Microlaena* pasture in woodland areas than in slope areas whereas wallaroo density is not significantly different between the two areas.

There is also a difference between the two species in the use they make of habitat which is isolated (i.e. > 200 m) from continuous rocky hills. The additional transect sampled on Lana contained a large proportion of this isolated savanna woodland. The density of grey kangaroo was 0.760 animals (a)/ha during feeding periods. No wallaroo were seen during late afternoon and they occurred at a density of 0.018 a/ha during early morning. Thus it appears that, in contrast to grey kangaroo, wallaroo do not utilize woodland unless there is suitable habitat nearby (i.e. rocky hills) into which individuals can flee if disturbed.

The density of wallaroo is similar to the density of grey kangarroo in savanna woodland sampled on the transects. However, since wallaroo utilize only a fraction of the area of this habitat utilized by the grey kangaroo, the proportions of the populations of the two species utilizing this habitat may differ markedly. To calculate the proportions of the populations of each species present in each habitat type, the density of animals was multiplied by the proportion of the area of habitat present. For the grey kangaroo the area of each habitat was the area present on the whole study area. The area of savanna woodland used by the wallaroo was taken as the proportion of the area seen on transects which was savanna woodland. This was done because savanna woodland isolated from rocky hills will not be used by wallaroo. Isolated savanna woodland was not included in the area seen on transects. The estimates of the proportion of the population of each species utilizing each habitat during feeding periods is shown in Table 5.11. It can be seen that a much higher proportion of grey kangaroo than wallaroo are found in savanna woodland.

The pattern of use of habitats during sheltering periods for the grey kangaroo and wallaroo is significantly different ($F(1,8) = 19.1$, $p < 0.001$) (Fig. 5.6). The density of grey kangaroo is significantly greater than wallaroo density in savanna woodland ($p < 0.01$), dense woodland ($p < 0.05$) and small dense rock slope at the base of hills ($p < 0.05$) and significantly less than wallaroo density in large boulder slope ($p < 0.001$), rocky slope ($p < 0.001$), small dense rock slope at the top of hills ($p < 0.001$), dense medium rock slope ($p < 0.001$) and low-sight-distance slope ($p < 0.001$) and not significantly different

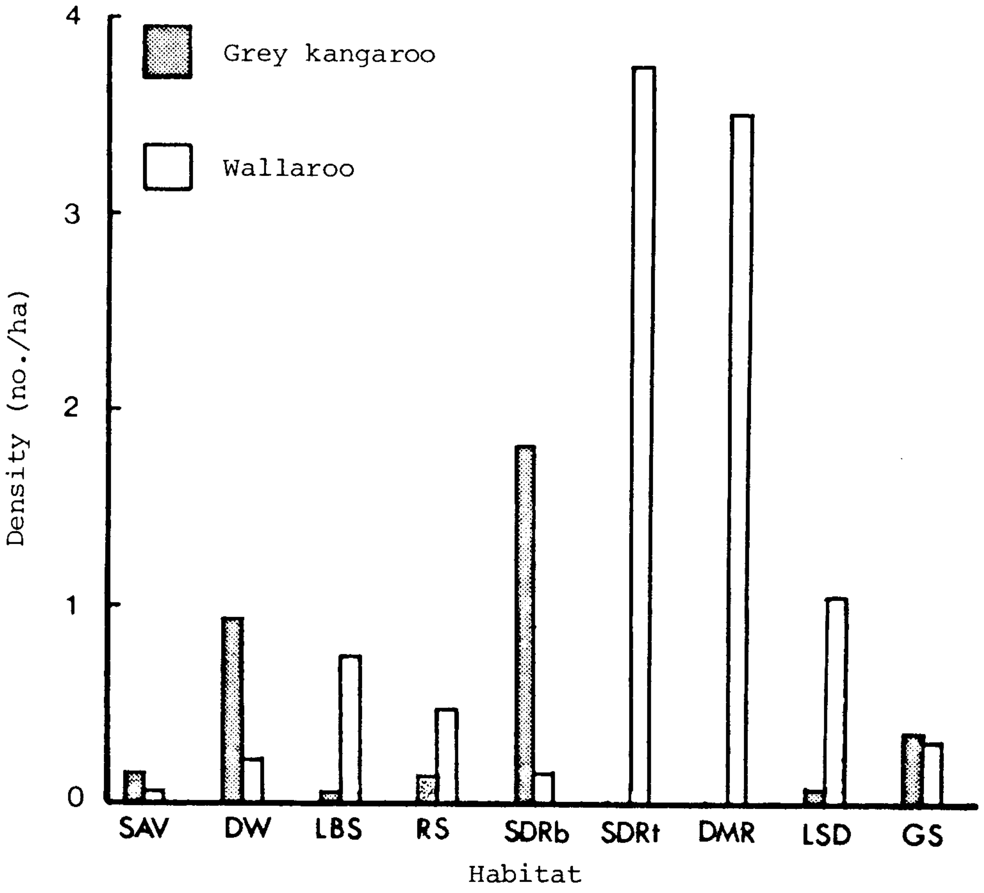

Fig. 5.6. Comparison of the density of grey kangaroo and wallaroo in each habitat on Lana during sheltering periods.

Table 5.12 The percentage of the grey kangaroo and wallaroo population present in each habitat on Lana during sheltering periods.

	Habitat								
	SAV	DW	LBS	RS	SDRb	SDRt	DMR	LSD	GS
Grey kangaroo	45.5	34.1	0.8	6.1	0.9	0	0	0.8	11.8
Wallaroo	12.3	8.7	16.0	21.3	0.1	3.8	13.1	12.7	12.0

from wallaroo density in gentle slope. Differences also exist in the species preferences for different subhabitats during sheltering periods. Thus wallaroo were found to prefer savanna woodland with frequent rock whereas grey kangaroo showed no such preference. For dense woodland grey kangaroo occurred at greater densities in non-rocky areas whereas wallaroo showed no preference between these. The proportions of the grey kangaroo and wallaroo population found in each habitat during sheltering periods is given in Table 5.12. The differences in the proportions of the population of each species found among habitat types are similar to that found with direct density comparisons.

(d) Differences in habitat use between months

The analysis of differences in the pattern of habitat use between months had to be carried out at a fairly coarse level due to the low sampling intensity for individual months. Various characteristics of each species led to difficulties in interpreting which changes in habitat use between months had ecological significance. For the grey kangaroo, for instance, the sighting of one large group, as opposed to one small group, in a habitat with a small area could be enough to change significantly the pattern of habitat use between months. Yet this difference could simply be the result of a chance sighting of a large or small group in this habitat. The wallaroo's need for sheltering habitat adjacent to feeding areas led to differences in the use of these habitats between months which simply reflected the level of disturbance or the prevailing weather conditions. For example, if the level of disturbance during feeding periods is increased more wallaroo will be seen in sheltering areas adjacent to feeding areas. The analysis of changes in habitat use between months was based on a χ^2 analysis of changes in the proportion of kangaroos seen in each habitat. The significance level for this analysis was taken as 0.01 in order to minimize the effects of differences due to low sampling intensity and species' peculiarities just mentioned.

(i) Grey kangaroo

For feeding periods large boulder slope, dense rock slope and low-sight-distance slope were not included in the analysis because of their obvious unimportance as feeding habitat (two individuals were seen in dense rock slope and none in the other two habitats). Dense woodland and rocky slope were grouped to increase frequencies for statistical analysis. The numbers of grey kangaroo seen per habitat in each month are given in Table 5.13. The overall χ^2 (χ^2 = 144,

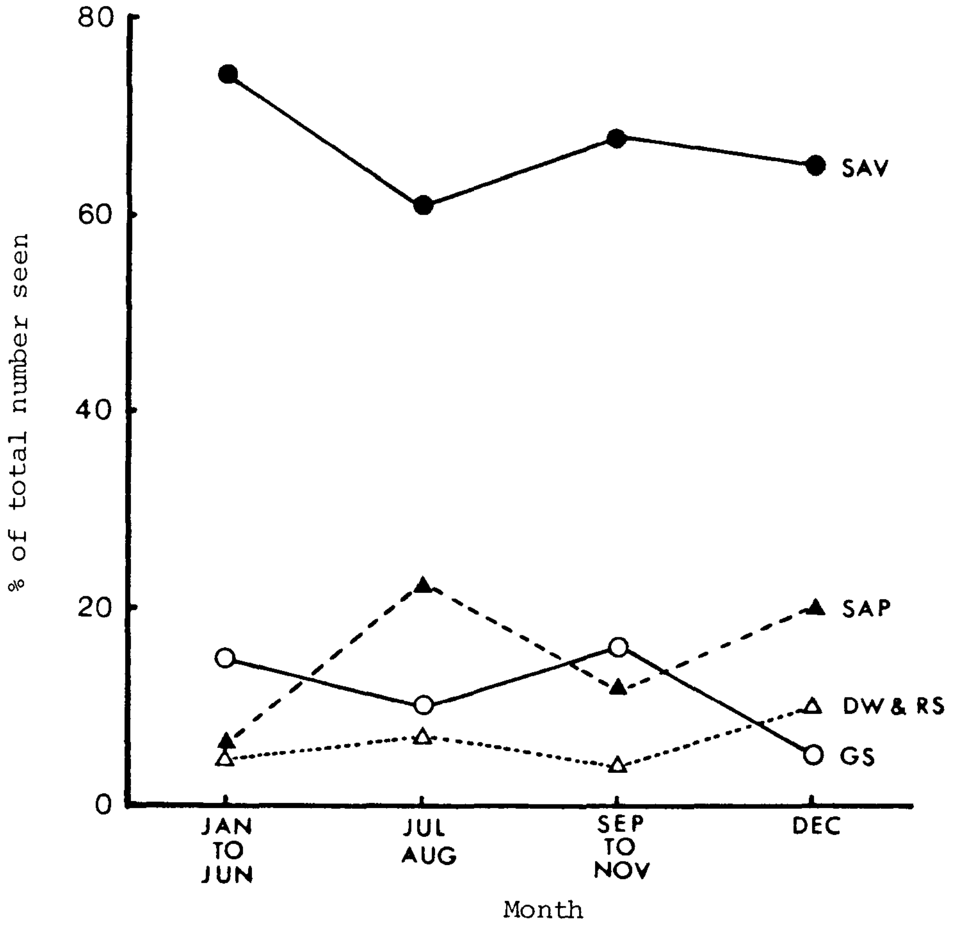

Fig. 5.7 Percentage of grey kangaroo seen in each habitat on Lana in each group of months with a similar pattern of habitat use during feeding periods.

Table 5.13 Number of grey kangaroo seen in each habitat during monthly transect counts in feeding periods on Lana. Values in brackets are the number of groups seen.

	Month											
Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Savanna woodland	83	67	86	99	68	91	59	112	63	92	104	81
Dense woodland and rocky slope	9	8	1	4	4	8	13	6	7	3	5	12
Gentle slope	24	20	19	17	10	11	17	10	31	22	9	6
Sheep-affected pasture	12 (2)	2 (1)	11 (2)	2 (1)	5 (1)	7 (1)	23 (5)	38 (9)	18 (4)	15 (5)	10 (3)	25 (5)

df = 33, $p < 0.001$) showed that differences in habitat use occurred between months.

Consecutive months were tested for homogeneity of habitat use. The proportion of grey kangaroo per habitat in each group of months with a similar pattern of habitat use is shown in Fig. 5.7. Even though differences in the use of sheep-affected pasture did occur during the months January to June, these differences were related to the size of groups seen rather than to the number of groups seen. Therefore these months were taken as having a similar pattern of habitat use. The pattern of change in use of sheep-affected pasture and dense woodland and rocky slope is similar, as is the pattern of change in use of savanna woodland and gentle slope. Although differing in pasture biomass, savanna woodland and gentle slope are probably similar in terms of seasonal changes in vegetation composition. The use of savanna woodland drops and the use of sheep-affected pasture increases in July and August compared with the period from midsummer to early winter. Use of savanna woodland increases with the spring growth flush. The increase in use of dense woodland and sheep-affected pasture again in December may be related to the death of grass stem in savanna woodland leading to "shielding" of green grass shoots from the kangaroos. In sheep-affected pasture (and dense woodland to a lesser extent) the biomass of dead stem and the dead stem to live leaf ratio are lower than in savanna woodland. The increased use of dense woodland and sheep-affected pasture in December may also be related to a lag between the death of cool season annuals and the growth of warm season annuals. A greater proportion of the grass species in sheep-affected pasture and dense woodland are perennials and hence these habitats will be less affected by pasture composition changes than savanna woodland.

For the analysis of changes in habitat use between months for the grey kangaroo during sheltering periods habitats around the top of hills (i.e. SDRt, DRM and LSD) were excluded because of their obvious unimportance as sheltering habitat (only two small groups were seen in these habitats). Sightings in large boulder slope were included with dense woodland as these kangaroos were always near the edge of dense woodland. The numbers of grey kangaroo seen per habitat in each month for sheltering periods are given in Table 5.14. An overall χ^2 analysis ($\chi^2 = 221$, df = 28, $p < 0.001$) showed that changes in habitat use occurred over the months. When each pair of consecutive months was tested for differences in the pattern of habitat use, all pairs of months were found to be significantly different. Sampling intensity was too low to cope with differences due to changes in the size of groups seen in habitat with only a small area (i.e. SDRb). Therefore non-savanna woodland habitats were grouped, and seasonal changes in the occurrence of grey kangaroo in savanna woodland were examined (Table 5.15).

Table 5.14 Number of grey kangaroo seen in each habitat during monthly transect counts in sheltering periods on Lana.

	Month							
Habitat	Jan.	Mar.	Apr.	Jun.	Jul.	Sep.	Oct.	Dec.
Savanna woodland	46	39	65	31	33	22	72	31
Dense woodland	27	49	9	5	62	12	48	50
Rocky slope	10	10	2	14	14	14	5	0
Small dense rock slope at base of hills	14	1	15	2	3	10	6	1
Gentle slope	24	13	18	31	17	44	27	26

Table 5.15 Percentage of grey kangaroo seen in savanna woodland and non-savanna woodland habitats during monthly transect counts in sheltering periods on Lana.

	Month							
Habitat	Jan.	Mar.	Apr.	Jun.	Jul.	Sep.	Oct.	Dec.
Savanna woodland	38.0	34.8	59.6	37.3	25.6	21.6	45.6	28.7
Non-savanna woodland habitats	62.0	65.2	40.4	62.7	74.4	78.4	54.4	71.3

The proportions of grey kangaroo in savanna woodland were not significantly different in December, January and March and in June, July and September. It thus appears that during the hottest months and the coldest months the greatest proportions of grey kangaroo are found in non-savanna woodland habitats. Morning frosts occurred during the months of June to September in the year when habitat use was measured. Grey kangaroo may be influenced by frosts to move into areas of greater tree cover where the effects of frost on ground temperature is less. Kangaroos may prefer the better shade present in areas of greater tree cover during the hotter months. The highest proportion of grey kangaroo in non-savanna woodland habitats occurred during the hottest month (i.e. December). The greatest proportion of grey kangaroo was found in savanna woodland during the milder months (i.e. April, October).

(ii) Wallaroo

The number of wallaroo per habitat for each month for feeding periods is given in Table 5.16. Eight individuals from dense rock slope were included in sheep-affected pasture. They were seen just above sheep-affected pasture and were probably feeding here before I disturbed them. Habitats around the top of hills (i.e. SDRt, DMR, LSD) were excluded from the analysis because of the small number of sightings in these habitats. Large boulder slope was also excluded because this habitat was thought to be unimportant as a feeding habitat (see section 5.3.lb). The difference between the pattern of habitat use in February and March was due to increased use of rocky slope and dense woodland. This was thought to be due to wallaroo sheltering from heavy rain which fell during the transect counts in March. Differences between May and June were due to changes in the proportion of wallaroo seen in savanna woodland and gentle slope. For reasons given previously (section 5.3.lb) a change in the proportion of wallaroo seen in savanna woodland and gentle slope probably does not represent an ecologically significant change in habitat use. October and September were also different due to changes in the proportion seen in savanna woodland and gentle slope. October was the first month that transects were walked and hence my disturbance of the wallaroo would probably have been greatest. When examining changes in habitat use over the months the differences noted above were excluded.

The proportion of wallaroo seen per habitat in months considered to have a similar pattern of habitat use is shown in Fig. 5.8. During months December to July use of sheep-affected pasture and savanna woodland was high. High use of gentle slope at these times was probably related to wallaroo using these areas as access points into savanna woodland. During late winter the drop in gentle slope use and the increase in savanna woodland use may result from the fact that wallaroo occur in savanna woodland at greater distances from rocky hills at this time. Hence, if disturbed, wallaroo do not have as ready access to gentle slope resulting in more wallaroo being seen in savanna woodland. There is also an increase in use of dense woodland during late winter leading to fewer wallaroo using gentle slope as an access point to savanna woodland. The increased use of dense woodland was probably related to increased use of lower quality grasses (e.g. *Danthonia racemosa*) which occur here. During early spring wallaroo increased their use of savanna woodland and lowered their use of sheep-affected pasture compared to previous months. During early spring legumes and grass infloresence are abundant and wallaroo feed extensively on these

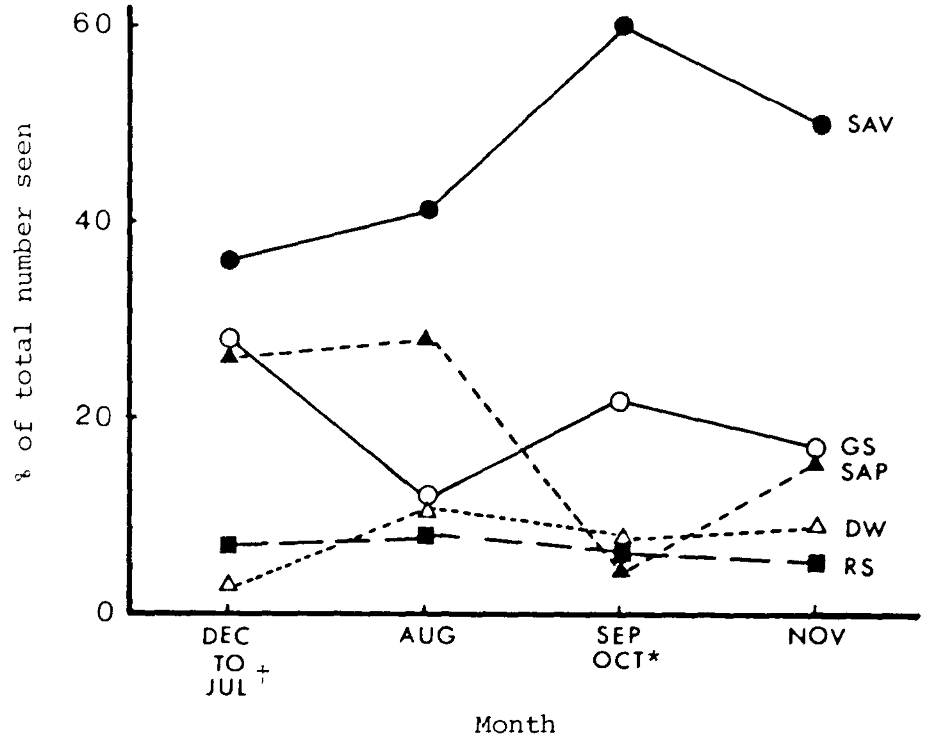

Fig. 5.8. Percentage of wallaroo seen in each habitat on Lana in each group of months with a similar pattern of habitat use during feeding periods.

÷ March and June not included in calculation of average
* October not included in calculation of average

Reasons for the exclusion of these months are given in the text.

Table 5.16 Number of wallaroo seen per habitat during monthly transect counts in feeding periods on Lana.

	Month											
Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Savanna woodland	18	32	47	25	31	56	40	66	91	28	66	48
Dense woodland	6	1	13	3	3	5	1	17	11	10	12	2
Rocky slope	4	4	34	10	5	5	9	13	10	11	7	9
Gentle slope	27	25	26	20	21	12	27	20	34	38	24	30
Sheep-affected pasture	17	17	18	26	11	31	26	45	7	3	23	45

(Chapter 4). In late spring sheep-affected pasture use increases as grass growth increases and as legumes and grass stems brown off as temperature increases. This trend continues into summer.

For the analysis of changes in habitat use during sheltering periods for the wallaroo, small dense rock slope at the base of hills was excluded because of the small number of sightings in this habitat. The number of wallaroo seen in dense rock habitats in October is very low in relation to other months. The transects were walked for the first time in October and it is possible that disturbance by me was responsible for this. Therefore October was excluded from the analysis. Dense medium rock slope, low-sight-distance slope, and small dense rock slope at the top of hills were grouped as habitats occurring around the top of hills. Rocky slope and large boulder slope were also grouped as they were similar sheltering habitat occurring in different sections of the study area. The number of wallaroo seen in each habitat per month for sheltering periods is given in Table 5.17. An overall χ^2 analysis showed that there were significant differences in habitat use over the months (χ^2=51.1, df = 24, $p < 0.001$). September, December, January and March had a similar pattern of habitat use, as did months April, June and July. The pattern of habitat use between these two groups of months is significantly different (χ^2 = 32.4, df = 4, $p < 0.001$). The proportion of wallaroo seen in each habitat during these groups of months is given in Table 5.18. A greater use of savanna woodland and gentle slope and a lower use of rocky slope and large boulder slope occurs in the colder months (i.e. April, June and July) than in the warmer months (September, December, January and March). Wallaroo probably use savanna woodland and gentle slope more during the colder months because of the greater number of sunny areas in these habitats. Many wallaroo were seen basking in the sun during cold days.

5.3.2 Habitat use by kangaroos on Newholme

Structural features of the Lana and Newholme study areas are broadly similar. Thus on both areas rocky hills were present with flat country surrounding the slopes. However on Newholme increased variability in pasture composition within areas with the same structural features led to different habitat names being applied to areas which were otherwise similar. On Lana, for example, most of the rocky hills were classified as rocky slope according to structural features because pasture composition in these areas is relatively uniform. On Newholme, however, the slopes were separated depending

Table 5.17 Number of wallaroo seen per habitat in each month during sheltering periods on Lana.

Habitat	Month Jan.	Mar.	Apr.	Jun.	Jul.	Sep.	Oct.	Dec.
Savanna woodland	11	7	20	21	27	14	11	18
Dense woodland	7	8	4	10	3	6	13	7
Large boulder slope	18	25	24	9	15	17	9	7
Rocky slope	35	25	15	18	28	28	24	39
Small dense rock slope at top of hills	7	7	12	8	21	12	0	11
Dense medium rock slope	5	11	8	10	18	17	3	15
Low-sight-distance slope	14	8	16	15	8	8	17	3
Gentle slope	10	18	21	27	36	14	52	13

Table 5.18 Percentage of wallaroo seen per habitat in months with a similar pattern of habitat use during sheltering periods on Lana.

Habitat	Months Apr., Jun. and Jul. %	Jan., Mar., Sep. and Dec. %
Savanna woodland	17	11
Dense woodland	4	6
Rocky slope and Large boulder slope	28	44
Dense rock slope and Low-sight-distance slope	30	27
Gentle slope	21	12
Total Number Seen	394	445

mainly on the species of *Poa* present and its biomass in relation to low-fibre grass species. This was done so that the role of pasture biomass and composition in determining use of a habitat could be investigated. The range of tree densities is also greater on Newholme than on Lana leading to a greater range of habitats on Newholme.

(a) Grey kangaroo

The average density of grey kangaroo in each habitat on Newholme during early morning and late afternoon is shown in Fig. 5.9. When the density of grey kangaroo in each habitat was compared between early morning and late afternoon only *Eragrostis* grassland had a significantly greater density during late afternoon (l.s.d., $p < 0.01^{\dagger}$). An analysis of variance showed no significant difference between the pattern of habitat use during early morning and late afternoon. The data for early morning and late afternoon were therefore grouped when examining grey kangaroo habitat preferences for feeding.

The density of grey kangaroo in each habitat during feeding periods on Newholme is shown in Table 5.19. The highest density occurs in grassland areas (i.e. EG and PPG). The steep slopes (i.e. PS, GrS, CS, DRS) receive little use. *Microlaena* pasture, shrub slope, *Poa* grassy woodland and *Poa* forest with *Acacia* receive intermediate use. Differences in usage within habitats also occurs. *Microlaena* pasture in *Poa* slopes and in drainage areas were never seen to be used by grey kangaroo, in contrast to *Microlaena* pasture which occurred at the top of slopes (0.292 animals (a)/ha) and in savanna slope (0.212 a/ha). For *Poa-Pennisetum* grassland, small areas on *Poa* slopes and areas at the base of steep slopes with no flat areas of woodland near were never seen to be used by grey kanagaroo . An area of *Poa-Pennisetum* grassland with suitable shelter for grey kangaroo near one end was utilized only at this end (0.077 a/ha). Small areas of *Poa-Pennisetum* grassland present in woodland were utilized (0.584 a/ha). One small area of *Poa-Pennisetum* grassland with good drainage into it and with good shelter around it received the heaviest use (0.983 a/ha). The only grey kangaroo seen in *Poa sieberana* slope during feeding periods were near the top of the slope near *Poa* forest with *Acacia*. No grey kangaroo were seen in *Poa costiniana* slope. The only grey kangaroo seen in *Poa labillardieri* slope were in an area with abundant flatish rock which formed a series of steps. At the top of this slope was a sheep camp where grey kangaroo were sometimes seen. The only grey

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[†] l.s.d. (least significant difference) is a students t-test using a pooled error variance (Steel and Torrie, 1960).

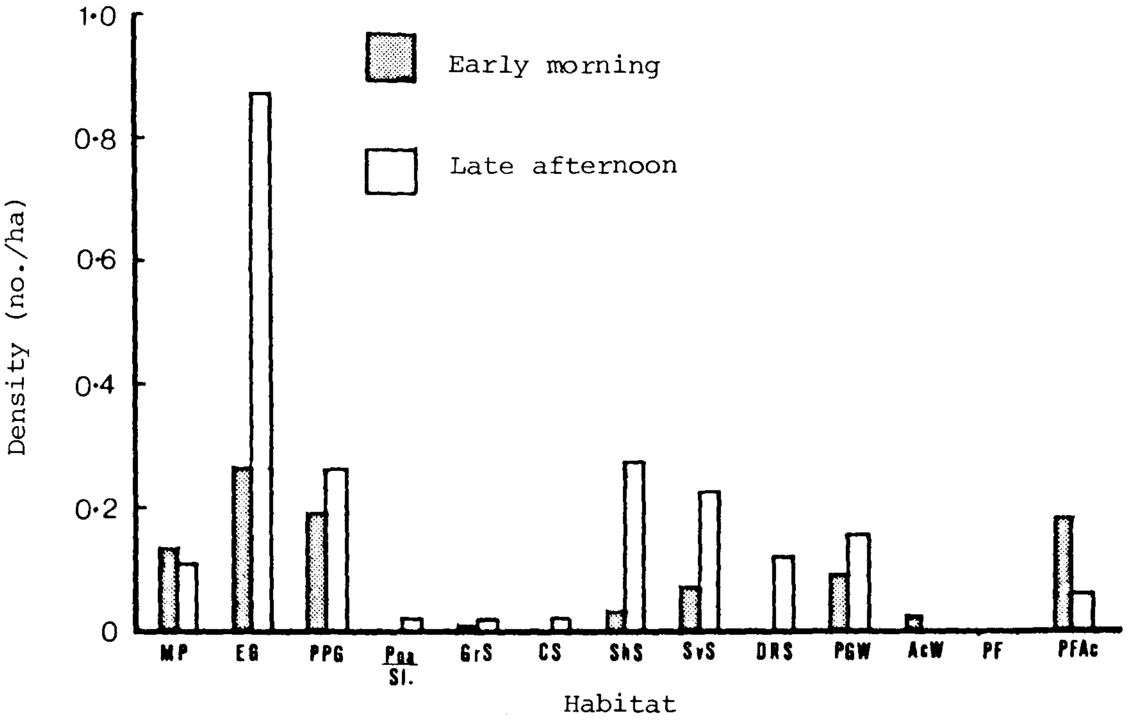

Fig. 5.9. Comparison of the density of grey kangaroo in each habitat on Newholme during early morning and late afternoon.

Table 5.19 Average density (no./ha) of grey kangaroo in each habitat on Newholme during feeding periods. Density values are means ± standard error.

Habitat		Density
Microlaena pasture	(MP)	0.124 ± 0.056
Eragrostis grassland	(EG)	0.567 ± 0.205
Poa-Pennisetum grassland	(PPG)	0.258 ± 0.064
All *Poa* slopes		0.004 ± 0.003
Grassy slope	(GrS)	0.011 ± 0.008
Cymbopogon slope	(CS)	0.012 ± 0.012
Shrub slope	(ShS)	0.155 ± 0.061
Savanna slope	(SvS)	0.150 ± 0.038
Dense rock slope	(DRS)	0.063 ± 0.035
Poa grassy woodland	(PGW)	0.126 ± 0.025
Acacia woodland	(AcW)	0.011 ± 0.011
Poa forest	(PF)	0 ± 0
Poa forest with *Acacia*	(PFAc)	0.106 ± 0.068

kangaroo seen in *Cymbopogon* slope were in a gentle sloping area with many small saplings (0.083 a/ha). This area was next to the sheep camp above the area of *Poa labillardieri* slope just mentioned and here too the grey kangaroo's presence was probably associated with the sheep camp. Grey kangaroo seen in grassy slope were always near the base of the slope. A small area of savanna slope surrounded by *Poa sieberana* slope was not used by grey kangaroo in contrast to other larger areas which adjoined woodland (0.152 a/ha). Most dense rock slope areas were present on steep slopes and were not utilized by the grey kangaroo. However one area of dense rock slope had a gentle slope and a number of small saplings and was used by grey kangaroo (0.447 a/ha). One area of *Poa* grassy woodland received more use (0.558 a/ha) than other areas (0.108 a/ha) even though this habitat was continuous around three sides of the heavily utilized section.

The pattern of habitat use by the grey kangaroo on Newholme is significantly different between feeding and sheltering periods ($F(1,10) = 3.1$, $p < 0.01$) (Fig. 5.10). The density for grassland habitats was significantly greater during feeding periods (l.s.d., $p < 0.01$). The density of grey kangaroo in shrub slope was significantly greater during sheltering periods (l.s.d., $p < 0.001$). The density of grey kangaroo in other habitats was not significantly different between the two periods.

The density of grey kangaroo in each habitat during sheltering periods on Newholme is given in Table 5.20. As for sheep-affected pasture on Lana, *Microlaena* pasture was classified according to its structural habitats when examining use of habitats for sheltering. Open areas (i.e. grasslands) and steep slope areas (i.e. *Poa* slopes, GrS, CS) were utilized infrequently. The habitat with the lowest sight distance (i.e. shrub slope) was utilized to the greatest extent. Differences also existed within habitats in their usage during sheltering periods. For *Poa* slopes grey kangaroo were only seen in *Poa sieberana* slope. One group of six individuals was seen in this habitat in an area with a gentle slope which occurred next to savanna slope. The only other group seen in this habitat was a group of six in normal *Poa sieberana* slope. This group was moving when seen and was thus not using this habitat as a resting area. Only one group of two individuals was seen in *Cymbopogon* slope and this was near the base of the slope next to woodland. The highest density of grey kangaroo in savanna slope occurred in a small area of dense shrubs (6.944 a/ha). Underneath the shrub cover was an open grassy area

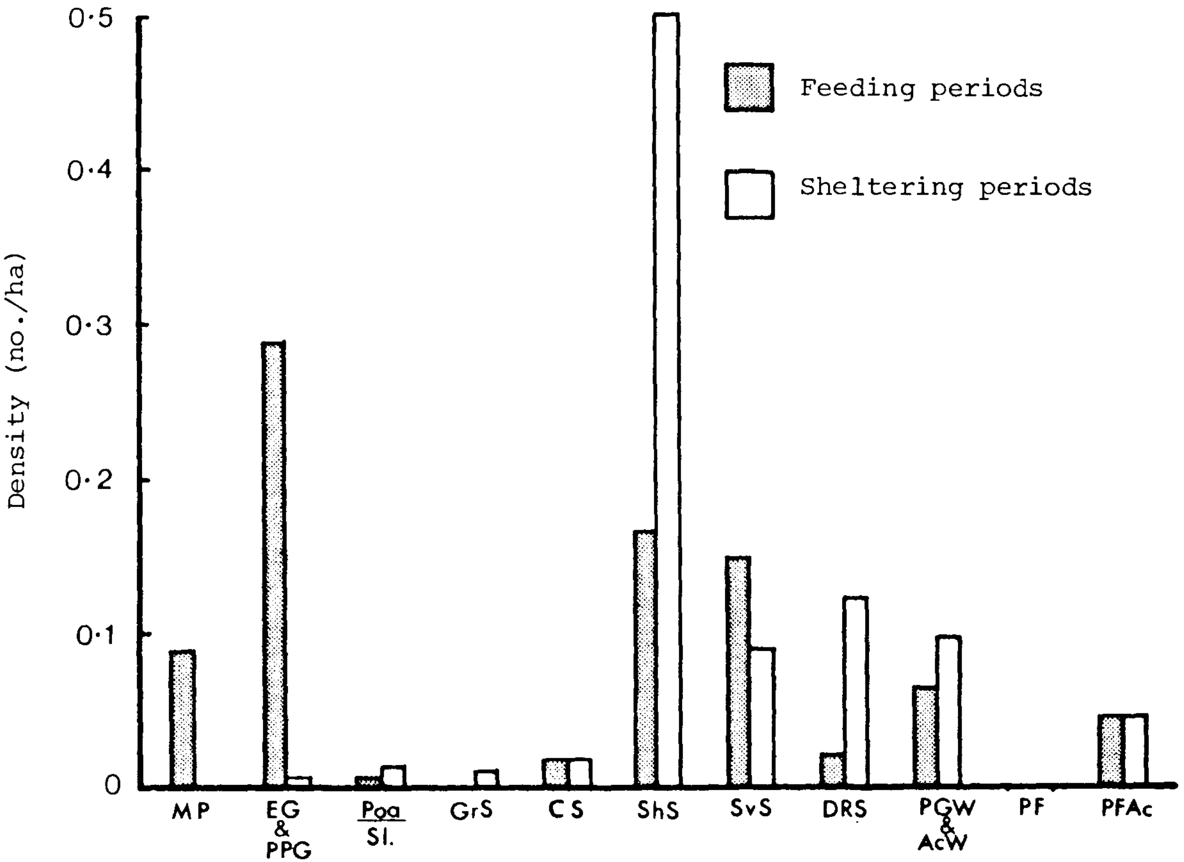

Fig. 5.10. Comparison of the density of grey kangaroo in each habitat on Newholme during feeding and sheltering periods.

Table 5.20 Average density (no./ha) of grey kangaroo in each habitat on Newholme during sheltering periods. Density values are means ± standard error.

Habitat	Density
Grasslands (EG + PPG)	0.005 ± 0.005
All *Poa* slopes	0.024 ± 0.016
Grassy slope	0.011 ± 0.011
Cymbopogon slope	0.018 ± 0.018
Shrub slope	0.502 ± 0.156
Savanna slope	0.079 ± 0.027
Dense rock slope	0.127 ± 0.127
Woodlands (PGW + AcW)	0.098 ± 0.020
Poa forest	0 ± 0
Poa forest with *Acacia*	0.041 ± 0.027

where grey kangaroo were seen lying down. The only area of dense rock slope used was the same area used during feeding periods. For the woodland areas, *Poa* grassy woodland (0.116 a/ha) received a higher use than *Acacia* woodland (0.043 a/ha).

Thus grey kangaroo avoid areas with steep slope at all times. Grasslands within a close distance of shelter are favoured feeding areas. During sheltering periods greatest use is made of areas with a low sight distance, little use being made of grassland areas at these times.

(b) Wallaroo

The density of wallaroo in each habitat during early morning and late afternoon is shown in Fig. 5.11. The density of wallaroo in *Microlaena* pasture is significantly greater during late afternoon than during early morning (l.s.d., $p < 0.01$). The density of wallaroo in all other habitats is not significantly different between early morning and late afternoon. An analysis of variance showed that the pattern of habitat use during early morning was significantly different from that for late afternoon ($F(1,12) = 2.1$, $p < 0.05$). For the same reasons as given for wallaroo on Lana, late afternoon was taken as best representing habitat preferences for feeding by wallaroo on Newholme.

The average density of wallaroo in each habitat during late afternoon (= feeding periods) is given in Table 5.21. The greatest density of wallaroo occurred in *Microlaena* pasture. The steeper slopes were used by wallaroo in contrast to the grey kangaroo. The grasslands and woodlands received little use. Differences also existed in the usage of areas within habitats. The density of wallaroo in *Microlaena* pasture occurring on savanna slope (0.159 a/ha) was lower than the density in *Microlaena* pasture on *Poa* slopes (0.759 a/ha), at the top of slopes (0.729 a/ha) or in drainage areas (0.704 a/ha). The *Microlaena* pasture on savanna slope was adjacent to *Poa* slope yet it still received less use from wallaroo than did other areas. One small area of *Poa sieberana* slope, near a small drainage line where water sometimes flowed, was seen to be used by wallaroo for three months in succession and never in other months. One section of *Poa costiniana* slope that had been ringbarked was used less (0.083 a/ha) than other areas (0.334 a/ha). For *Cymbopogon* slope, an area which had been ringbarked was never seen to be used and a flatter area with many small saplings (0.167 a/ha) was used more than other areas (0.049 a/ha). One small flatish area of grassy slope where the soil appeared wetter than

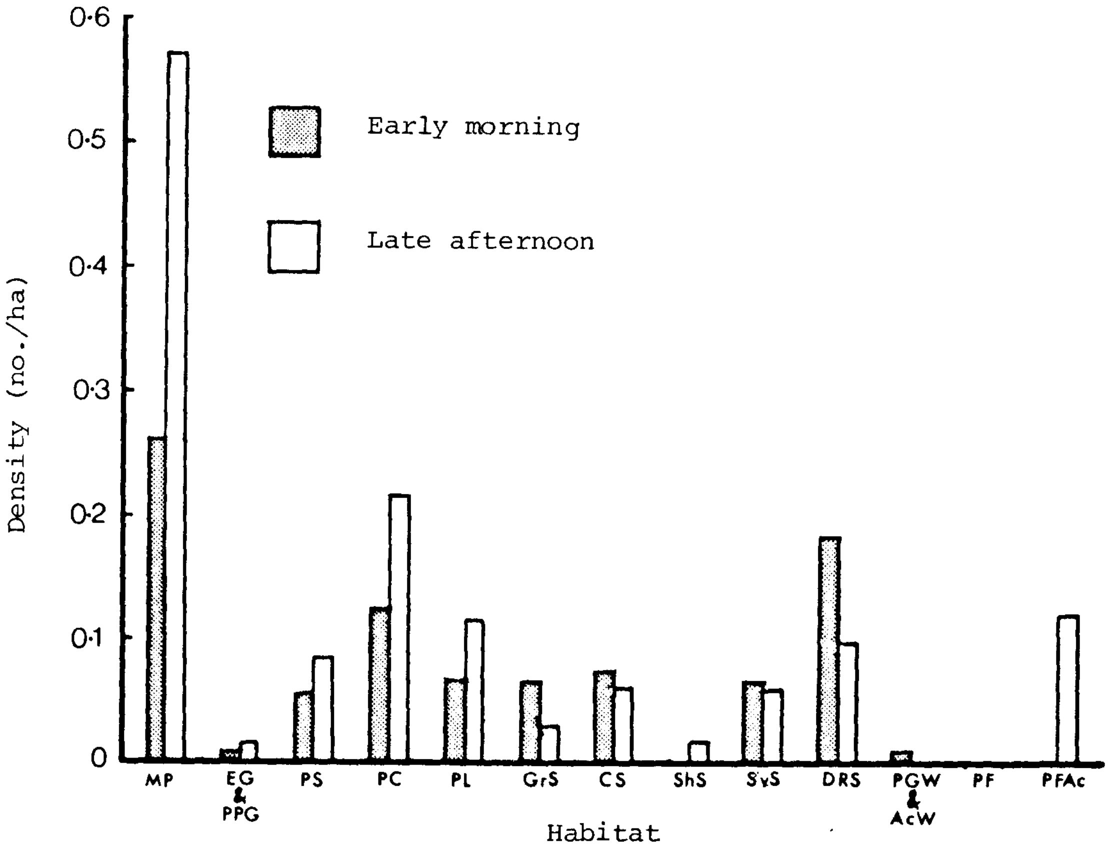

Fig. 5.11. Comparison of the density of wallaroo in each habitat on Newholme during early morning and late afternoon.

Table 5.21 Average density (no./ha) of wallaroo in each habitat on Newholme during late afternoon periods (= feeding periods). Density values are means ± standard error.

Habitat	Density
Microlaena pasture	0.573 ± 0.113
Grasslands (EG + PPG)	0.014 ± 0.014
Poa sieberana slope	0.087 ± 0.025
Poa costiniana slope	0.234 ± 0.078
Poa labillardieri slope	0.138 ± 0.080
Grassy slope	0.030 ± 0.023
Cymbopogon slope	0.061 ± 0.049
Shrub slope	0.017 ± 0.017
Savanna slope	0.054 ± 0.046
Dense rock slope	0.099 ± 0.057
Woodlands (PGW + AcW)	0 ± 0
Poa forest	0 ± 0
Poa forest with *Acacia*	0.121 ± 0.081

surrounding areas was used by wallaroo for two months in succession and never in other months. The density of wallaroo in a small area of savanna slope surrounded by *Poa* slope (1.528 a/ha) was greater than the density in other areas (0.024 a/ha). For dense rock slope the gentle sloping area utilized by grey kangaroo was never seen to be used by wallaroo during late afternoon. An area of dense rock slope with many saplings which was just below a hilltop with a large sheep camp was used (2.252 a/ha) more frequently than other areas (0.041 a/ha).

An analysis of variance showed that there was a significant difference between the pattern of habitat use during feeding periods (= late afternoon) and sheltering periods ($F(1,12) = 5.9$, $p < 0.001$) (Fig. 5.12). The density of wallaroo was significantly greater in *Cymbopogon* slope (l.s.d., $p < 0.05$) and dense rock slope (l.s.d., $p < 0.01$) during sheltering periods and was significantly less in *Microlaena* pasture (l.s.d., $p < 0.001$) during sheltering periods. Other habitats were not significantly different with respect to the density of wallaroo present during feeding and sheltering periods.

The density of wallaroo in each habitat during sheltering periods on Newholme is given in Table 5.22.

Table 5.22 Average density (a/ha) of wallaroo in each habitat on Newholme during sheltering periods. Density values are means ± standard error.

Habitat	Density
Grasslands (EG + PPG)	0 ± 0
Poa sieberana slope	0.072 ± 0.017
Poa costiniana slope	0.164 ± 0.053
Poa labillardieri slope	0.045 ± 0.031
Grassy slope	0.039 ± 0.016
Cymbopogon slope	0.173 ± 0.053
Shrub slope	0 ± 0
Savanna slope	0.010 ± 0.010
Dense rock slope	0.359 ± 0.055
Woodlands (PGW + AcW)	0.004 ± 0.004
Poa forest	0 ± 0
Poa forest with *Acacia*	0.041 ± 0.041

Dense rock slope and *Cymbopogon* slope supported the highest density of wallaroo during sheltering periods. Grassland and woodland areas were largely avoided by wallaroo as occurred during feeding periods. Steep

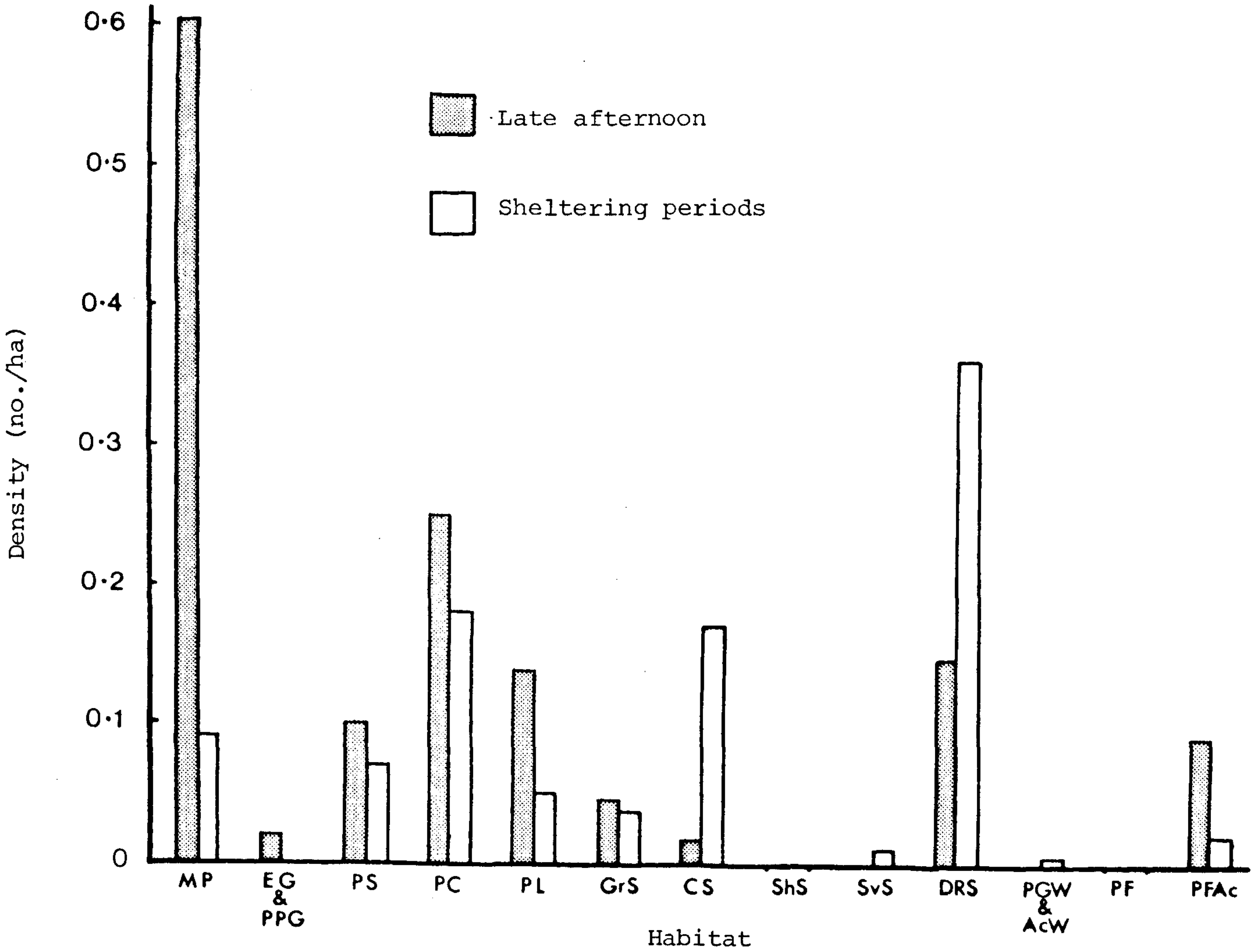

Fig. 5.12. Comparison of the density of wallaroo in each habitat on Newholme during late afternoon and sheltering periods.

slope areas were used by wallaroo during sheltering periods as during feeding periods. Ringbarked areas of *Poa costiniana* slope had a higher density of wallaroo (0.225 a/ha) than other areas (0.125 a/ha) due to use of ringbarked areas during the colder months. Wallaroo were frequently observed during winter months in sunny patches which occurred in these ringbarked areas. The use of different areas of *Cymbopogon* slope during sheltering periods was similar to their use during feeding periods; i.e. ringbarked areas were not used and the area with a gentle slope and frequent saplings had a higher density of wallaroo (0.250 a/ha) than normal areas (0.182 a/ha). Only two wallaroo were seen in savanna slope and these were in the sun next to *Poa sieberana* slope during September. For dense rock slope, as occurred during late afternoon, the highest density was found in the area with frequent saplings below a sheep camp (3.716 a/ha). The dense rock slope area with a gentle slope where grey kangaroo sometimes occurred was used by wallaroo during sheltering periods (0.668 a/ha). A few wallaroo were seen in woodland areas during sheltering periods but they occurred in areas with frequent rock. One individual was found in woodland when snow covered the top of hills but not the woodland areas. One group of two was seen in a sunny patch of woodland next to a *Poa* slope area.

Thus, grassland and woodland areas are used very little by wallaroo. During feeding periods wallaroo favour areas with high quality pasture (i.e. *Microlaena* pasture). During sheltering periods areas of dense rock are preferred. Differences in use of areas within habitats appears to be influenced by the adjoining habitat, by differences in tree cover and rock density and, during feeding periods, possibly by differences in pasture quality.

(c) Comparison of habitat use by grey kangaroo and wallaroo on Newholme

An analysis of variance showed that the pattern of habitat use for grey kangaroo and wallaroo on Newholme during feeding periods was significantly different ($F(1,10) = 8.2$, $p < 0.001$) (Fig. 5.13). The density of wallaroo was significantly greater than the density of grey kangaroo in *Microlaena* pasture ($p < 0.01$) and on *Poa* slopes ($p < 0.001$). The density of grey kangaroo was significantly greater than wallaroo density in grasslands ($p < 0.001$), shrub slope ($p < 0.05$) and *Poa* grassy woodland ($p < 0.001$). Differences in usage by the two species also exist for most other habitats. Grassy slope was used by grey kangaroo only at the base of the slope whereas wallaroo were seen over the whole slope. *Cymbopogon* slope was used by grey kangaroo only in the area near

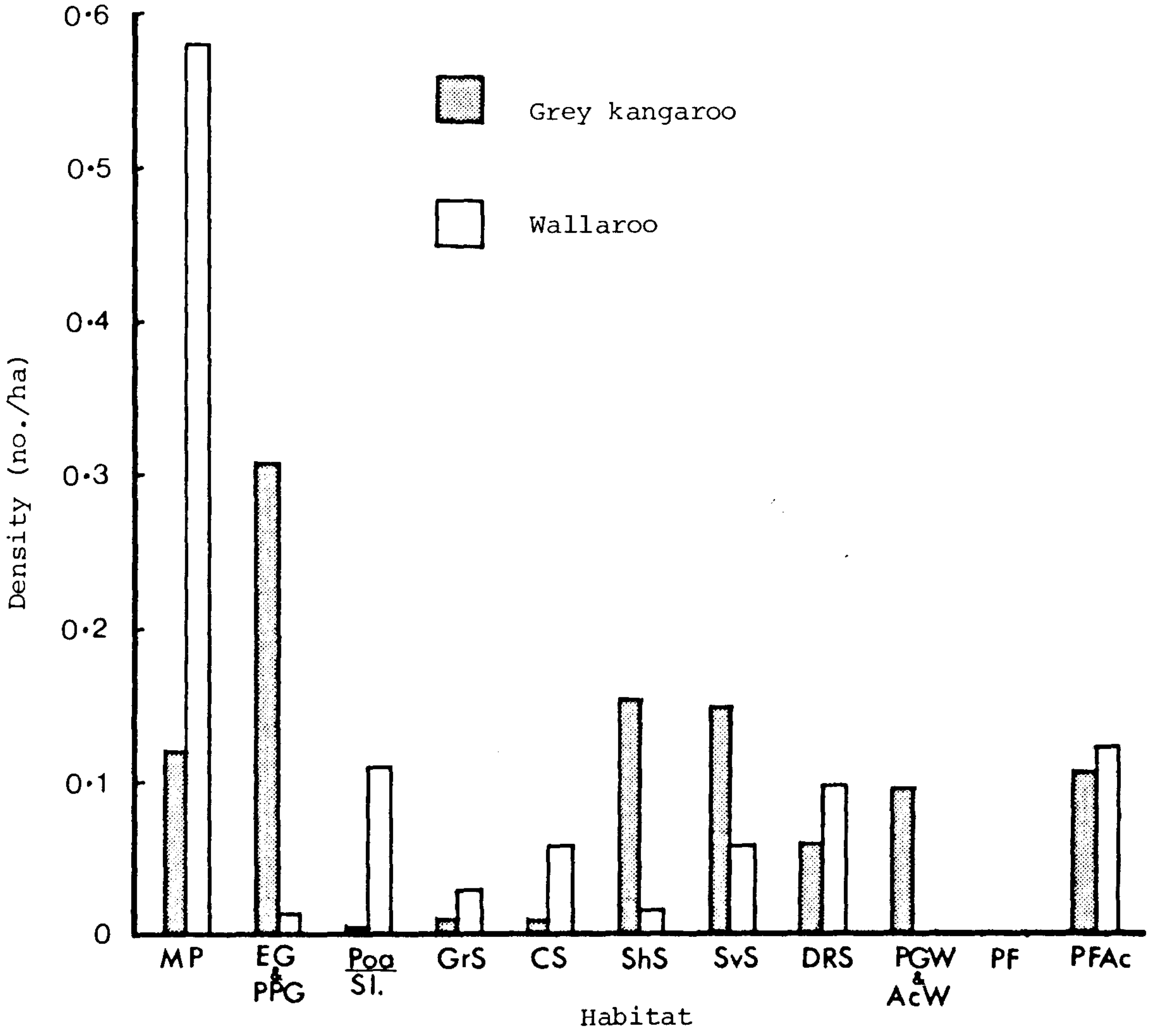

Fig. 5.13. Comparison of the density of grey kangaroo and wallaroo in each habitat on Newholme during feeding periods.

the sheep camp at the top of an area of *Poa labillardieri* slope whereas wallaroo utilized most areas of *Cymbopogon* slope. In savanna slope grey kangaroo utilized all areas except the isolated area surrounded by *Poa* slope whereas wallaroo utilized this isolated area and in other areas were found only on the edge of savanna slope near *Poa* slope. In dense rock slope grey kangaroo were only seen in the gentle sloping area whereas during late afternoon periods wallaroo were seen in all areas except this gentle sloping area.

The pattern of habitat use by grey kangaroo and wallaroo also differed significantly during sheltering periods ($F(1,9) = 6.6$, $p < 0.001$) (Fig. 5.14). The density of wallaroo was significantly greater than the density of grey kangaroo for *Poa* slopes ($p < 0.01$) and *Cymbopogon* slope ($p < 0.05$). The density of grey kangaroo was significantly greater than wallaroo density for shrub slope ($p < 0.01$), savanna slope ($p < 0.05$) and *Poa* grassy woodland ($p < 0.01$). For dense rock slope grey kangaroo only used the area with a gentle slope whereas wallaroo were seen in all areas. For grassy slope grey kangaroo only used the base of the slope whereas wallaroo used the whole slope.

(d) Differences in habitat use between months

The sampling intensity per habitat was lower on Newholme than on Lana due to the lower density of kangaroos on Newholme and the larger number of habitats recognized on Newholme. Thus it was even more difficult to assess changes in habitat usage between months on Newholme than on Lana.

(i) Grey kangaroo

In order to simplify the analysis of changes in habitat use between months, habitats with similar pasture were grouped. Also, kangaroos occurring on the edge of a habitat due to the presence of a second habitat next to it were placed in the second habitat. For example, two individuals in *Cymbopogon* slope next to a sheep camp were placed in the *Microlaena* pasture habitat. The number of grey kangaroo in these adjusted and grouped habitats is shown in Table 5.23. The frequency of cells with no sightings of kangaroos precluded statistical analysis. Instead each habitat was examined separately for possible changes in usage over the months. *Microlaena* pasture may have been used more during winter. This was probably due to the presence of high quality grass here even during winter. Increased use of sheep-affected pasture (similar to *Microlaena* pasture) by grey kangaroo also occurred during winter on Lana. For *Eragrostis* grassland there may have been a drop in use during winter although spotlighting here at night showed that some grey kangaroo

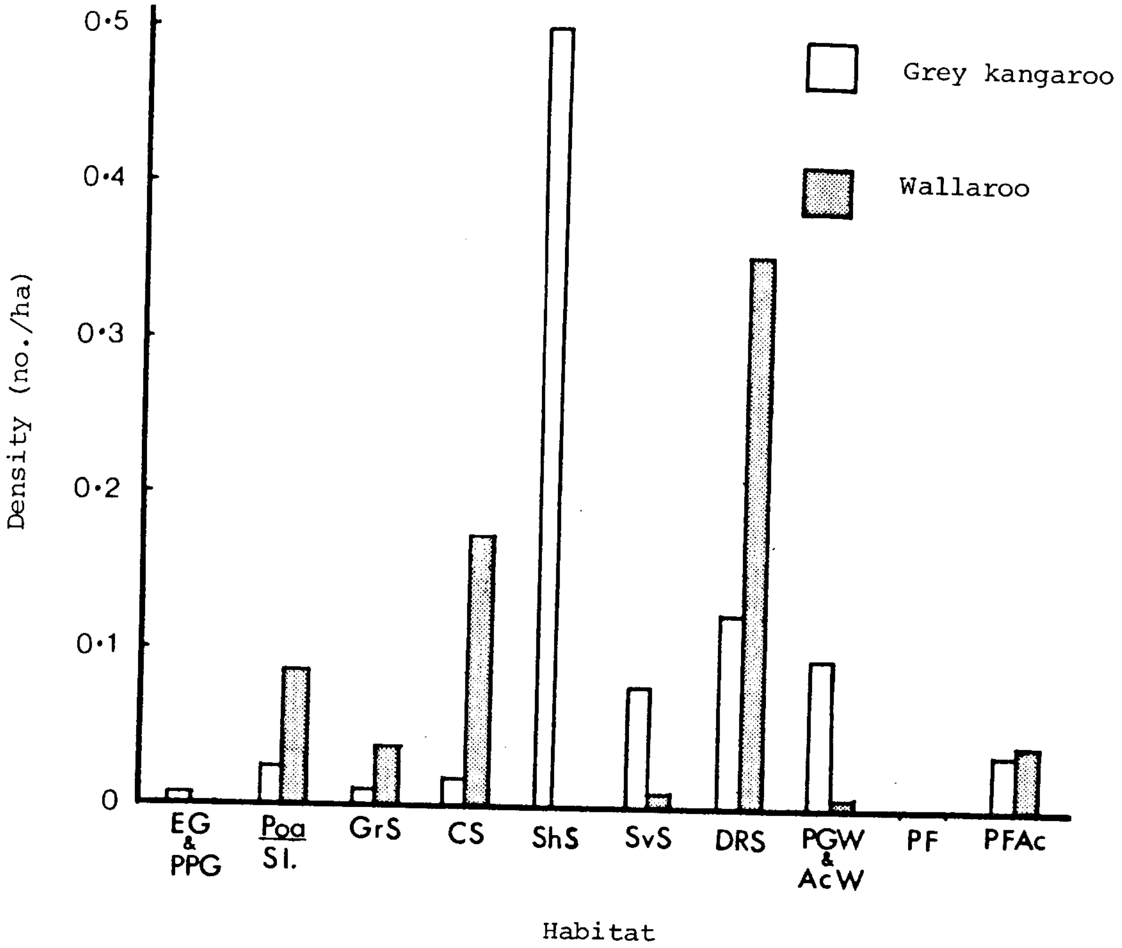

Fig. 5.14. Comparison of the density of grey kangaroo and wallaroo in each habitat on Newholme during sheltering periods.

still used this habitat in winter. The pasture in *Eragrostis* grassland during winter contained a large proportion of dead material which could have deterred grey kangaroo from using this habitat.

Table 5.23 Number of grey kangaroo in each habitat on Newholme for each month during feeding periods. Values in brackets are percentages of grey kangaroo seen in each habitat per month.

	Month											
Habitat	J	F	M	A	M	J	J	A	S	O	N	D
Microlaena pasture	2 (14)	1 (3)	2 (7)	0	0	6 (18)	4 (17)	5 (24)	0	0	2 (5)	0
Eragrostis grassland	0	4 (13)	8 (29)	2 (9)	5 (13)	0	0	0	10 (83)	0	10 (23)	0
Poa-Pennisetum grassland	0	0	6 (21)	12 (52)	4 (10)	11 (32)	3 (13)	4 (19)	0	4 (36)	6 (13)	0
Poa forest with *Acacia*	0	1 (3)	0	0	5 (13)	4 (12)	0	0	0	0	0	0
Others	12 (86)	26 (81)	12 (43)	9 (39)	25 (64)	13 (38)	17 (70)	12 (57)	2 (17)	7 (64)	26 (59)	14 (100)

Use of *Eragrostis* grassland may also have been low during early summer (i.e. December, January). Use of *Poa-Pennisetum* grassland may also have decreased in summer when low-fibre grass is most abundant. Use of *Poa-Pennisetum* grassland during winter, in contrast to *Eragrostis* grassland, may have been related to the presence of *Poa* tussocks. High soil moisture may also have allowed more growth of grasses in *Poa-Pennisetum* grassland than in most other habitats. *Poa* forest with *Acacia* was probably utilized more during winter because of the presence of *Poa* tussocks which increased in importance in the diet during winter (see Chapter 4). There were also sheep camps present along the top of the slope where *Poa* forest with *Acacia* was situated and these areas appeared to be used more in winter. The highest use of woodland areas (the major component of the clumped habitats) probably occurred during summer when low-fibre grasses were most abundant.

For an examination of differences between months in habitat use during sheltering periods, grasslands and *Poa* slopes were excluded because of their obvious unimportance as sheltering habitat. All other habitats except shrub slope and savanna slope were grouped. The greatest proportion of kangaroos in the grouped habitats was found in woodland areas. The results are shown in Table 5.24. No trends occurring over successive months are evident. If seasonal changes did occur during sheltering periods the sampling intensity was too small to pick them up.

Table 5.24 Number of grey kangaroo in each habitat on Newholme for each month during sheltering periods. Values in brackets are percentages of grey kangaroo seen in each habitat per month.

	Month							
Habitat	Jan.	Mar.	Apr.	Jun.	Jul.	Sep.	Oct.	Dec.
Shrub slope	11 (37)	0	3 (17)	11 (39)	4 (27)	4 (36)	6 (21)	0
Savanna slope	4 (13)	0	3 (17)	0	0	5 (46)	2 (7)	2 (40)
Others	15 (50)	9 (100)	12 (66)	17 (61)	11 (73)	2 (18)	21 (72)	3 (60)

(ii) Wallaroo

The use of habitats by the wallaroo during feeding time (i.e. late afternoon) was too variable between consecutive months to allow any change in the use of habitats over the months to be found. Again more intensive sampling is needed to investigate seasonal changes in habitat use. The same is true for the analysis of seasonal changes in habitat use for wallaroo on Newholme during sheltering periods. During the colder months, however, there was a noticeable increase in the use of sunny areas including areas adjacent to steeper slopes.

5.3.3 Relationship between the biomass of low-fibre grass leaf and use of a habitat by kangaroos

Both kangaroo species have been shown to select for low-fibre grass leaf in their diet (section 4.3.5). In order to assess the influence of the abundance and quality of low-fibre grass leaf on use of a habitat by kangaroos, the correlation between the density of kangaroos and the biomass of low-fibre grass leaf was investigated. Other studies (e.g. Veirea, 1980; Robinson and Lazenby, 1976) have shown that sheep camps and areas of improved pasture have a higher productivity than native pastures. In the present study it was also shown that sheep camps and improved pastures contain grasses of a higher quality (Chapter 3). Thus it was not possible to separate the effects of differences due to quality or to productivity when comparing use of areas differing in these aspects. In this section, although differences in the use of some areas are discussed in terms of differences in the quality of pasture, it is recognized that differences in productivity may be just as important, or more important,in determining these differences.

(i) Grey kangaroo

For grey kangaroo on Lana, low-sight-distance slope, dense rock slope and large boulder slope were not included in the analysis as these habitats were unsuitable for use by the grey kangaroo. For sheep-affected pasture, *Microlaena* pasture in slope areas was not included as these areas were not grazed by grey kangaroo. The average density of grey kangaroo per habitat at feeding times was plotted against the biomass of low-fibre grass leaf in each habitat (Fig. 5.15). The mean biomass of low-fibre grass leaf for the four seasonal pasture samples (see Chapter 3) was used as an estimate of the yearly average. The density of grey kangaroo present in a habitat was significantly correlated ($r = 0.91$, $p < 0.05$) with the abundance of low-fibre grass leaf.

For grey kangaroo on Newholme *Poa* slopes, *Cymbopogon* slope and grassy slope were not included as these habitats were not utilized by grey kangaroo due to their steep slope. Areas of *Poa-Pennisetum* grassland not utilized because of lack of nearby shelter were not included. Small areas of *Acacia* woodland and savanna slope surrounded by *Poa* slopes and thus not accessible to grey kangaroo were not included. *Microlaena* pasture areas not used by grey kangaroo were not included (i.e. on *Poa* slopes and in drainage areas). Low-fibre grass leaf was also correlated with the density of grey kangaroo during feeding periods for habitats on Newholme ($r = 0.93$, $p < 0.01$) (Fig. 5.15). The density of grey kangaroo in shrub slope is likely to be overestimated in terms of usage for feeding due to its high usage as a sheltering habitat. It is likely that some grey kangaroo that were sheltering and not feeding may have been seen here during feeding periods. The low sight distance in this habitat may also encourage grey kangaroo to feed here to a greater extent than would be predicted on the basis of the biomass of low-fibre grass leaf.

An analysis of covariance showed no significant differences between Lana and Newholme in the slopes of the regression lines relating the biomass of low-fibre grass leaf to the density of grey kangaroo. However the intercepts for Lana and Newholme were significantly different ($F(1,9) = 5.3$, $p < 0.05$). Thus for a given biomass of low-fibre grass leaf the density of grey kangaroo on Lana was higher than the density of grey kangaroo on Newholme. The increased density of grey kangaroo

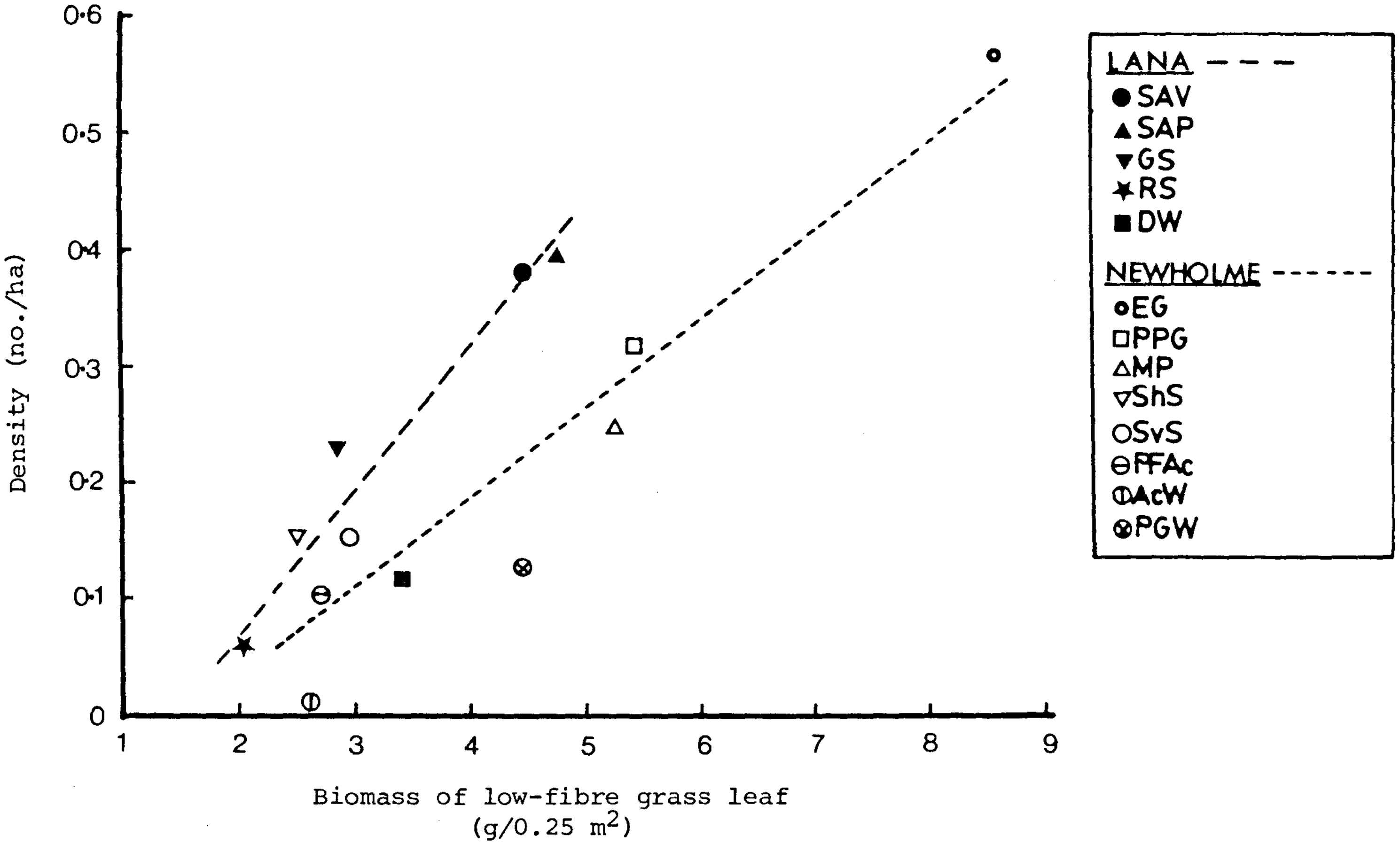

Fig. 5.15. Relationship between the density of grey kangaroo and the biomass of low-fibre grass leaf for habitats on Lana and Newholme.

For Lana; Y = 0.12X - 0.19 For Newholme; Y = 0.08X - 0.12

where Y = density of grey kangaroo, and X = biomass of low-fibre grass leaf for a given biomass of low-fibre grass leaf on Lana may be due to the higher quality and greater productivity of grasses on Lana compared to Newholme. The potential magnitude of the differences between the two properties may be greater than shown in Fig. 5.15 due to culling of grey kangaroo on Lana maintaining the population below the carrying capacity. Thus the potential density of grey kangaroo per unit of biomass of low-fibre grass leaf may be higher on Lana than recorded during this study.

There is also other evidence of the effects of grass quality influencing grey kangaroo density. For sown pasture on Lana the biomass of low-fibre grass leaf was not different from that found in other savanna woodland areas (sown pasture = 4.39 g/0.25 m^2; normal pasture = 4.54 g/0.25 m^2). However the density of grey kangaroo in sown pasture (0.790 a/ha) was greater than in normal pasture (0.370 a/ha). Sown pasture contains a lot of *Phalaris tuberosa*, an introduced grass of higher quality than many other low-fibre grasses (see Table 3.4). The increased density on sown pasture may thus be a result of the increased quality of grass present here.

Since increased quality of grass seems to increase grey kangaroo use of a habitat, it is surprising that sheep-affected pasture is not above the regression line for habitats on Lana. This would also apply to *Microlaena* pasture on Newholme. The relationship between the biomass of low-fibre grass leaf and the density of grey kangaroo on Lana in February (summer), July (winter) and November (spring) is shown in Fig. 5.16. Sheep-affected pasture appears to be used in accordance with the quantity of leaf present in spring but in summer may be underutilized in terms of the biomass of low-fibre grass leaf present. Only in winter is sheep-affected pasture used more than would be predicted from the quantity of low-fibre grass leaf present. The density of grey kangaroo in dense woodland shown in Fig. 5.15 appears to be lower per unit of biomass of low-fibre grass leaf than for other habitats on Lana. Dense woodland lies close to the regression line for Newholme. It may be the case that grasses in dense woodland are of a lower quality than in other habitats on Lana. *Danthonia racemosa* is abundant in dense woodland. On Lana most grass samples (including *Danthonia racemosa*) collected for analysis were obtained in savanna woodland and so the quality of grass in dense woodland and other habitats cannot be compared.

(ii) Wallaroo

Dense rock slope and large boulder slope were not included in the

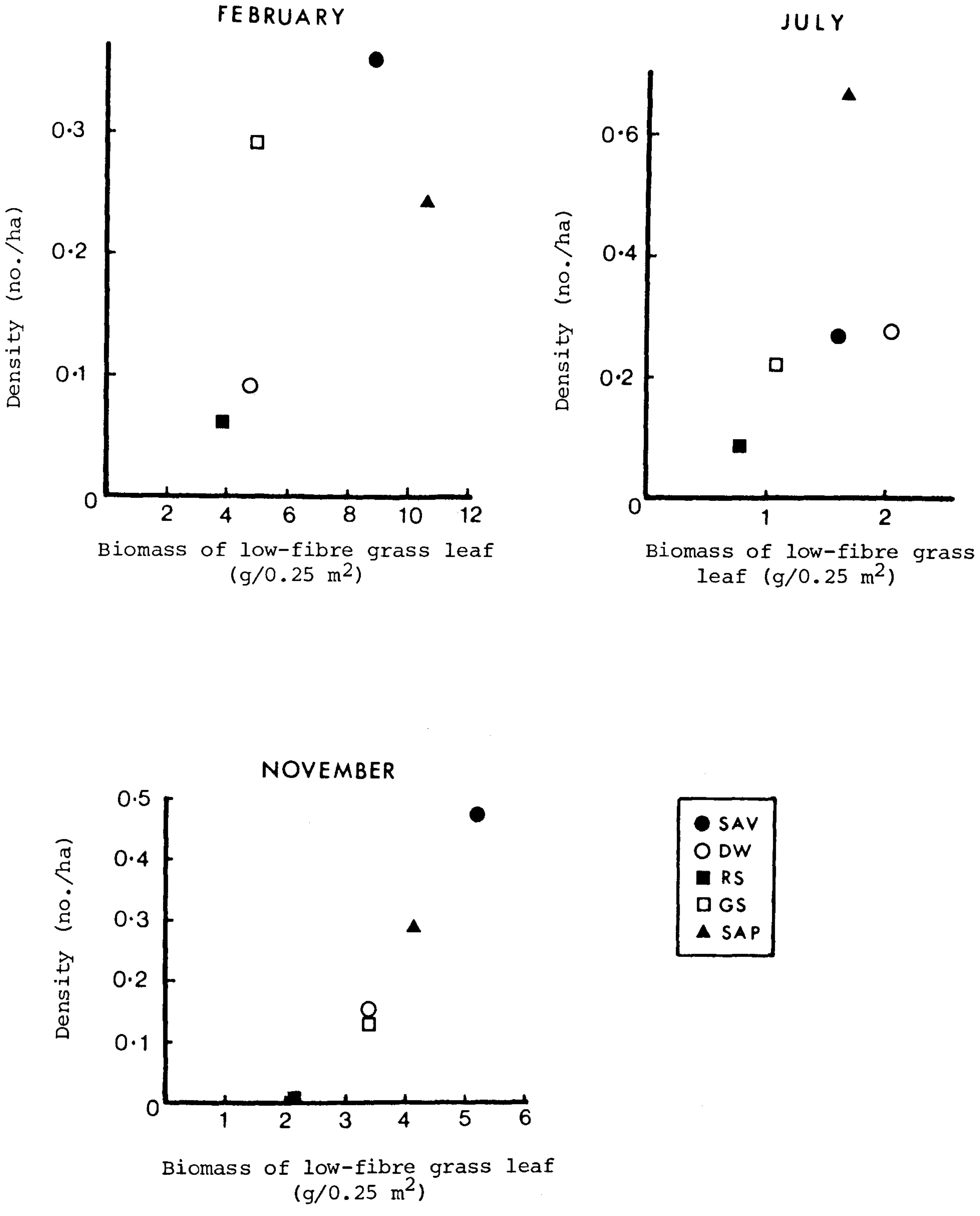

Fig. 5.16. Relationship between density of grey kangaroo and the biomass of low-fibre grass leaf for habitats on Lana at different seasons.

investigation of the relationship between the biomass of low-fibre grass leaf and the density of wallaroo on Lana. Both of these habitats were thought to have density estimates which overestimated their importance as feeding habitat (discussed in section 5.3.1(b)). The density of wallaroo per habitat on Lana during feeding periods was not significantly correlated with the biomass of low-fibre grass leaf present (r = 0.63) (Fig. 5.17). Gentle slope use is greater than expected and savanna woodland use is less than expected on the basis of the biomass of low-fibre grass leaf present. This is probably the result of the way in which these habitats are used by wallaroo. As discussed previously, wallaroo tend to congregate on the edge of gentle slope near savanna woodland. If the relationship between the biomass of low-fibre grass leaf and use of habitat for feeding were to be investigated more thoroughly for the wallaroo, measurements on the proportion of time spent feeding when present in a habitat would need to be obtained. It may be that wallaroo spend a much higher proportion of time feeding when in savanna woodland compared to when in gentle slope.

As for grey kangaroo, wallaroo density was greater in sown pasture (1.362 a/ha) than in normal pasture (0.321 a/ha). Hence it is likely that the quality of grass is also influencing the number of wallaroo feeding in a habitat. To investigate the effects of differences in quality of low-fibre grass leaf on density, sheep-affected pasture was separated into its subhabitats. Gentle slope and savanna woodland were excluded from the analysis. However the gentle slope subhabitat with no steeper slope above was included. This subhabitat was thought to provide a better measure of use of gentle slope for feeding because of less bias related to wallaroo use of gentle slope as a "stepping stone" into savanna woodland. It can be seen from Fig. 5.18 that sheep-affected areas with *Microlaena* pasture are greatly overused in relation to the biomass of low-fibre grass leaf present in comparison to other habitats. When sheep-affected pasture with *Microlaena* pasture is excluded there is a significant correlation between the biomass of low-fibre grass leaf and the density of wallaroo ($r = 0.90$, $p < 0.01$). Sheep-affected pasture with other grass species dominant also contains grasses of high quality (e.g. see value for *Agropyron* from sheep camp in Table 3.4). It is therefore probable that these high values for *Microlaena* pasture also indicate a preference for *Microlaena* rather than just a preference for high quality grasses per se. The higher density of wallaroo in *Microlaena* pasture on slopes compared to *Microlaena* pasture in woodland is not related to

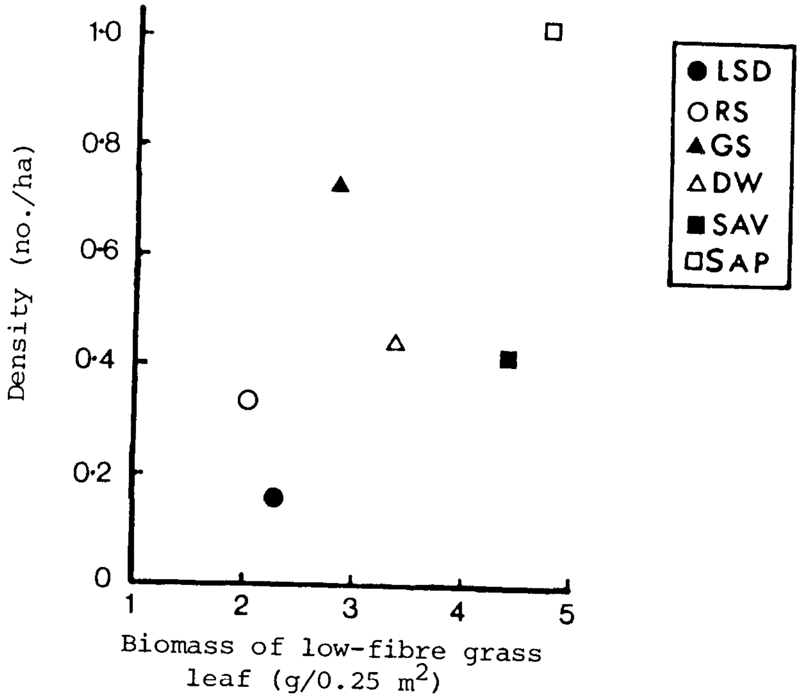

Fig. 5.17. Relationship between the density of wallaroo and the biomass of low-fibre grass leaf for habitats on Lana.

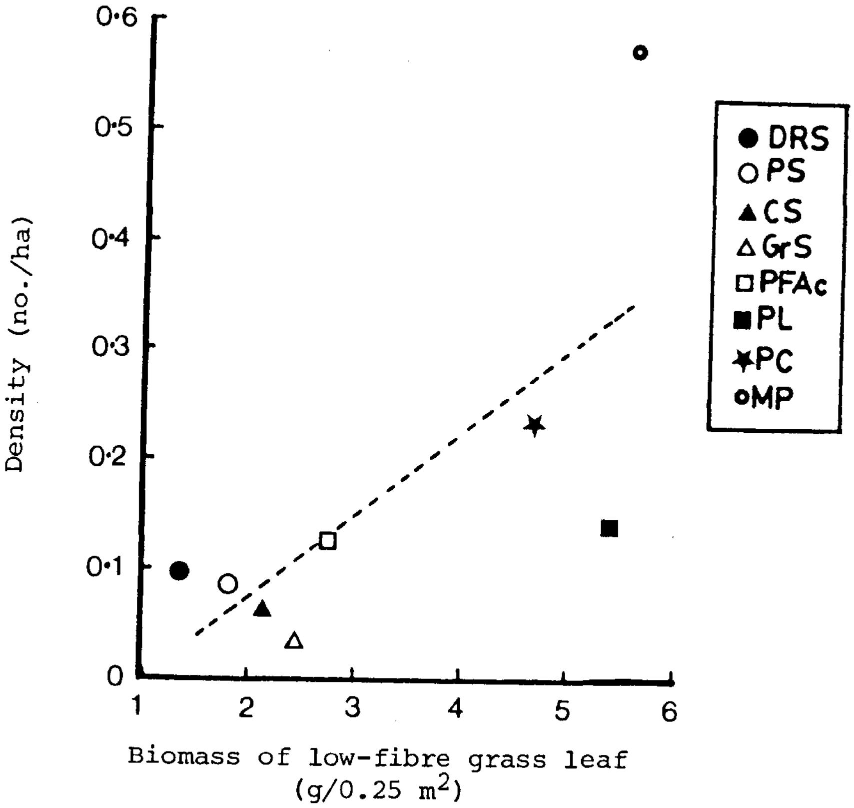

Fig.5.19 Relationship between the density of wallaroo and the biomass of low-fibre grass leaf for habitats on Newholme. Density = 0.07 biomass of low-fibre grass leaf - 0.07

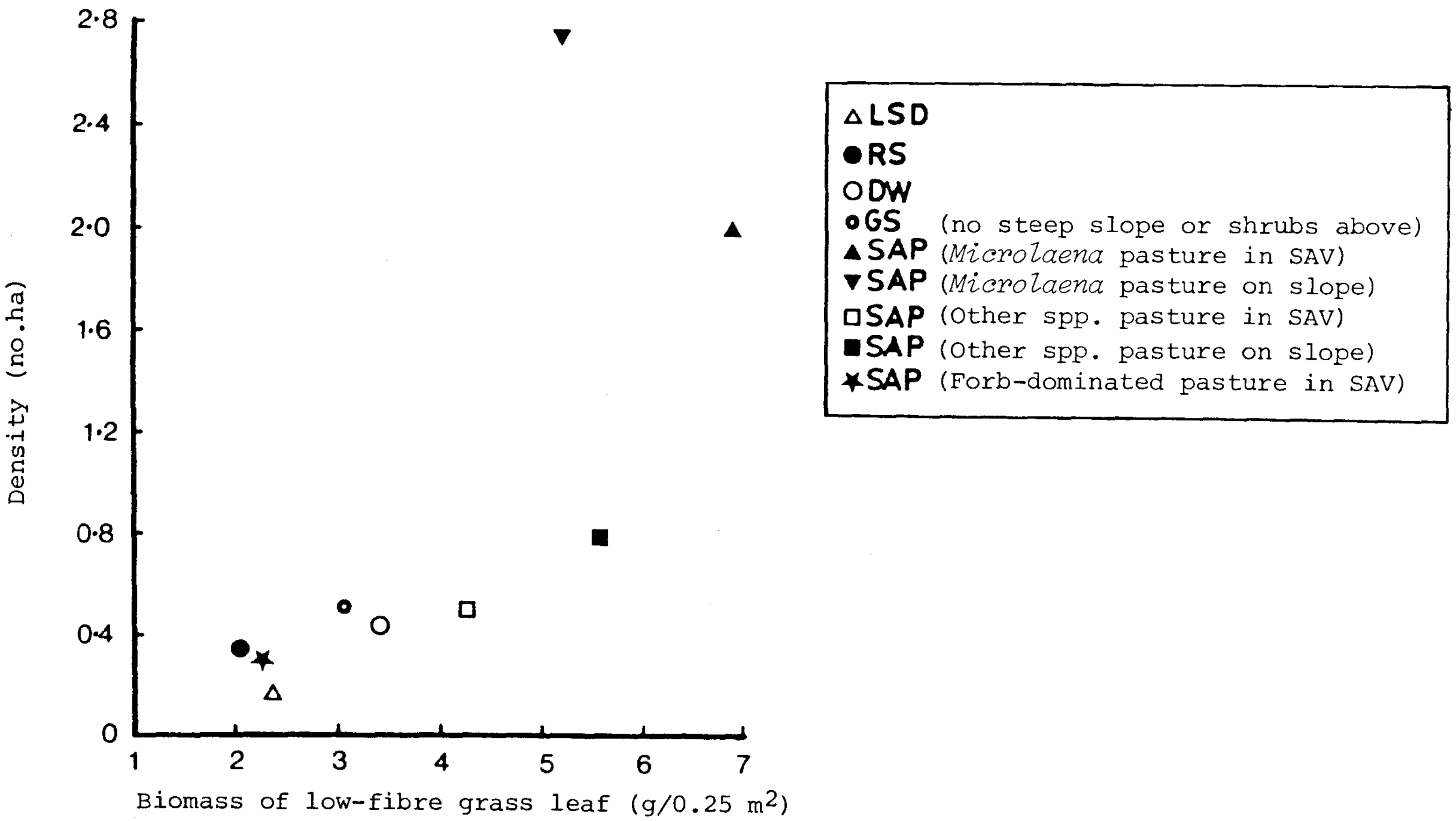

Fig. 5.18. Relationship between the density of wallaroo and the biomass of low-fibre grass leaf for habitats on Lana when savanna woodland and gentle slope are excluded and sheep-affected pasture is divided up into subhabitats.

a higher biomass of low-fibre grass leaf on slopes.

For wallaroo on Newholme the grasslands, woodlands and savanna slope were excluded from the analysis as wallaroo either did not use these areas or used them only at the interface with slope areas. The relationship between the biomass of low-fibre grass leaf and density for the wallaroo during feeding periods on Newholme is shown in Fig. 5.19. The two are significantly correlated ($r = 0.71$, $p < 0.05$). If *Microlaena* pasture is excluded however, there is no significant correlation ($r = 0.68$). It is likely that use of these other habitats is also influenced by the quality of grasses rather than just the biomass of these. The observed intense use of small sections of habitat over a series of months by the wallaroo on Newholme is evidence of the importance of differences in the quality of plants within habitats.

When the regression line for Newholme (including *Microlaena* pasture is compared to the regression line for Lana (excluding sheep-affected pasture with *Microlaena* dominant) there is no difference in the slope of the lines but the intercepts are significantly different ($F(1,11) = 18.2$, $p < 0.01$). Thus even though *Microlaena* pasture on Lana was not included it was still found that for a given biomass of low-fibre grass leaf there is a higher density of wallaroo on Lana than on Newholme. As for grey kangaroo this is probably associated with the higher quality and productivity of grasses on Lana compared to Newholme.

(iii) Comparison of the grey kangaroo and wallaroo

When the regression lines relating the biomass of low-fibre grass leaf and density for the grey kangaroo and wallaroo on Newholme are compared there is no significant difference between the slopes or intercepts of the regression lines. Thus on Newholme the grey kangaroo and wallaroo achieve similar densities on a given biomass of low-fibre grass leaf. For Lana, even when the wallaroo regression line excluding sheep-affected pasture with *Microlaena* is used, this regression line has no significant difference in slope but does have a significantly different intercept to that for the grey kangaroo ($F(1,9) = 18.7$, $p < 0.01$). Thus for a given biomass of low-fibre grass leaf wallaroo achieve a higher density than grey kangaroo on Lana. This is probably partly explained by the fact that grey kangaroo are culled regularly on Lana whereas wallaroo are not. However, since *Microlaena* pasture was not included for wallaroo in the comparison, it is still likely that wallaroo occur at higher densities than do grey kangaroo on areas of higher quality pasture (particularly if

Microlaena is dominant).

5.4 Discussion

The greatest consistent difference between the diets of grey kangaroo and wallaroo was in the proportion of *Microlaena stipoides* in the diet (see section 4.3.2). The differences found in the use of sheep-affected pasture (on Lana) and *Microlaena* pasture (on Newholme) by the two species during feeding periods is consistent with a greater use of high quality pasture by wallaroo. Wallaroo utilized sheep-affected pasture extensively. Grey kangaroo, however, only appeared to use sheep-affected pasture on a par with the quality and quantity of grass present when there was a shortage of other low-fibre grass species (i.e. during winter). The period when the habitat use of the two species overlapped to the greatest extent (i.e. spring) corresponded to the period when the similarity of the diets was lowest (see section 4.3.2).

The use of habitat by the grey kangaroo during feeding periods appears to be controlled by three main factors. These are:

(1) Topography. Grey kangaroo did not utilize the steeper slopes to any great extent on either Lana or Newholme. Only the bases of most steep slopes were used.

(2) Shelter. Even though grasslands on Newholme were fairly homogeneous, large areas of these habitats were not used because of the lack of nearby suitable shelter for grey kangaroo. Grey kangaroo appear reluctant to feed beyond a certain distance from shelter. This is most probably an anti-predator strategy.

(3) Quantity and quality of low-fibre grass leaf. On a yearly average basis there was a significant correlation between the density of grey kangaroo feeding in a habitat and the abundance of low-fibre grass leaf in that habitat. On Lana there was a higher density of grey kangaroo per unit biomass of low-fibre grass leaf than on Newholme probably related to the higher quality and productivity of grasses on Lana. Evidence was presented to show that areas with high quality grass on Lana have an increased density of grey kangaroo compared to areas with the same biomass of low-fibre grass leaf but with grasses of a lower quality. However grey kangaroo did

not appear to respond in a uniform way to the presence of high quality grasses in sheep-affected pasture. Sheep-affected pasture was only overutilized, in terms of the quantity of low-fibre grass leaf present, during winter. It may be that grey kangaroo prefer not to feed in sheep-affected pasture areas when grass is abundant in other habitats. This is probably related to an avoidance of *Microlaena* which is abundant in large areas of sheep-affected pasture. Grey kangaroo did not utilize areas of sheep-affected pasture on slopes dominated by *Microlaena* pasture whereas areas on slopes dominated by other grass species were used. In comparison with wallaroo grey kangaroo diets contained a lot less *Microlaena* in summer and spring (section 4.3.2). Thus although grey kangaroo do feed on *Microlaena*, during periods when other grass leaf is abundant they appear to prefer other species. Why grey kangaroo should prefer other lower quality grass species to *Microlaena* is not known. The grey kangaroo's avoidance of sheep-affected pasture in summer and overuse (in terms of the quantity of grass leaf present) of this pasture during winter may be related to obtaining the best nutritional balance within a fixed total bulk of food as Westoby (1974) hypothesizes for large herbivore diets. However, wallaroo prefer sheep-affected pasture all year round and it is unlikely that two species as similar as the grey kangaroo and wallaroo would differ markedly in their nutritional requirements.

In coastal lowland of south-east Queensland the density and height of undergrowth have been shown to be important in influencing the grey kangaroo's use of a habitat (Taylor, 1980). In these areas dense undergrowth discourages kangaroos from actively feeding in a habitat. For natural habitats suitable for use as feeding areas the abundance of grey kangaroo was correlated with the abundance of *Themeda australis* (Taylor, 1980). In these areas *T. australis* was the only source of abundant food. A correlation between density and grass abundance has also been found for the quokka on Rottnest Island (Holsworth, 1967).

On both Lana and Newholme grey kangaroo exhibited the same pattern of habitat use during early morning and late afternoon, although open habitats (i.e. savanna woodland on Lana and *Eragrostis* grassland on Newholme) had a significantly higher density during late afternoon periods. These areas are favoured feeding areas and it is possible that a greater proportion of the population is feeding during late afternoon in comparison to early morning (e.g. see Coulson, 1978). Both study areas have within habitat differences due to structural and pasture composition differences. On Newholme, however, there appears to be more within habitat variation in use which may be related to differences in pasture quality. The high use of an area of *Poa-Pennisetum* grassland and the high use of an area of *Poa* grassy woodland are examples of this. The presence of good shelter nearby the *Poa-Pennisetum* grassland area may, however, have also played a role in the increased use of this area.

On both study areas the grey kangaroo exhibited a different pattern of habitat use during sheltering periods compared to feeding periods. There was a decreased use of open areas (i.e. savanna woodland on Lana and grasslands on Newholme) and an increased use of areas with a denser tree canopy (i.e. dense woodland on Lana) and/or areas with a low sight distance (i.e. small dense rock slope at base of hills on Lana and shrub slope on Newholme) during sheltering periods. Caughley (1964a) found a positive correlation between grey kangaroo density and vegetation density in an area of south-west Queensland.

The quality of pasture affected use of a habitat for feeding by wallaroo as it did for grey kangaroo. However wallaroo occurred at higher densities on areas of higher quality pasture than did grey kangaroo. This was especially true for *Microlaena* pasture. The role of topography and abundance of low-fibre grass leaf in determining the density of wallaroo in a habitat during feeding periods could not be separated. An index of time spent feeding when in an area would be needed to separate the role of these two factors. Thus on Lana it may be that wallaroo spend a greater proportion of time feeding when in savanna woodland in comparison to when they are in gentle slope areas overlooking savanna woodland. Casual observations indicate that this is probably the case. Thus this would explain why gentle slope had a higher density of wallaroo and savanna woodland had a lower density of wallaroo than would have been predicted for feeding periods on the basis of the biomass of low-fibre grass leaf in these habitats. The higher density of wallaroo than predicted on the basis of the biomass of low-fibre grass leaf in slope areas of sheep-affected pasture with *Microlaena* dominant in comparison to woodland areas of sheep-affected pasture with *Microlaena* dominant may also be explainable in terms of differences in the percentage of time spent feeding whilst in these areas. However, it could also be the case that wallaroo may be able to achieve a higher rate of intake of food on slope *Microlaena* pasture than in woodland *Microlaena* pasture despite a higher biomass of low-fibre grass leaf in woodland areas. Wallaroo may be "more secure" in slope areas and hence spend less time alert. They may thus be able to spend more time feeding when in slope areas in comparison to when in woodland areas.

On both study areas the pattern of habitat use for wallaroo was significantly different between late afternoon and early morning periods. Late afternoon was taken as best representing the habitat preferences for feeding as the important feeding areas were used most during this time and because Osazuwa (1978) has shown that a greater proportion of time is spent feeding by wallaroo during late afternoon than during early morning. On Lana during feeding periods wallaroo made extensive use of savanna woodland around the base of hills whereas on Newholme no use was made of grassland areas. Tussock grasses are superabundant on slope areas on Newholme so there was no need for wallaroo to enter grassland areas to obtain these. The quality of low-fibre grass leaf in grassland on Newholme may not be great enough to warrant wallaroo leaving the security of the hills. In areas on Newholme where sheep camps were developed at the base of hills wallaroo could be found feeding but grasslands in the same relative position were not used.

Differences in within habitat use, probably related to differences in pasture quality and not to differences in pasture composition, occurred on Newholme but not on Lana. These differences were also suspected for grey kangaroo on Newholme but the differences for the wallaroo were more pronounced. Differences in use within habitats based on differences in species composition occurred on Lana. On Newholme, however, there was obvious high use of small areas within habitats which appeared to have similar pasture composition to surrounding areas. The high use of these small areas only lasted for a few months indicating that their use was not related to the presence of nearby shelter or their occurrence on possible pathways utilized by wallaroo for movement.

The pattern of habitat use for wallaroo on Lana and Newholme was significantly different during sheltering periods in comparison to late afternoon feeding periods. On both study areas an increase in use of dense rock areas and a drop in the use of sheep camps (i.e. sheep-affected pasture on Lana and *Microlaena* pasture on Newholme) occurred during sheltering periods. The increase in use of dense rock areas during sheltering periods is not as marked on Newholme as on Lana. This is probably due to the slopes on Newholme being much wider and more extensive than on Lana. Thus the non-dense rock slopes on Newholme may provide better shelter than these areas on Lana.

Apart from the differences in use of sheep-affected pasture (and *Microlaena* pasture), the main differences in habitat use by the wallaroo and grey kangaroo are based on differences in the importance of steep slope areas. Wallaroo utilize steep slope areas extensively and rarely occur in woodland/grassland areas more than a short distance from the slopes. Grey kangaroo, on the other hand, avoid the steep slope areas and utilize all areas of woodland and areas of grassland within a short distance of woodland. The major differences in habitat use during feeding periods between the two study areas for both species were related to the effects of differences in the quality of pasture on the two areas. Habitat use during sheltering periods differed little between the two study areas for both species.

CHAPTER 6

ASPECTS OF REPRODUCTION AND MORTALITY

Data on reproduction and mortality were gathered, where possible, in order to investigate whether any differences might exist in these aspects between the two study areas because of the different levels of food quality and abundance, different densities of populations and differences in the management of grey kangaroos on these areas.

6.1 Fecundity of females

Twenty nine female wallaroo and twenty nine grey kangaroo on Lana, and fifteen grey kangaroo and nine wallaroo on Newholme were shot and examined during the course of the study. The pouch of each shot female was examined. Presence of a pouch young was noted and the female's teats were examined to determine whether or not they were lactating. If there was no pouch young and a lactating teat was present it was assumed that the female was suckling a young-at-foot. Females with no everted teats and no pouch young present were considered to be sexually immature. Pes and tail length of pouch young were measured and tables given in Kirkpatrick (1965b) were used to estimate age. Weight of pouch young was also measured whenever possible.

There was only one sexually mature female found, out of the seventy shot during the course of the study, in anoestrous. This was a grey kangaroo on Lana during winter in 1978. It is probable that this animal had stopped reproductive cycling due to her poor nutritional status. This was probably due to unseasonal climatic conditions and would not be a normal seasonal occurrence (see Chapter 7). For the grey kangaroo all females examined that were less than 1.8 years old were immature and all females greater than 2.2 years old were mature. On Newholme two out of the three female grey kangaroo in the 1.8 to 2.2 years of age group were sexually mature and on Lana three out of the six female grey kangaroo in this age group were sexually mature. There is thus no evidence of differences in the age of sexual maturity for female grey kangaroo on the two properties. No immature female wallaroo were sampled on Newholme. There is, therefore, no evidence of differences in female fecundity rates between the two study areas for either species.

6.2 Pouch young development and mortality

To test whether mortality of pouch young differed between Lana and

Newholme, the pouch young sampled were grouped into age classes and the proportions in each age class compared. If the rate of increase of pouch young mortality with age differs between the two study areas there should be a difference in the proportion of pouch young in different age classes. The results are shown in Table 6.1. Unfortunately the number of pouch young sampled are inadequate to make any comparison between properties. The higher proportion of pouch young sampled during winter on Newholme in comparison to Lana will also affect the results.

Table 6.1 Number of pouch young of grey kangaroo and wallaroo sampled in three age classes on Lana and Newholme

SPECIES	PROPERTY	AGE CLASS		
		< 100 days	100-200 days	> 200 days
Grey kangaroo	Lana	2	4	5
	Newholme	1	4	8
Wallaroo	Lana	4	4	3
	Newholme	4	4	1

To investigate whether any differences exist in growth rate of pouch young between the two study areas, the regression of weight against pes length was compared for the two properties (Fig. 6.1 and Fig. 6.2). From visual examination of the two curves there appears to be no difference in pouch young growth rates between study areas for either species. It is possible that if growth rate is lowered both weight and skeletal development will be impaired. However most investigations of pouch young growth rates in kangaroos (e.g. Ealey, 1967d; Sadleir, 1963; Frith and Sharman, 1964) have concluded that growth is only affected by periods of severe nutritional stress on the mother. Sharman *et al.* (1964), for example, have suggested that the growth of pouch young in red kangaroo approximates to an "all or none" phenomenon.

The weight-for-age relationships for grey kangaroo and wallaroo pouch young are given in Fig. 6.3 and Fig. 6.4. The growth rate for grey kangaroo pouch young is less than for wallaroo, i.e. for a given age wallaroo pouch young weigh more than grey kangaroo pouch young. Average length of pouch life is also longer for the grey kangaroo (297 days) than for wallaroo (254 days) (Kirkpatrick, 1965b). The longer pouch life in the grey kangaroo leads to a heavier weight for young-at-foot when they finally leave the pouch (see Table 6.2). Moreover the weight of the pouch young at the end of pouch life as a percentage of the fully grown

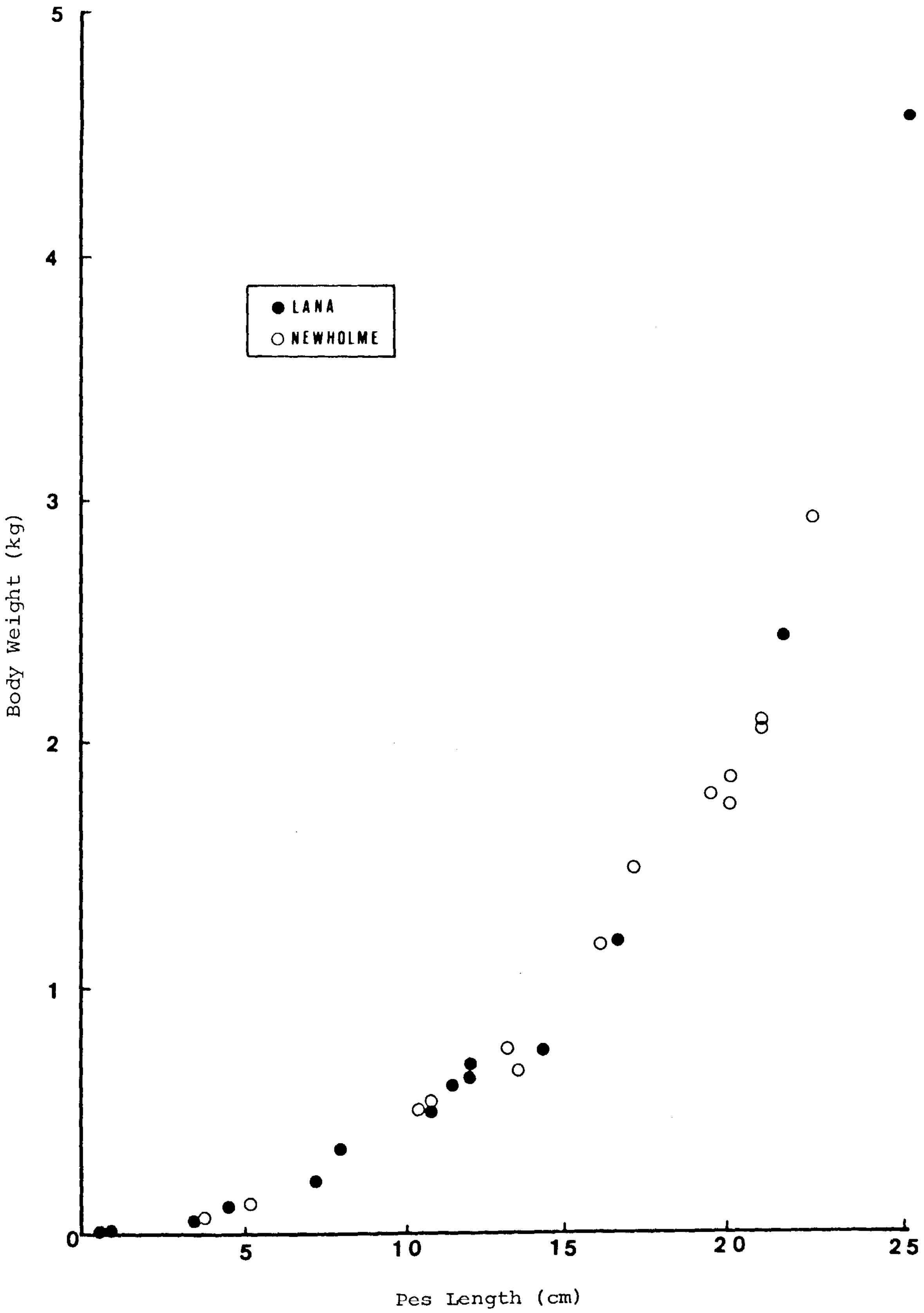

Fig. 6.1. Relationship between body weight and pes length for grey kangaroo pouch young.

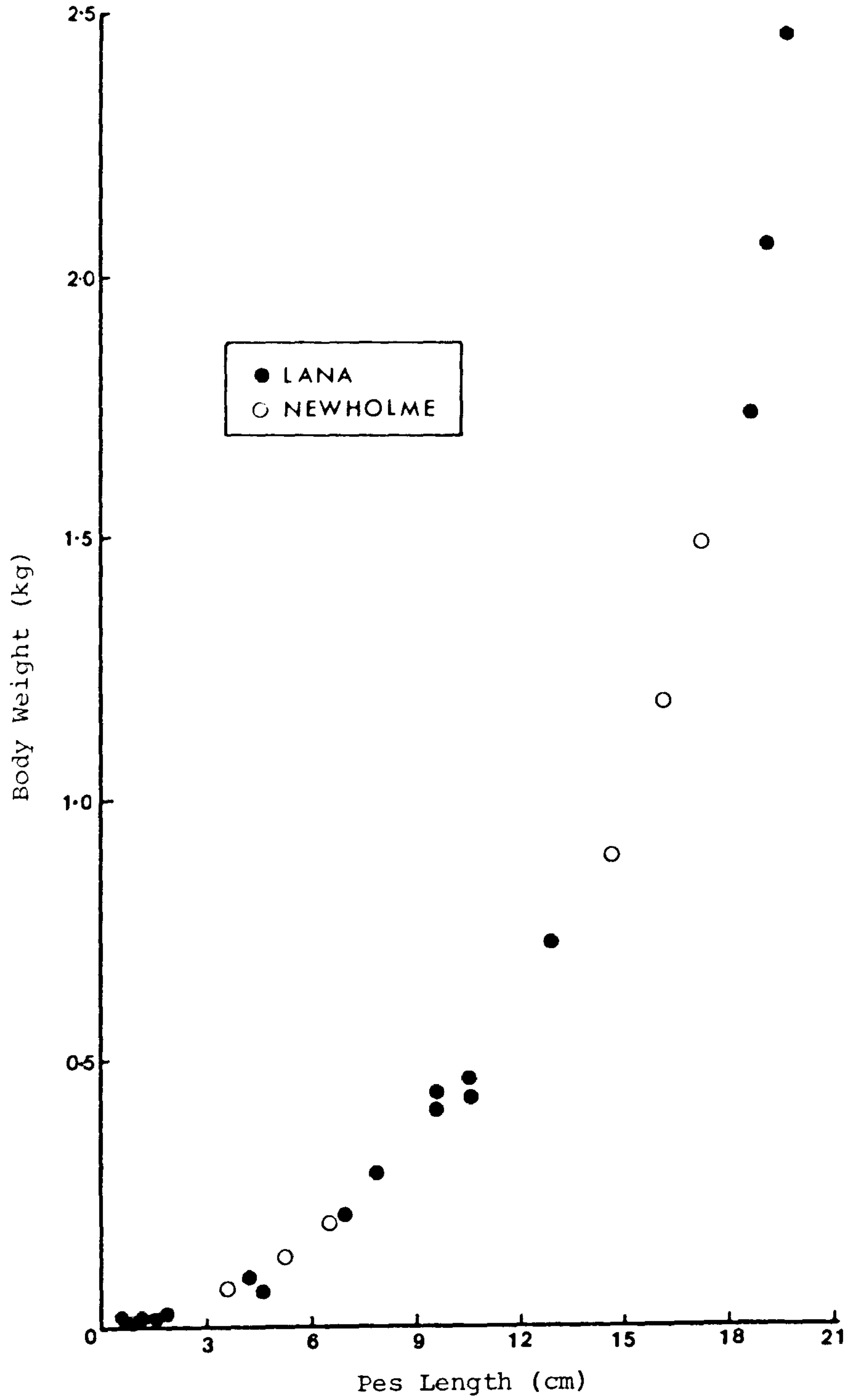

Fig. 6.2. Relationship between body weight and pes length for wallaroo pouch young.

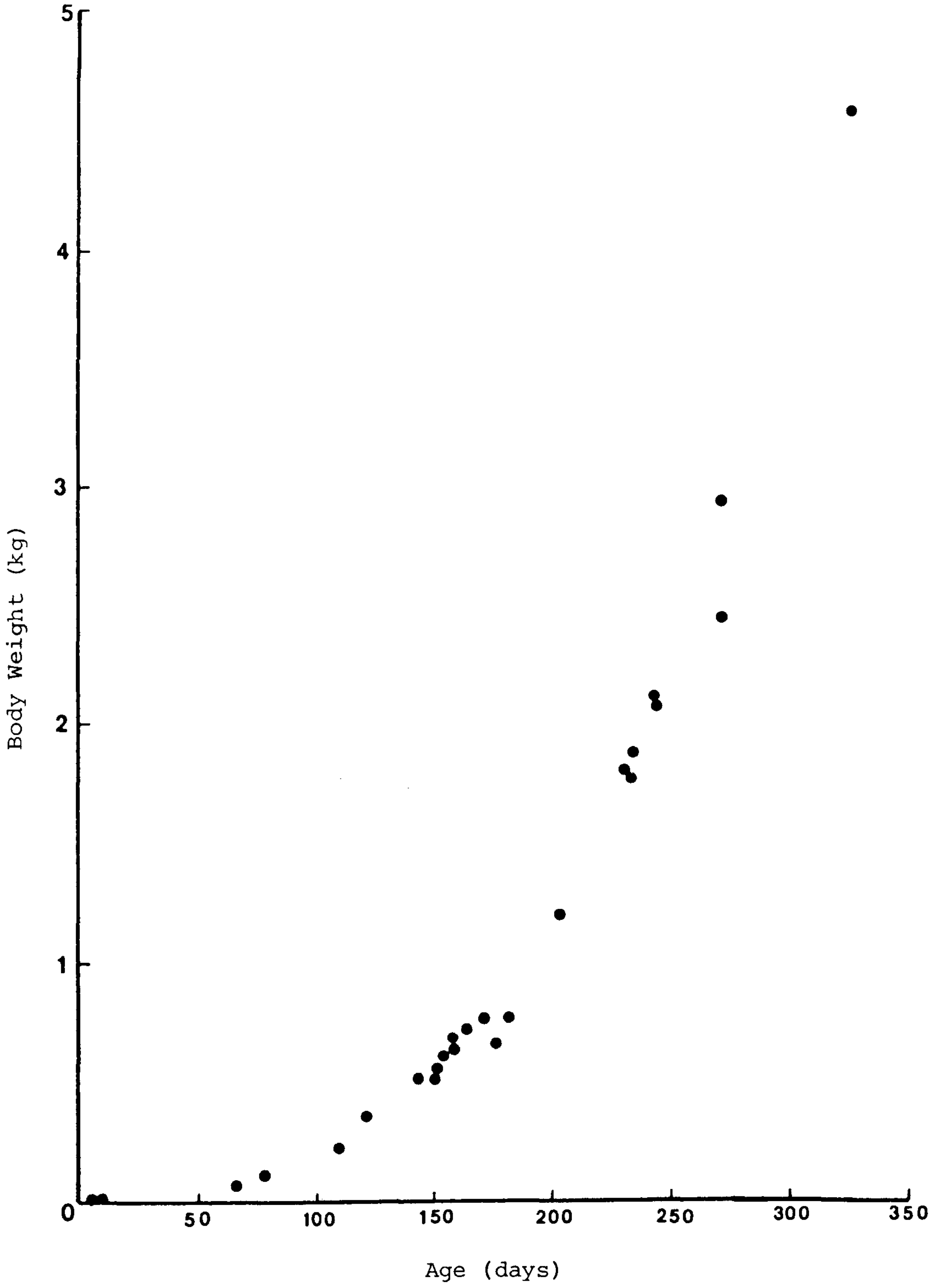

Fig. 6.3. Relationship between body weight and age for grey kangaroo pouch young.

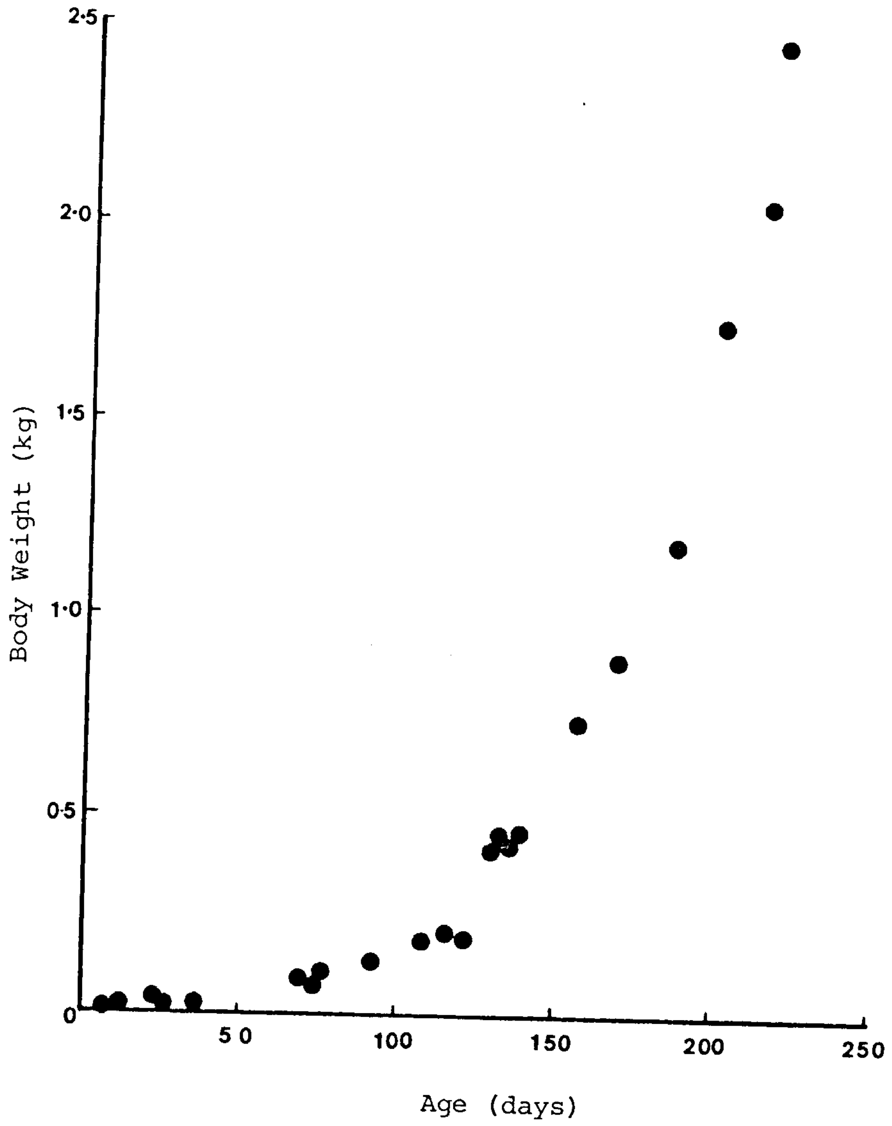

Fig. 6.4. Relationship between body weight and age for wallaroo pouch young.

Table 6.2 Weight of pouch young at the end of pouch life, weight of fully grown adult female and pouch young weight at the end of pouch life as a percentage of the fully grown adult female weight for the grey kangaroo and wallaroo. Values in brackets are the number of individuals in the sample.

	Wallaroo	Grey Kangaroo
Pouch young weight at end of pouch life (kg)*	3.85 (2)	5.77 (4)
Fully grown adult female empty body weight (kg)[†]	19.2 (14)	24.0 (15)
Weight of pouch young at end of pouch life as a percentage of full grown adult female weight	20.1	24.0

* Data from Kirkpatrick (pers. comm.).

[†] Empty body weight = body weight - stomach contents weight. The fully grown adult female weight was estimated as the mean weight of females four years of age or older.

adult female weight is greater for the grey kangaroo than the wallaroo. This result is the opposite of the trend for mammals of decreasing newborn young weight in relation to maternal weight with increasing maternal weight shown by Leitch *et al.* (1959). Presumably pouch young weight at the end of pouch life and length of pouch life have been selected to maximize the number of young-at-foot which will survive to maturity and breed. Thus it appears that grey kangaroo newly-emerged young-at-foot need to have a higher weight per se and a higher weight in relation to a fully grown adult female in order to maximize their chance of surviving in comparison to wallaroo. Most pouch young emerge during spring (see section 6.3). Since wallaroo diets contain a greater proportion of higher quality items (e.g. legumes, sheep camp grasses), wallaroo young-at-foot may be better able to survive at a lower weight than grey kangaroo young-at-foot. Also, since the largest proportion of adult females will be carrying large joeys during winter/early spring in both species, the growth rate of grey kangaroo pouch young may be lower than for wallaroo because of the mothers greater dependence on a larger intake of lower quality items as a feeding strategy (see Chapter 4).

Since samples were inadequate to assess pouch young mortality, the combined mortality of pouch young and young-at-foot was examined by comparing the proportions of adult females who were accompanied by young-at-foot on the two properties. Kangaroos included in the sample were those seen on transect counts. It was not possible to spend the amount of time needed to classify individuals as to age and sex for grey kangaroo on these transect counts. Hence data on the proportion of adult females with young-at-foot were only collected for wallaroo. On Newholme, of the 155 sightings of adult females, only 18 (11.6%) were accompanied by young-at-foot, in comparison to Lana where 343 (30.2%) of the 1135 sightings of adult females were of a female accompanied by a young-at-foot. This difference in the proportion of adult females with young-at-foot between properties is statistically significant ($\chi^2 = 23.4$, df = 1, $p < 0.001$). Since fecundity of females is probably no different between the two areas, pouch young mortality and/or mortality of young-at-foot must be greater on Newholme than on Lana.

6.3 Distribution of births through the year

6.3.1 Eastern Grey Kangaroo

The date of birth of pouch young was calculated using their estimated ages. The number of biths recorded in each month is shown in Fig. 6.5 for combined samples from Lana and Newholme[†]. Although sample size is small, it is likely that more births occur in November and December than in other months although births are likely to occur during all months.

Another study in the New England region (Kavanagh, 1977), with a larger number of females included in the sample, showed a similar trend of distribution of births per month although a greater proportion of births were recorded in January and February than in the present study. Poole (1973) also found a drop in the births occurring in autumn and winter in a grey kangaroo population (*M. giganteus* and *M. fuliginosus*) in central New South Wales. Since the pouch life of grey kangaroo extends for approximately ten months (Poole and Pilton, 1964; Kirkpatrick, 1967), most young will emerge from the pouch during spring. Emergence of young in spring probably maximizes the time available to the young for growth before periods of reduced availability of food (i.e. winter) ensue. It is probable that the older young-at-foot are during winter the more likely it is that they will be able to survive this period of nutritional stress. The poor condition of two young-at-foot sampled in winter who had finished pouch life in autumn (see Chapter 7) is evidence to support this. The older an animal the lower its growth rate is and the lower are its requirements per unit body weight. The reproductive strategy of the grey kangaroo ensures that the highest lactation demands by the pouch young must be endured

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[†] When the data were corrected for differences in the number of mature females sampled in each season the results were very similar to the uncorrected results and so only the original data is presented.

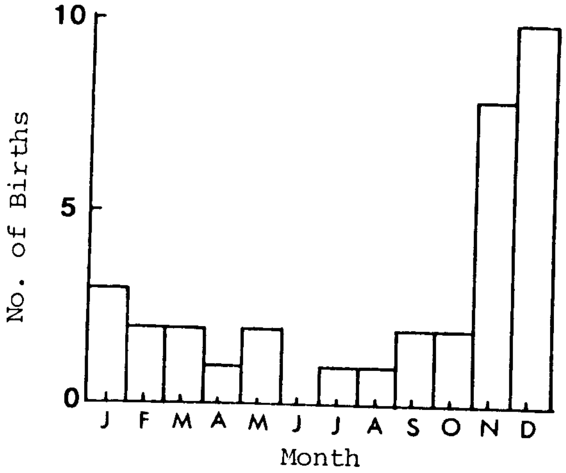

Fig. 6.5. Distribution of births by month for the grey kangaroo.

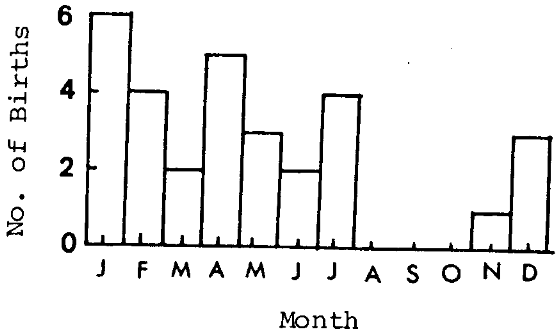

Fig. 6.6. Distribution of births by month for the wallaroo.

by the mother during periods of reduced availability of food.

6.3.2 Wallaroo

The number of births recorded in each month for wallaroo on Lana and Newholme are given in Fig. 6.6. Births appear to be more likely in some months than in others. During August to October, for example, no births were recorded. Since pouch life is approximately eight and a half months (Kirkpatrick, 1968) the absence of births during August to October probably means that few young will finish pouch-life just prior to winter or during early winter. Most births are likely to occur in spring or early summer. Since the sample size was small the proportion of females with young-at-foot seen each month was examined (Table 6.3). On Lana the ratio of adult female to adult female with young-at-foot is not constant over all months ($\chi^2 = 40.8$, df = 11, $p < 0.001$). The highest proportion of adult females with young-at-foot was found in October. The three month period with the lowest proportion of adult female with young-at-foot was in July to September. Although sample size is smaller for Newholme there appears to be a similar pattern of occurrence of young-at-foot. Thus these results agree with the pattern obtained from the distribution of births per month.

Table 6.3 Percentage of sightings of wallaroo adult females each month in which the female was accompanied by a young-at-foot. Figures in brackets are the total number of adult females sighted each month.

MONTH	PROPERTY	
	LANA %	NEWHOLME %
JANUARY	28.4 (67)	13.6 (22)
FEBRUARY	42.6 (54)	0 (3)
MARCH	36.5 (85)	14.3 (14)
APRIL	39.3 (89)	14.3 (14)
MAY	34.5 (55)	40.0 (5)
JUNE	30.4(112)	11.8 (17)
JULY	20.0(150)	6.6 (15)
AUGUST	30.9 (94)	0 (3)
SEPTEMBER	19.0(137)	4.8 (22)
OCTOBER	45.7(105)	50.0 (12)
NOVEMBER	20.7 (82)	5.9 (18)
DECEMBER	30.5(105)	0 (10)

Distribution of births of *M. robustus* recorded in north-west New South Wales by Russell and Richardson (1971) was not significantly different than that expected from equal numbers of births in all months. The rainfall during their study was evenly spread over all months. Ealey (1962) found a decrease in number of births recorded in December and January for *M. robustus* in the Pilbara region of Western Australia. In his study most rain fell in the summer months. Seasonality of climatic conditions will thus probably influence the occurrence of seasonality of births and pouch young emergence. In the red kangaroo, for example, which lives in areas where rainfall is variable in time and space, breeding occurs continuously unless interrupted by periods of lengthy drought (e.g. Frith and Calaby, 1969).

6.4 Sex ratio of pouch young and young-at-foot

The numbers of each sex recorded for pouch young of grey kangaroo and wallaroo on both properties and for wallaroo young-at-foot are given in Table 6.4. Wallaroo young-at-foot were easily sexed by differences in coat colour. Sex of grey kangaroo young-at-foot seen on transect counts were not recorded. None of the sex ratios obtained differed significantly from parity. Caughley and Kean (1964) have reported a sex ratio for pouch young of a population of grey kangaroo biased towards males. However all other studies on grey kangaroo (e.g. Kirkpatrick, 1965; Poole, 1973) and other kangaroo species (e.g. Frith and Sharman, 1964; Ealey, 1962) have found an even sex ratio for pouch young.

Table 6.4 Number of each sex recorded for pouch young of grey kangaroo and wallaroo and for sightings of wallaroo young-at-foot on both properties.

		Male	Female
Pouch young	Grey kangaroo	12	13
	Wallaroo	16	9
Sightings of young-at-foot	Wallaroo	172	172

6.5 Sexual maturity in males

Other studies (e.g. Sadlier, 1965) have shown that in macropods the testes increase rapidly in size at the time of physiological maturity. The relationship between testis length and weight and age was examined to determine criteria to assess sexual maturity in males. Testis length is plotted against weight and age for the grey kangaroo in Fig. 6.7 and Fig. 6.8. There are two obvious clusters of points in the two figures probably corresponding to sexually mature and immature individuals. Grey kangaroo males were hence classified as sexually mature if greater than two years old (or if weighing more than 22 kg). Testis length is plotted against weight and age for the wallaroo Fig. 6.9 and Fig. 6.10. Male wallaroo were classified as sexually mature if testis length was greater than 3.2 cm.

There does not appear to be as abrupt an increase in testis size at a certain age (or weight) in wallaroo as in grey kangaroo . Testis length is plotted against testis diameter in Fig. 6.11 for the wallaroo and Fig. 6.12 for the grey kangaroo. There is a gap in the regression line for grey kangaroo. This gap is not due to a certain age class not being sampled. It thus probably represents a time of rapid growth of testes. Because growth in this period is rapid the probability of sampling a testis at this stage may be reduced. The regression line for the wallaroo appears more continuous. Thus in wallaroo testes growth appears to be continuous until sexual maturity is reached. In grey kangaroo testes appear to grow very little in sub-adults until near the time of sexual maturity when rapid growth ensues. These conclusions must remain tentative until larger samples are examined.

The gap in the regression of testis length against testis diameter for the grey kangaroo may be the result of rapid testis growth from a sub-adult to an adult stage occurring at a time of year when animals were not sampled. It is possible that this rapid growth might occur during or just before the time when most females are coming into oestrus. From the distribution of births over the year for grey kangaroo (Fig. 6.5), it appears that most females will come into oestrus in spring and early summer. Samples of males around this time were obtained in August and late November. If rapid testis growth does occur near the time of greatest numbers of oestrous females being found, it is thus likely that rapid testes growth would occur in September, October and/or early November.

It is possible that differences between the two species in testis development may be due to grey kangaroo being a more seasonal breeder than wallaroo. Thus in the more seasonally breeding species (i.e. grey kangaroo) one finds a season where development of immature testes to maturity occurs whereas in the less seasonally breeding species (i.e. wallaroo) testes growth is continuous. From Figs. 6.5 and 6.6 it is possible that the occurrence of births for grey kangaroo is more seasonal than for wallaroo but the sample size is too small to draw any firm conclusions.

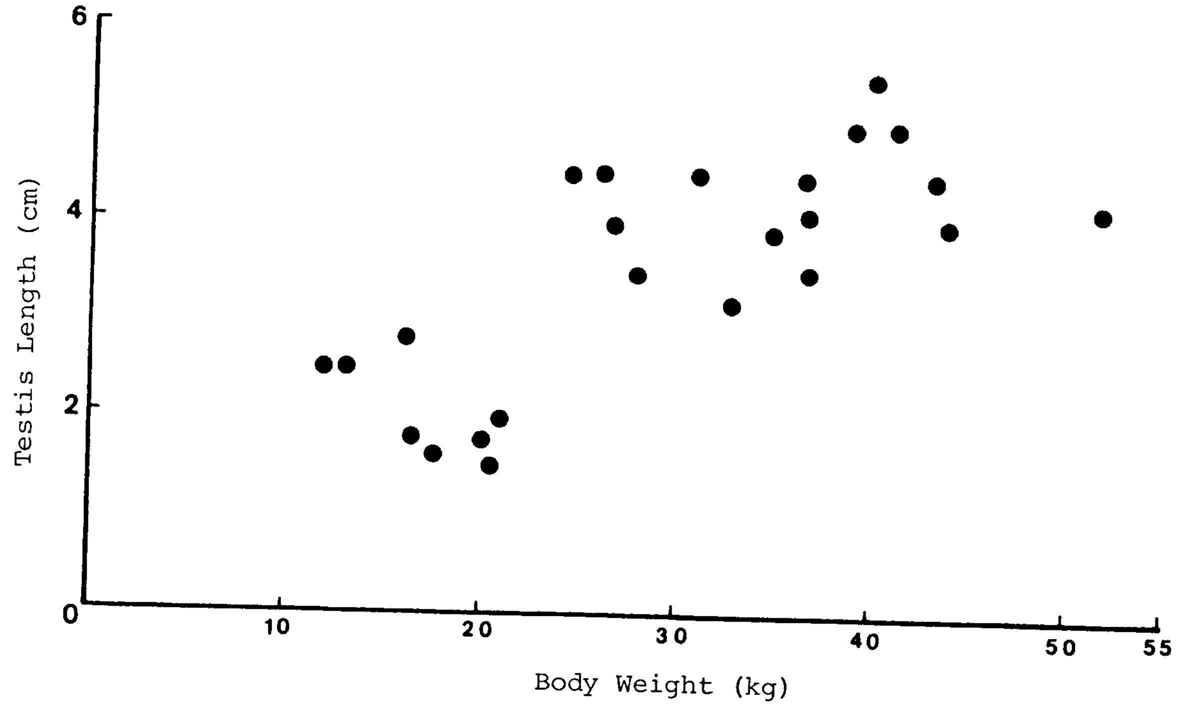

Fig. 6.7. Relationship between testis length and body weight for grey kangaroo.

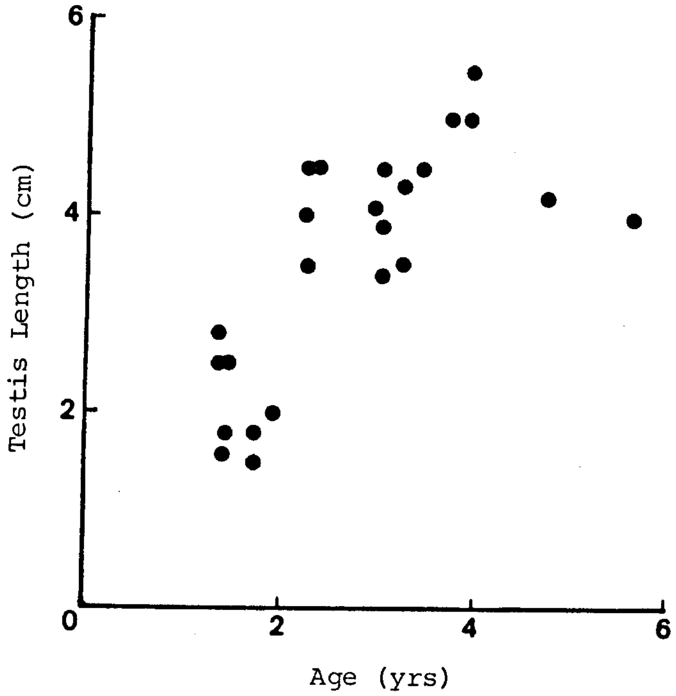

Fig. 6.8. Relationship between testis length and age for grey kangaroo.

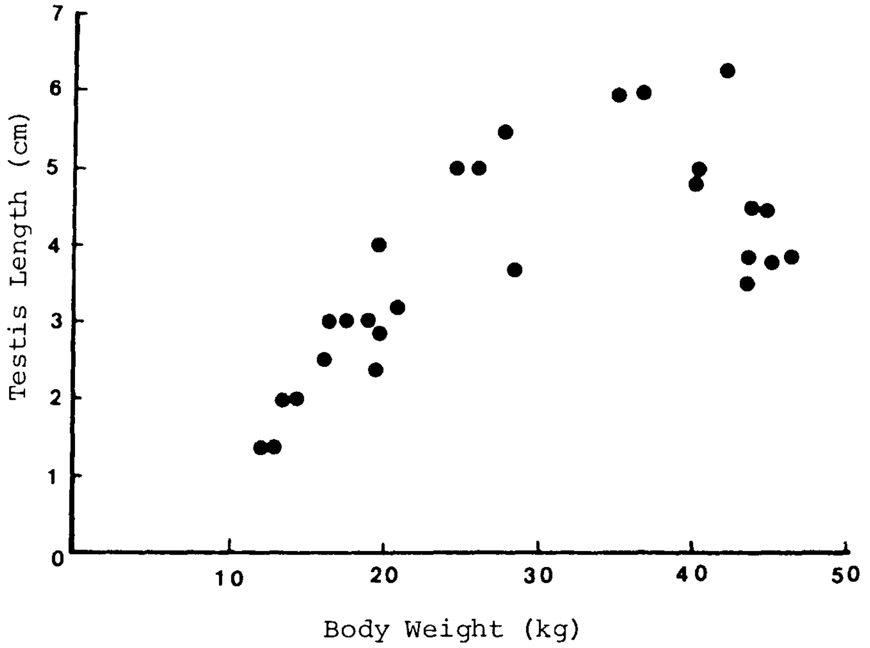

Fig. 6.9. Relationship between testis length and body weight for wallaroo .

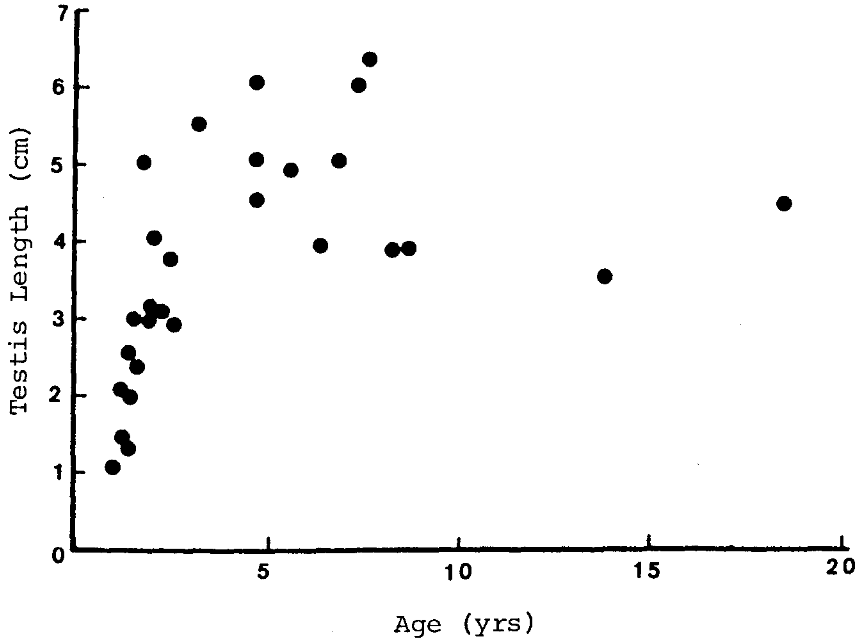

Fig. 6.10. Relationship between testis length and age for wallaroo .

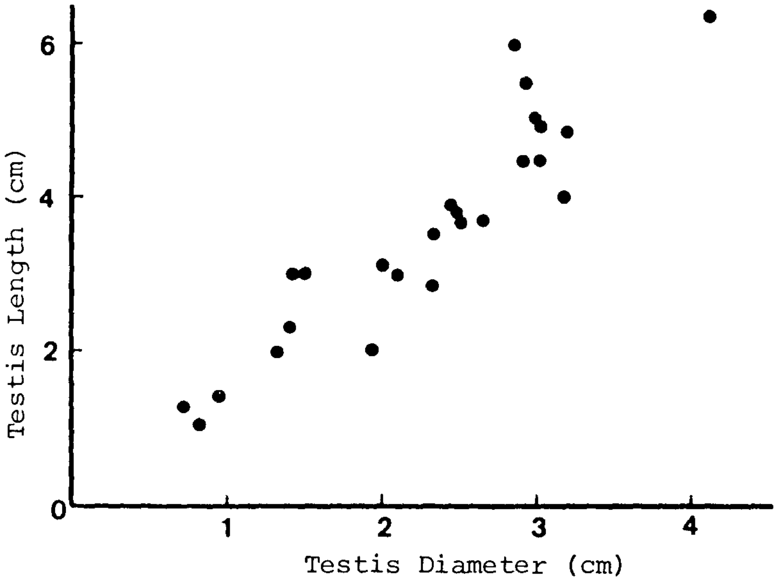

Fig. 6.11. Relationship between testis length and testis diameter for wallaroo.

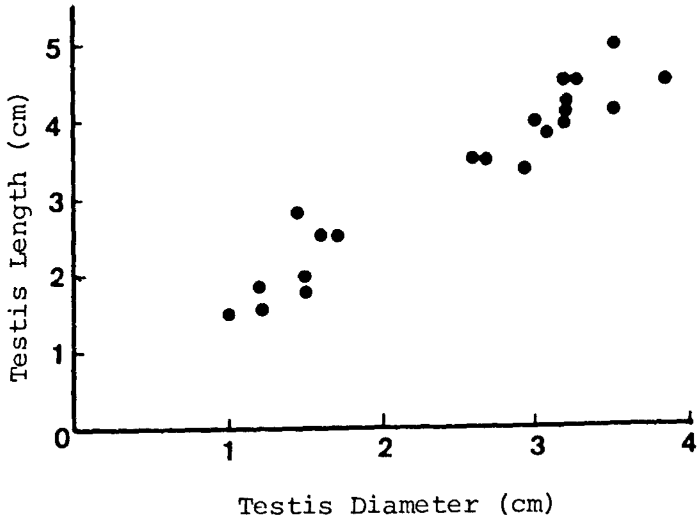

Fig. 6.12. Relationship between testis length and testis diameter for grey kangaroo.