

CHAPTER 7RELATIONSHIP BETWEEN CONDITION AND
QUALITY OF FOOD EATEN

7.1 Introduction

Examination of the factors responsible for changes in condition of herbivorous mammals has proved to be a challenging area of research. For example, the seasonal decline in condition of the quokka on Rottneest Island has been well known and intensively studied for many years (e.g. Barker *et al.*, 1974; Barker, 1961; Storr, 1964; Kitchener, 1972; Ramsay, 1966). Although in many situations the factors responsible for this decline in condition are still not known with any certainty, it seems that energy and/or protein deficiencies are generally involved.

One method of research into the affects of differences in food quality upon herbivore populations which has proved fruitful is a comparison of populations in areas of different range quality (e.g., Smith *et al.*, 1956; Wilson and Hirst, 1978; Klein, 1962, 1965; Seal *et al.*, 1978). Two examples of this approach in an Australian context are the studies of Myers and Bults (1977) and Ealey and Main (1967).

Data on the quality and quantity of food eaten by kangaroos were collected in order to assess the role of food in determining changes in the condition of kangaroos over seasons and between the two study areas.

7.2 Methods

The dates and times of day when the shot samples of kangaroos were obtained are given in section 4.2.1. As soon as an animal was shot blood and urine samples were obtained. Blood samples were obtained by heart puncture and collected in heparinized Vacutainers (Becton-Dickson, Rutherford, New Jersey). Urine samples were obtained by bladder puncture. The blood and urine samples were stored in ice. Carcasses were weighed. In the laboratory the blood haematocrit levels were measured using a micro-haematocrit centrifuge. Half of each blood sample was then centrifuged and the plasma removed. The blood plasma, whole blood and urine samples were then frozen until analysed.

In the laboratory the kangaroo's pes, leg and forearm lengths were measured. The pes length was measured along the plantar surface from the insertion of the claw into the fourth digit to the back of the heel. The forearm length was measured from the proximal extremity of

the radius and ulna to the outer edge of the wrist joint with the manus pushed down. The leg length was measured from the bottom of the lateral calcaneal ridge of the calcaneum of the tibia to the outer edge of the articular cartilage of the distal end of the femur (see Fig. 7.1). In males testis length and diameter were measured (see Chapter 6). The stomach was removed and weighed, then opened and a sample of its contents was taken for dietary analysis. Another sample ($\approx 200-400$ g) was taken in the same manner as for the dietary sample (see section 4.2.1). The stomach was then emptied of all remaining contents and stomach organ weight recorded. The stomach contents sample was weighed in a beaker then placed in an oven at 85°C for 36 hours or until dry. The sample was reweighed, then ground in a mill (sieve mesh 1 mm) in preparation for nitrogen, fibre and ash analysis. A sample of faecal pellets (≈ 30 g) was obtained from the rectum as close to the cloaca as possible. The faecal sample was treated in the same manner as the stomach contents sample. The liver and spleen were removed and weighed. One kidney from each animal was weighed with the perinephric fat attached and then reweighed after removal of all fat. The perinephric fat was taken as fat deposited around the kidney and extending from the kidney anteriorly and posteriorly. This body of fat was always continuous and separate from other fat deposits. The leg muscle and bone were weighed, then the muscle was taken off and the bone weighed.[†] The femur was opened and a sample of bone marrow from the middle portion of the bone (i.e. excluding the haemopoietic tissue) was placed in a petri dish, weighed and then dried in an oven at 85°C for 24 hours and then reweighed. The skulls were kept and later used to age animals using the regressions from Kirkpatrick (1965b) relating molar index of skulls to age.

7.3 Results

The amount of time required to process kangaroos and analyse samples obtained limited the number of animals which could be included in the sampling program. On Newholme the amount of time required to find and stalk animals also limited sample size. Unfortunately these small sample sizes were sometimes insufficient to show samples to be statistically significantly different even when the trend for a given parameter was consistent with other trends.

[†] The muscles and bones included in the leg muscle to bone ratio are given in Johnson (1977, p.66).

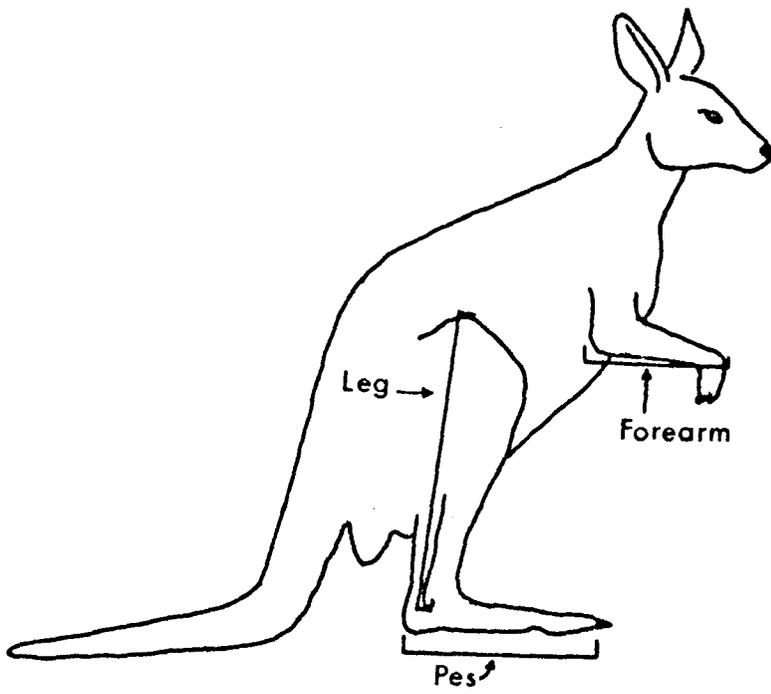


Fig. 7.1. Diagram showing the positions where body measurements were taken.

7.3.1 Assessment of the quality and quantity of food eaten

(a) Food quality

The dried stomach contents were analysed for nitrogen and fibre to assess the quality of the diet. Nitrogen and fibre were used as indices of the quality of the diet for reasons given in section 3.1.2. In mammals with forestomach fermentation, the stomach contents, due to bacterial action, contain higher nitrogen concentrations than the plants eaten. To examine whether the unwashed stomach contents were a good index of changes in nitrogen content of foodstuffs, some of the stomach samples were washed over a sieve (100 μm) and their nitrogen content was compared to the nitrogen content of the unwashed stomach sample. The results for grey kangaroo shot on Newholme and Lana during the second winter sample are given in Fig. 7.2. There was a significant correlation between the two measures ($r = 0.97$, $p < 0.001$). The relationship between nitrogen levels in washed and unwashed stomach samples was also examined for wallaroo using five stomach samples collected in different seasons and from both study areas covering a wide range of nitrogen levels. There was also a highly significant correlation between nitrogen levels of washed and unwashed stomach contents for the wallaroo ($r = 0.998$, $p < 0.01$, Fig. 7.2). When the regression lines for the two species were compared, although the slopes of the lines were not significantly different, the intercepts differed significantly ($F(1,20) = 13.8$, $p < 0.01$). For a given level of nitrogen in the plants eaten, wallaroo stomachs contained a greater concentration of total nitrogen than did grey kangaroos. Since the unwashed stomach samples were used to assess nitrogen levels of the diet, a comparison of the nitrogen content of the stomachs of the two kangaroo species must be interpreted with care as a higher nitrogen content in wallaroo stomachs may not necessarily mean that the nitrogen content of the plants eaten was higher than in the grey kangaroo.

The results of the analysis of nitrogen content of unwashed stomachs are given in Table 7.1. There were no significant differences in the nitrogen levels of stomach contents between the two kangaroo species on either property. However both kangaroo species had higher levels of nitrogen in the stomach on Lana compared to Newholme in all seasons. Changes in nitrogen content of stomachs also occurred between some seasons. On Lana the highest nitrogen levels in stomachs occurred in summer and the lowest levels were recorded in autumn. The highest nitrogen level in a wallaroo stomach (4.24%) was recorded for an individual on Newholme during the second winter sample. When this individual is excluded, the mean nitrogen level of stomach contents for

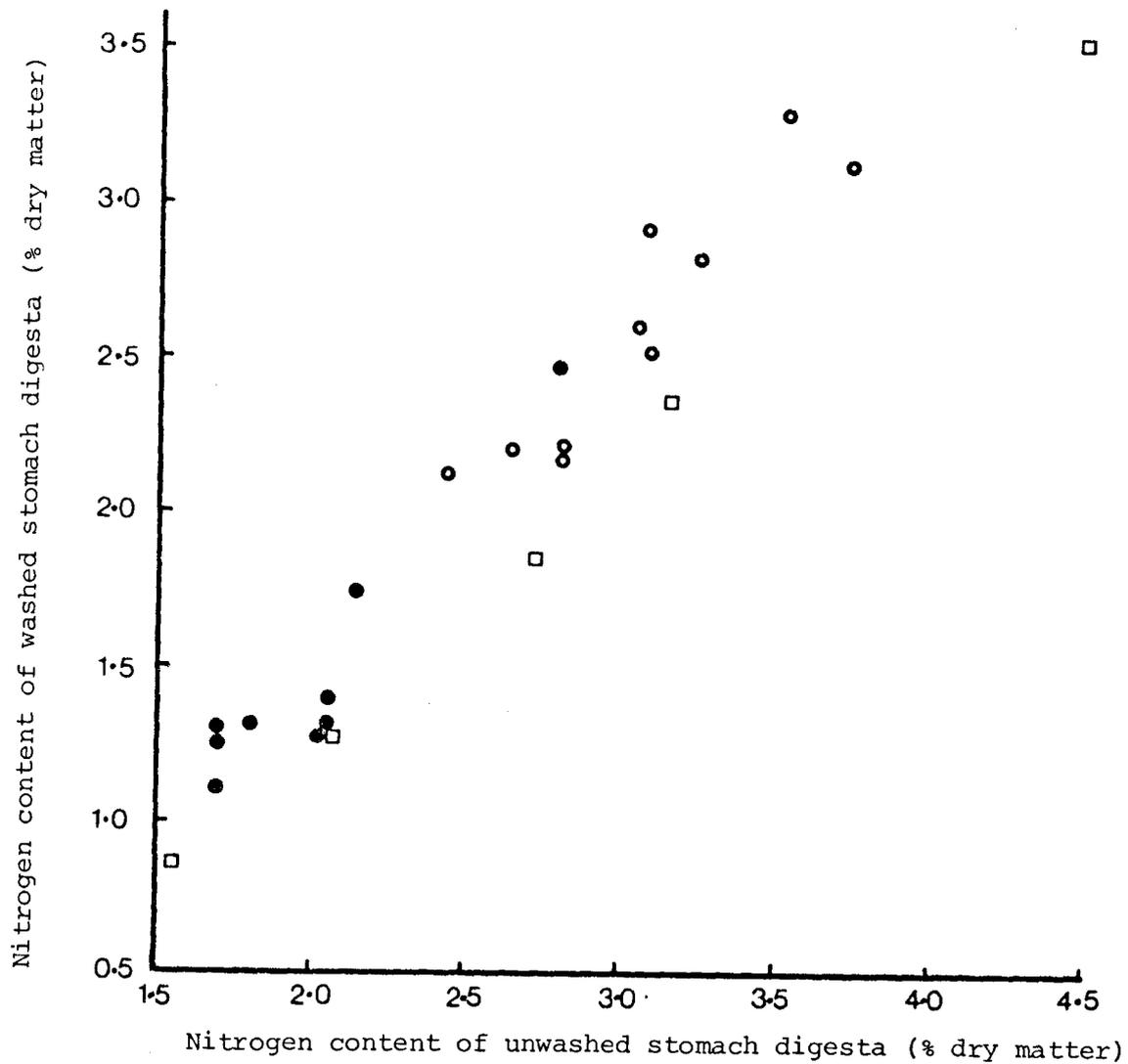


Fig. 7.2. Relationship between the nitrogen content of washed and unwashed stomach digesta for the grey kangaroo and wallaroo.

○ Grey kangaroo; Lana, August 1979.

● Grey kangaroo; Newholme, August 1979.

□ Wallaroo; various seasons and both study areas.

Grey kangaroo: $Y = 1.061X - 0.631$

Wallaroo: $Y = 0.993X - 0.740$

where Y = nitrogen content of washed stomach digesta

and X = nitrogen content of unwashed stomach digesta

Table 7.1 Nitrogen levels (g/100 g dry matter) in the stomach contents of the grey kangaroo and wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	3.05 \pm 0.08 (49)	3.15 \pm 0.08 (49)	2.12 \pm 0.10 (21)	2.44 \pm 0.18 (18)
Summer	3.67 \pm 0.13 (10)	3.55 \pm 0.09 (10)	2.76 \pm 0.04 (6)	2.91 \pm 0.11 (6)
Autumn	2.44 \pm 0.07 (10)	2.49 \pm 0.09 (10)	-	-
Winter 1	3.01 \pm 0.19 (10)	3.04 \pm 0.24 (10)	2.01 \pm 0.13 (6)	2.09 \pm 0.22 (7)
Winter 2	3.04 \pm 0.12 (10)	3.40 \pm 0.14 (10)	1.98 \pm 0.12 (9)	2.36 \pm 0.50 (5)
Spring	3.07 \pm 0.08 (9)	3.28 \pm 0.10 (9)	-	-

WALLAROO TO GREY KANGAROO

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

LANA TO NEWHOLME

WALLAROO overall [†]	***	GREY KANGAROO overall [†]	***
S	***	S	***
W1	**	W1	**
W2	**	W2	***

SEASONAL COMPARISON

LANA

Wallaroo		Grey Kangaroo	
S-A	***	S-A	***
A-W1	*	A-W1	*
W1-SP	NS	W1-SP	NS
W1-W2	NS	W1-W2	NS
SP-S	NS (p = 0.056)	SP-S	**
A-W2	***	A-W2	***
W2-SP	NS	W2-SP	NS

NEWHOLME

Wallaroo		Grey Kangaroo	
S-W1	**	S-W1	***
W1-W2	NS	W1-W2	NS
S-W2	NS	S-W2	***

The following symbols also apply to all other tables in this Chapter.

S	= Summer	NS	= no significant difference
A	= Autumn	*	= p < 0.05
W1	= Winter 1 (1978)	**	= p < 0.01
W2	= Winter 2 (1979)	***	= p < 0.001
SP	= Spring		

[†] used only seasons sampled on both study areas for this comparison.

wallaroo on Newholme during the second winter was 1.89%.

Correlations between the nitrogen concentration of feed and faeces have been found for animals in the laboratory (euro and red kangaroo, data from Hume (1974); wallaroo, Foley (1977)). In the present study nitrogen concentration of stomach contents was also found to be correlated with faecal nitrogen (grey kangaroo, $r = 0.88$, $p < 0.001$, Fig. 7.3; wallaroo, $r = 0.71$, $p < 0.001$, Fig. 7.4). The results of the analysis of faecal nitrogen are given in Table 7.2. As with stomach nitrogen, faecal nitrogen was higher on Lana than on Newholme for both species. Faecal nitrogen was significantly higher for the grey kangaroo than for the wallaroo in summer on Lana, and significantly greater for wallaroo than for grey kangaroo in winter 2 on Newholme. Seasonal changes in the concentration of faecal nitrogen occurred with summer levels being highest and autumn levels lowest. Although, with the exception of one individual, there was no increase in the level of stomach nitrogen for wallaroo in winter 2 on Newholme compared to winter 1 or summer, there was an increase in the concentration of faecal nitrogen during winter 2. When the individual with the high level of stomach nitrogen was excluded, the level of faecal nitrogen on Newholme during winter 2 was still high (i.e. 1.55%).

Both total fibre and organic matter fibre content of stomachs were negatively correlated with the level of stomach nitrogen (Grey kangaroo: total fibre, $r = -0.75$, $p < 0.001$; organic matter fibre, $r = -0.71$, $p < 0.001$, Fig. 7.5. Wallaroo: total fibre, $r = -0.66$, $p < 0.001$; organic matter fibre, $r = -0.63$, $p < 0.001$, Fig. 7.6). The results of the analysis of organic matter fibre content of stomachs are given in Table 7.3. Over all seasons where samples were collected on both properties, organic matter fibre was significantly higher on Newholme than on Lana for both species. On each property organic matter fibre content of stomachs was not significantly different between the two kangaroo species. There were no significant differences in organic matter fibre content of stomachs between seasons for either species on Newholme, although the mean values were greater in winter than in summer. On Lana both species exhibited the lowest organic matter fibre levels in stomach contents in summer and the highest levels in autumn. When the individual on Newholme in the winter 2 sample with the high level of stomach nitrogen was excluded the mean organic matter fibre content of stomachs of wallaroo on Newholme in the winter 2 sample was 35.6%. This mean was significantly different ($p < 0.01$) from the mean for the winter 2 sample for wallaroo on Lana (29.5%).

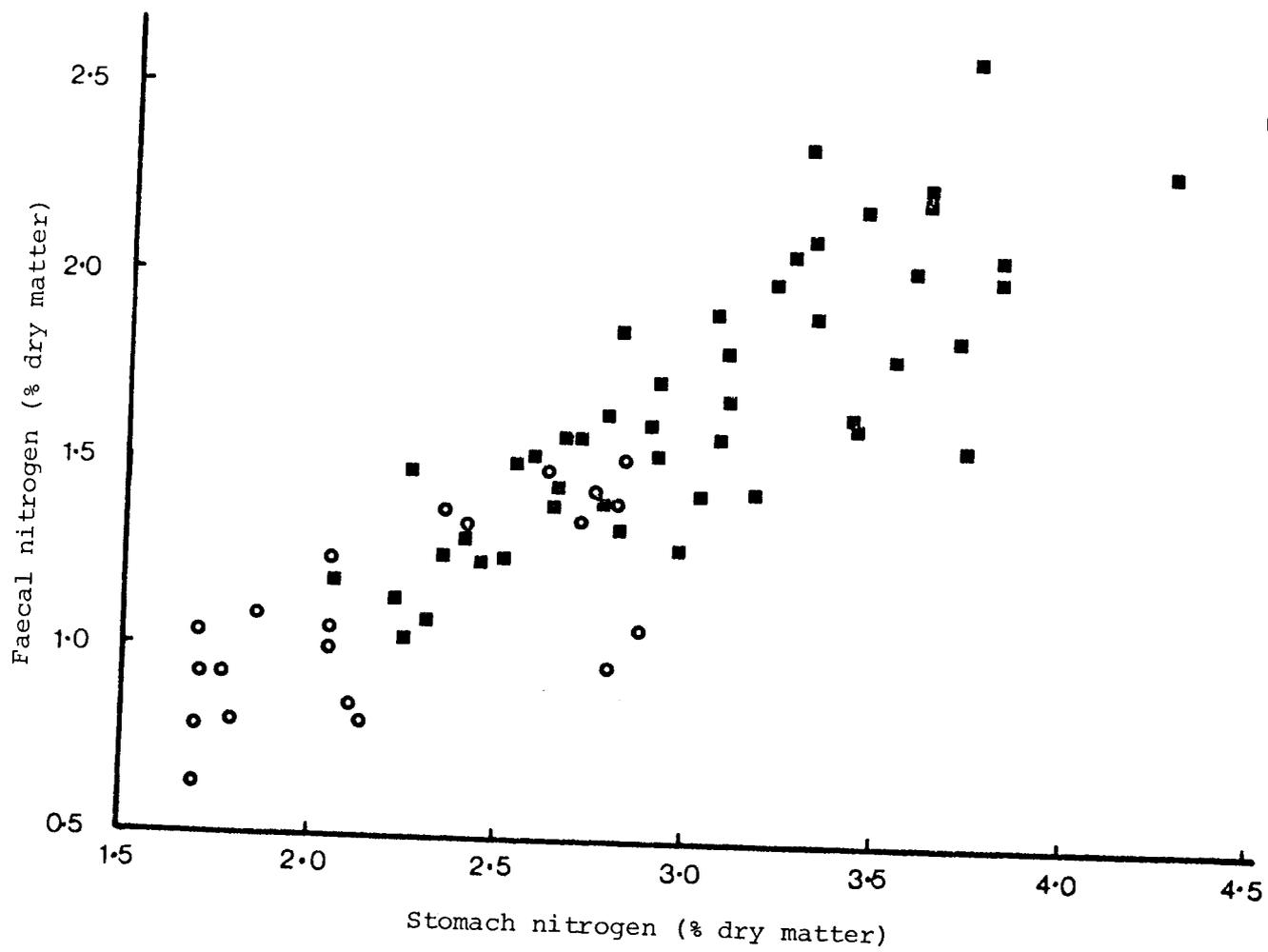


Fig. 7.3. Relationship between stomach nitrogen and faecal nitrogen for the grey kangaroo.

■ Lana
 ○ Newholme

$$\text{Faecal nitrogen} = 0.609 \text{ stomach nitrogen} - 0.185$$

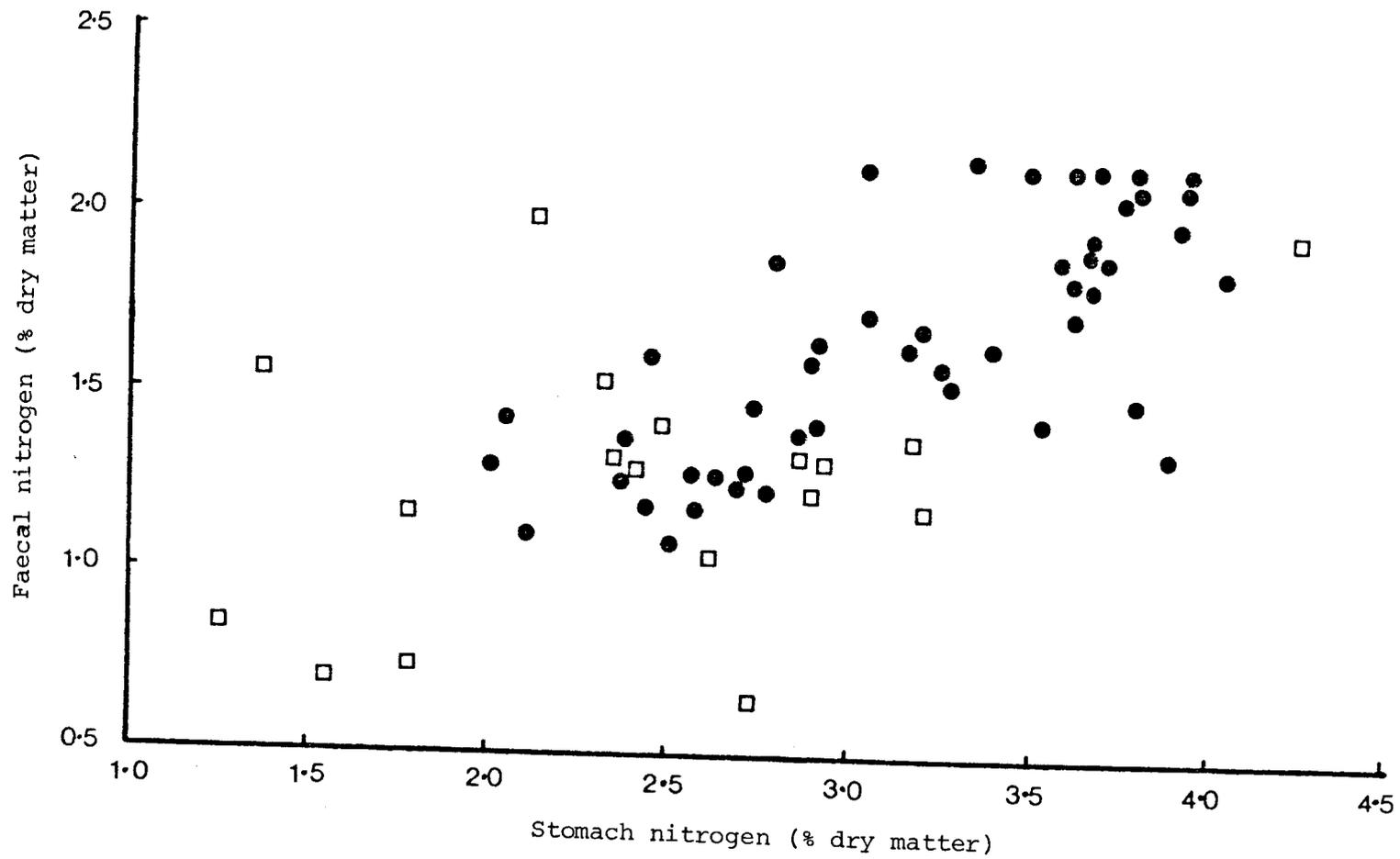


Fig. 7.4. Relationship between stomach nitrogen and faecal nitrogen for wallaroo

● Lana

□ Newholme

$$\text{Faecal nitrogen} = 0.392 \text{ stomach nitrogen} + 0.379$$

Table 7.2 Nitrogen content (g/100 g dry matter) of faecal pellets for the grey kangaroo and wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	1.70 \pm 0.06 (49)	1.64 \pm 0.05 (48)	1.10 \pm 0.06 (21)	1.26 \pm 0.09 (18)
Summer	2.26 \pm 0.06 (10)	2.06 \pm 0.04 (9)	1.38 \pm 0.07 (6)	1.31 \pm 0.03 (6)
Autumn	1.31 \pm 0.06 (10)	1.20 \pm 0.03 (10)	-	-
Winter 1	1.61 \pm 0.09 (10)	1.67 \pm 0.10 (10)	1.06 \pm 0.11 (6)	0.94 \pm 0.11 (7)
Winter 2	1.68 \pm 0.08 (10)	1.68 \pm 0.08 (10)	0.94 \pm 0.06 (9)	1.63 \pm 0.15 (5)
Spring	1.63 \pm 0.06 (9)	1.63 \pm 0.06 (9)	-	-

WALLAROO TO GREY KANGAROO

<u>LANA</u> overall	NS	<u>NEWHOLME</u> overall	NS
S	*	S	NS
A	NS	W1	NS
W1	NS	W2	***
W2	NS		
SP	NS		

LANA TO NEWHOLME

<u>WALLAROO</u> overall	***	<u>GREY KANGAROO</u> overall	***
S	***	S	***
W1	***	W1	**
W2	NS	W2	***

SEASONAL COMPARISON

LANA

Wallaroo

S-A	***
A-W1	***
W1-SP	NS
W1-W2	NS
SP-S	***
A-W2	***
W2-SP	NS

Grey Kangaroo

S-A	***
A-W1	*
W1-SP	NS
W1-W2	NS
SP-S	***
A-W2	**
W2-SP	NS

NEWHOLME

Wallaroo

S-W1	**
W1-W2	**
S-W2	*

Grey Kangaroo

S-W1	*
W1-W2	NS
S-W2	***

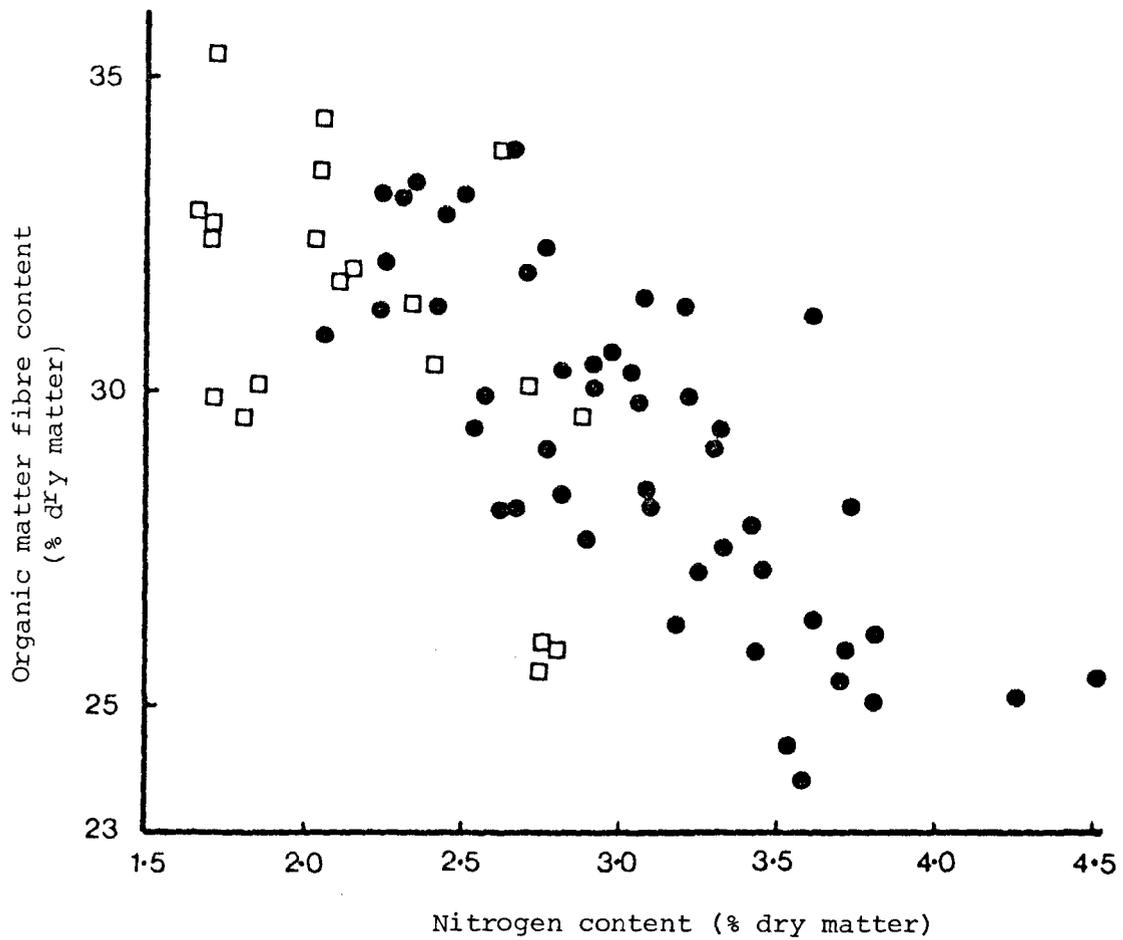


Fig. 7.5. Relationship between the organic matter content and nitrogen content of stomach digesta for the grey kangaroo.

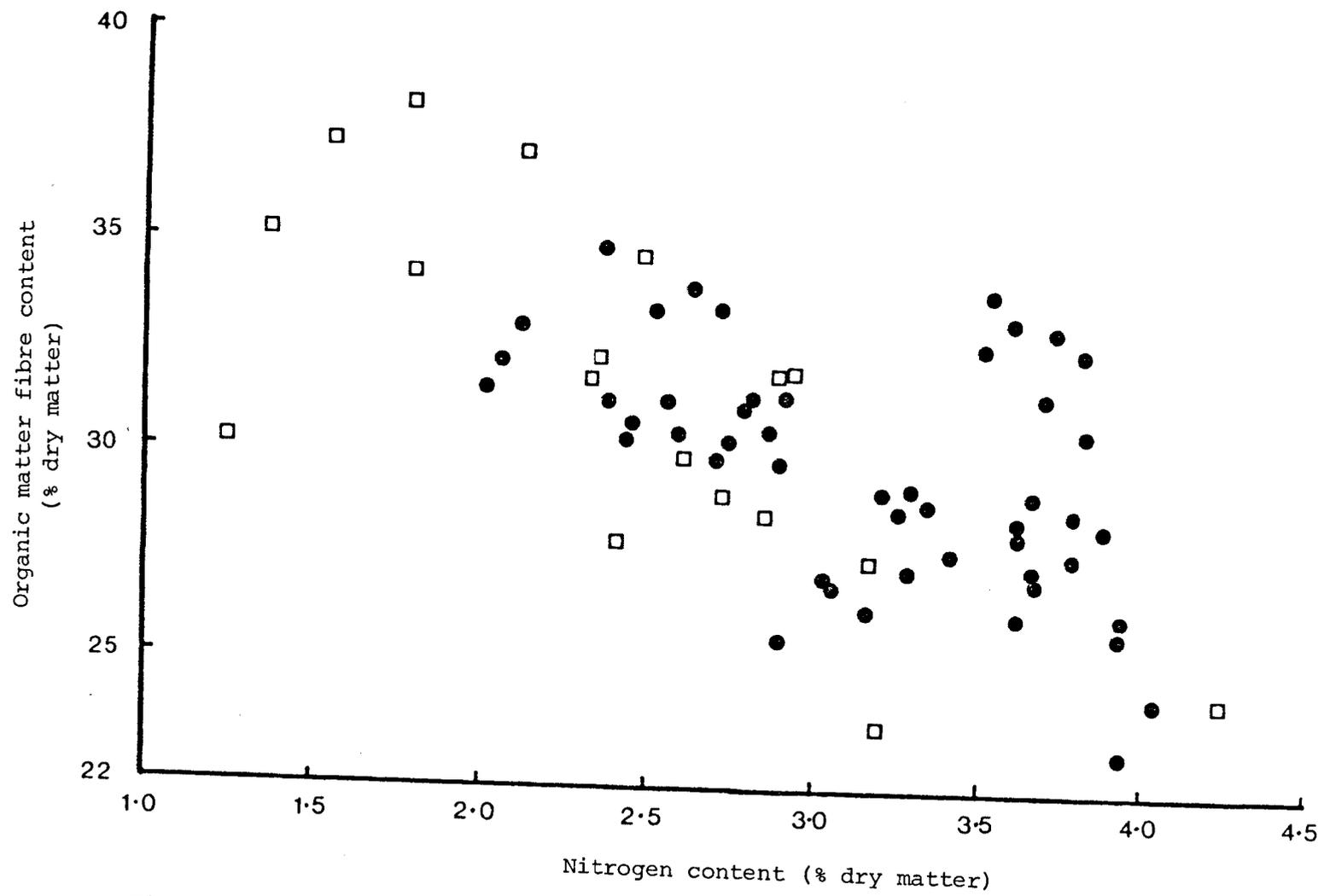


Fig. 7.6. Relationship between the organic matter fibre content and nitrogen content of stomach digesta for the wallaroo.

● Lana
□ Newholme

$$\text{Organic matter fibre content} = 40.00 - 2.99 \text{ nitrogen content}$$

Table 7.3 Organic matter fibre content (g/100 g dry matter) of stomach digesta for the grey kangaroo and wallaroo on Lana and Newholme. Values are means + standard errors. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	29.23+0.39(49)	29.69+0.40(49)	30.90+0.61(21)	31.41+1.01(18)
Summer	28.16+0.74(10)	28.45+0.63(10)	29.26+1.28(6)	29.68+1.62(6)
Autumn	32.00+0.56(10)	31.87+0.55(10)	-	-
Winter 1	27.85+0.83(10)	29.15+1.12(10)	30.99+0.42(6)	31.53+1.25(7)
Winter 2	28.95+0.93(10)	29.52+0.81(10)	31.94+1.01(9)	33.32+2.54(5)
Spring	29.17+0.61(9)	29.42+0.97(9)	-	-

WALLAROO TO GREY KANGAROO

<u>LANA</u> overall	NS	<u>NEWHOLME</u> overall	NS
S	NS	S	NS
A	NS	W1	NS
W1	NS	W2	NS
W2	NS		
SP	NS		

LANA TO NEWHOLME

<u>WALLAROO</u> overall	*	<u>GREY KANGAROO</u> overall	*
S	NS	S	NS
W1	NS	W1	*
W2	NS	W2	*

SEASONAL COMPARISON

LANA

Wallaroo

S-A	**
A-W1	*
W1-SP	NS
W1-W2	NS
SP-S	NS
A-W2	*
W2-SP	NS

Grey Kangaroo

S-A	***
A-W1	***
W1-SP	NS
W1-W2	NS
SP-S	NS
A-W2	*
W2-SP	NS

NEWHOLME

Wallaroo

S-W1	NS
W1-W2	NS
S-W2	NS

Grey Kangaroo

S-W1	NS
W1-W2	NS
S-W2	NS

The results of the analysis of ash content of stomachs are given in Table 7.4. Over all common sampled seasons ash content of stomachs was significantly greater on Newholme than on Lana for grey kangaroo but not for wallaroo. Ash levels of stomachs were not significantly different between the grey kangaroo and wallaroo on Newholme and only significantly different between the two kangaroos in spring on Lana. Only for the grey kangaroo on Lana did significant seasonal differences in ash levels of stomach contents occur.

The dry matter content of stomachs appeared to be dependant on the quality of food eaten for both kangaroo species. The percentage dry matter of stomach contents was negatively correlated with the nitrogen content of stomachs (grey kangaroo, $r = -0.53$, $p < 0.001$, Fig. 7.7; wallaroo, $r = -0.57$, $p < 0.001$, Fig. 7.8) and positively correlated with total fibre content (grey kangaroo, $r = 0.52$, $p < 0.001$, Fig. 7.9; wallaroo, $r = 0.59$, $p < 0.001$, Fig. 7.10). The dry matter content of faeces was also related to the quality of material in the faeces. There was a negative correlation between nitrogen content of faeces and dry matter content of faeces for both species (grey kangaroo, $r = -0.79$, $p < 0.001$, Fig. 7.11; wallaroo, $r = -0.54$, $p < 0.001$, Fig. 7.12). The dry matter content of faeces was also correlated with the dry matter content of stomachs (grey kangaroo, $r = 0.53$, $df = 63$, $p < 0.001$; wallaroo, $r = 0.43$, $df = 62$, $p < 0.001$).

(b) Physiological indices of diet quality

Recycling of urea to the gut has been shown to occur in macropodids (e.g., Brown, 1969) as it does in ruminants (e.g., Houpt, 1959). If energy is not limiting this extra-dietary nitrogen may be used as an additional source of nitrogen for microbial growth in the forestomach (and in the hindgut). Kinnear and Main (1975) have suggested that the ratio of urea-nitrogen to total nitrogen in the urine (the "UR ratio") can be used as an index of changes in urea recycling to the gut. A decrease in the UR ratio appears to be indicative of greater recycling (i.e. the recycling of a greater proportion of the urea synthesized in the liver).

The UR ratios for kangaroo urine collected in the present study are given in Table 7.5. On Lana the mean UR ratio for wallaroo was not significantly different from the mean UR ratio for the grey kangaroo. On Newholme, however, the grey kangaroo had a significantly lower mean UR ratio than did the wallaroo in all seasons except the first winter sample. There was no significant difference between wallaroo UR ratios on Newholme

Table 7.4 Ash levels (g/100 g dry matter) in stomach contents of the grey kangaroo and wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	8.93 \pm 0.69(49)	9.31 \pm 0.68(49)	11.61 \pm 0.70(21)	11.35 \pm 1.22(18)
Summer	10.07 \pm 1.00(10)	9.74 \pm 0.90(10)	11.88 \pm 0.72(6)	10.72 \pm 1.76(6)
Autumn	9.19 \pm 0.74(10)	8.25 \pm 0.71(10)	-	-
Winter 1	9.63 \pm 1.12(10)	9.36 \pm 0.69(10)	11.83 \pm 0.88(6)	13.30 \pm 3.38(7)
Winter 2	8.95 \pm 0.42(10)	9.14 \pm 0.39(10)	11.28 \pm 0.61(9)	9.35 \pm 0.76(5)
Spring	6.54 \pm 0.47(9)	10.17 \pm 1.40(9)	-	-

WALLAROO TO GREY KANGAROO

<u>LANA</u> overall	NS	<u>NEWHOLME</u> overall	NS
S	NS	S	NS
A	NS	W1	NS
W1	NS	W2	NS
W2	NS		
SP	*		

LANA TO NEWHOLME

<u>WALLAROO</u> overall	NS	<u>GREY KANGAROO</u> overall	*
S	NS	S	NS
W1	NS	W1	NS
W2	NS	W2	**

SEASONAL COMPARISON

LANA

Wallaroo

S-A	NS
A-W1	NS
W1-SP	NS
W1-W2	NS
SP-S	NS
A-W2	NS
W2-SP	NS

Grey Kangaroo

S-A	NS
A-W1	NS
W1-SP	*
W1-W2	NS
SP-S	**
A-W2	NS
W2-SP	**

NEWHOLME

Wallaroo

S-W1	NS
W1-W2	NS
S-W2	NS

Grey Kangaroo

S-W1	NS
W1-W2	NS
S-W2	NS

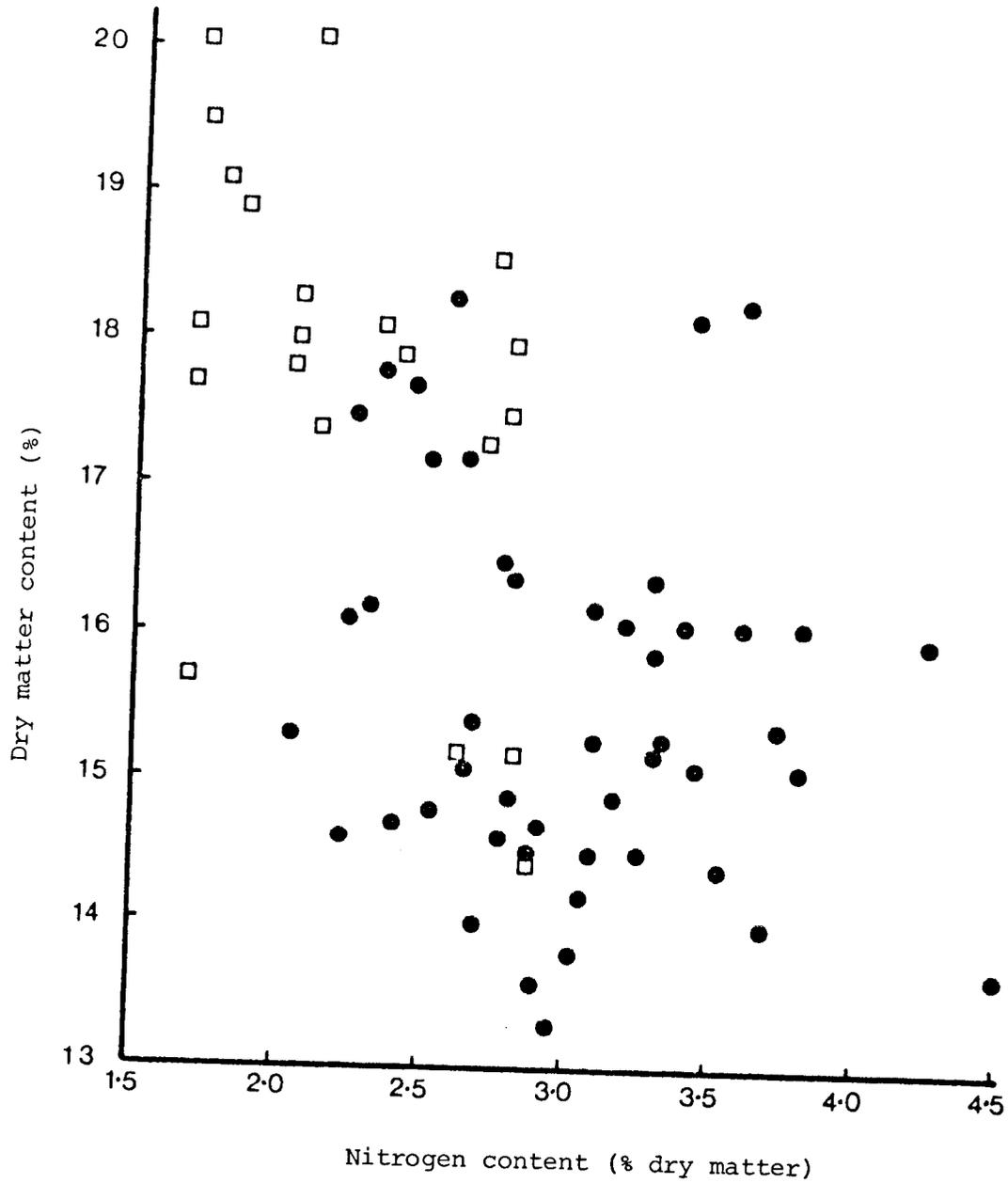


Fig. 7.7. Relationship between the dry matter content and nitrogen content of stomach digesta for the grey kangaroo.

● Lana
 □ Newholme

$$\text{Dry matter content} = 20.21 - 1.43 \text{ nitrogen content}$$

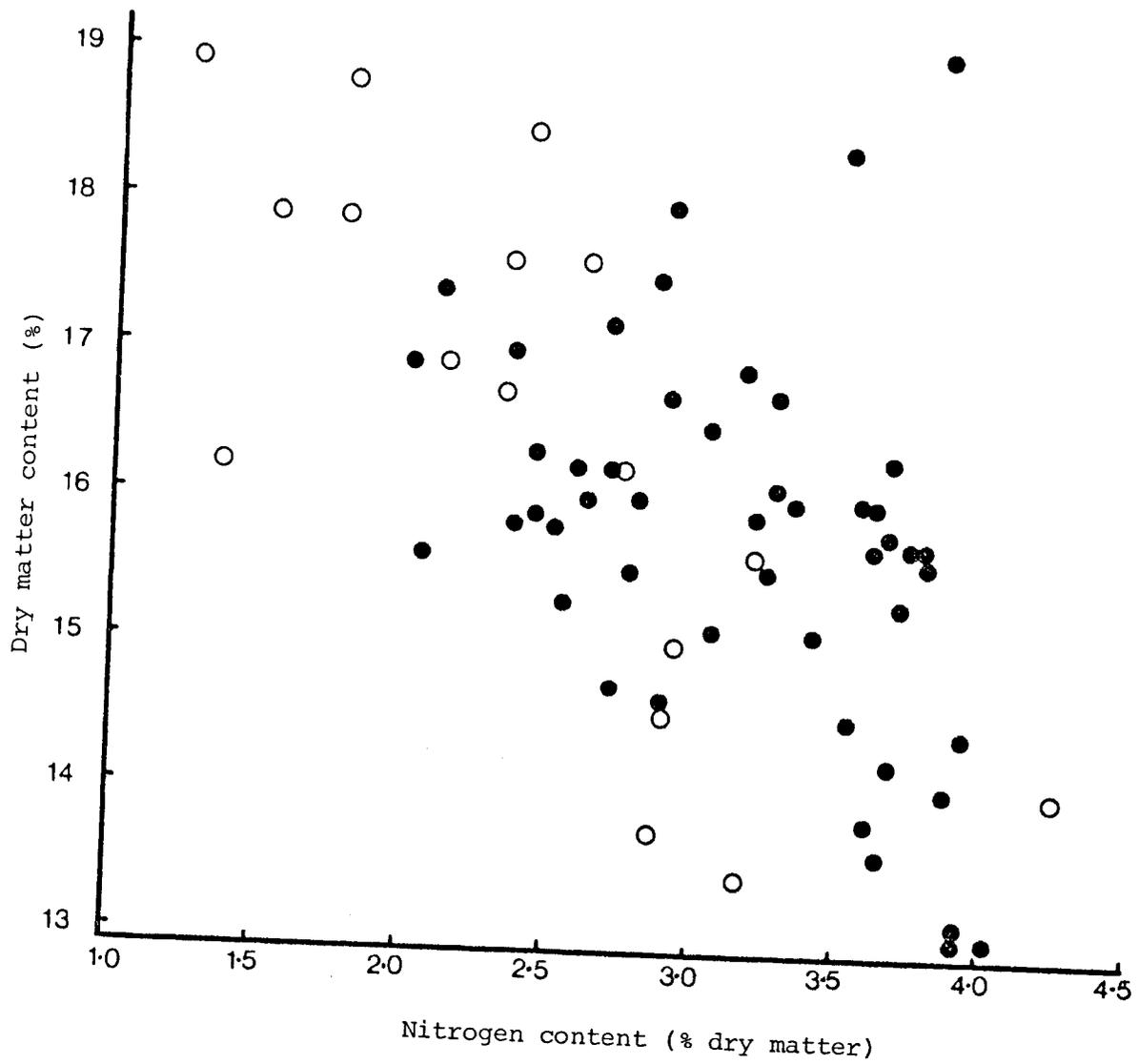


Fig. 7.8. Relationship between the dry matter content and nitrogen content of stomach digesta for wallaroo.

● Lana
○ Newholme

$$\text{Dry matter content} = 19.49 - 1.20 \text{ nitrogen content}$$

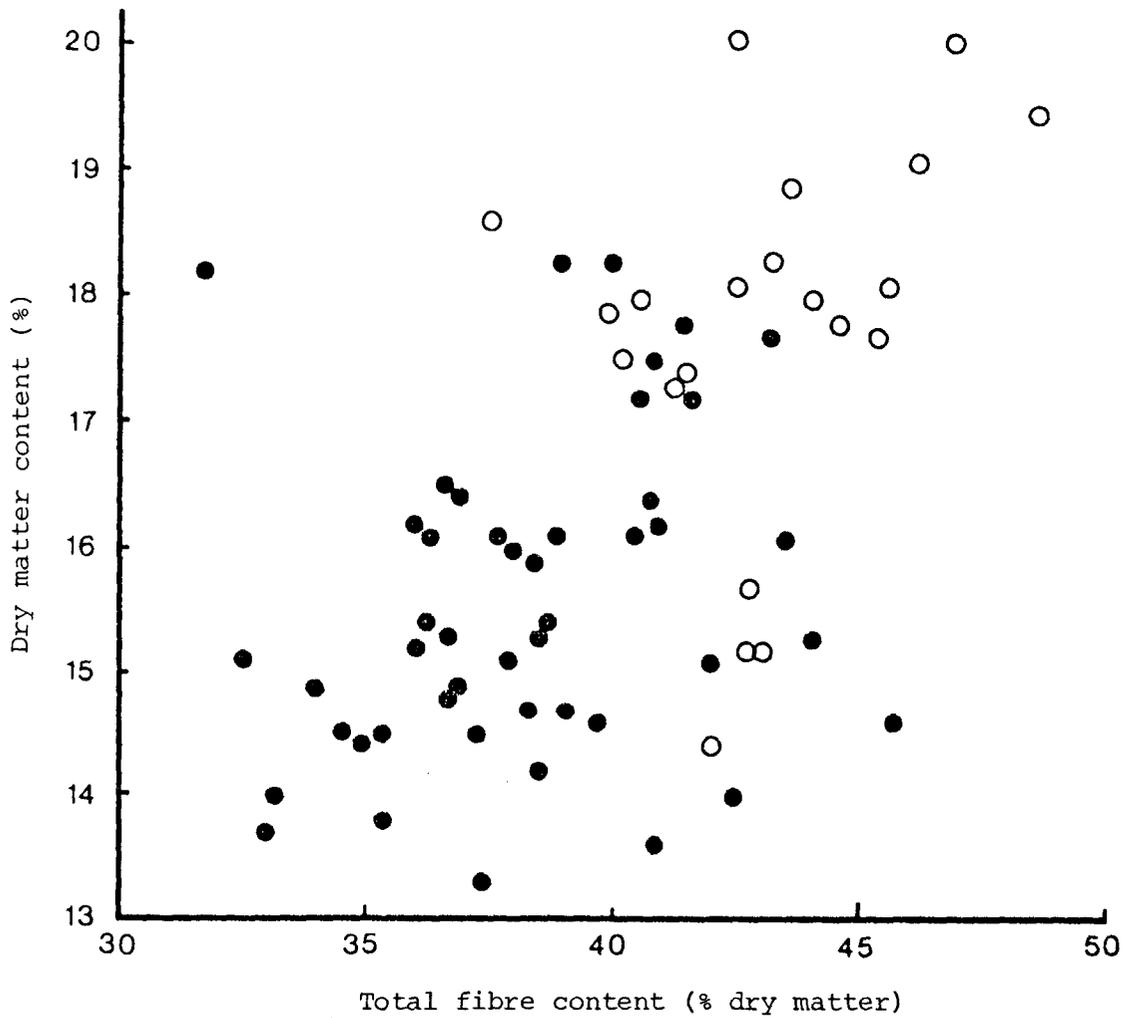


Fig. 7.9. Relationship between the percentage dry matter and total fibre content of stomach digesta for the grey kangaroo.

● Lana
○ Newholme

$$\text{Dry matter content} = 0.24 \text{ total fibre content} + 6.66$$

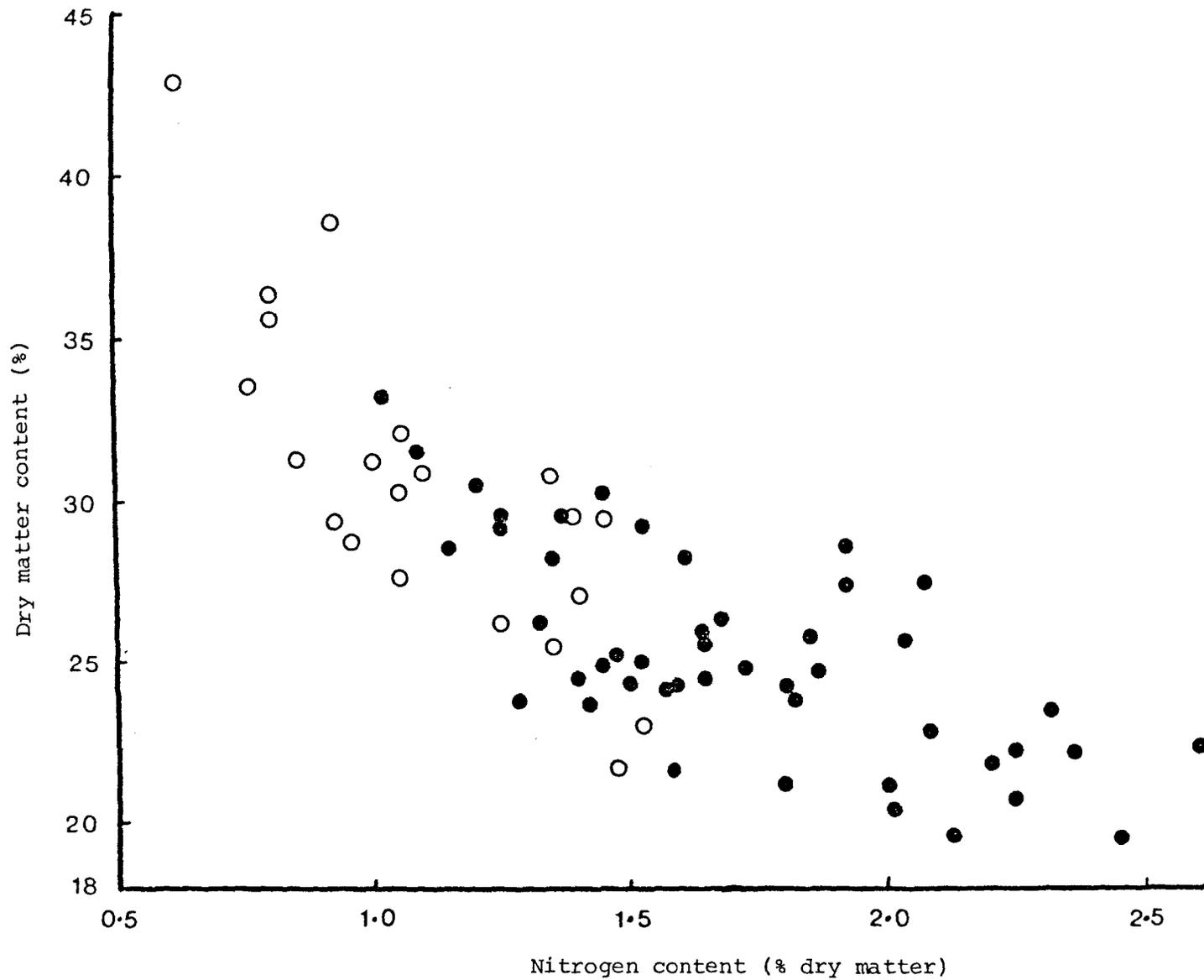


Fig. 7.11. Relationship between the dry matter content and nitrogen content of faeces for the grey kangaroo.

● Lana ○ Newholme
 Dry matter content = 38.89 - 7.91 nitrogen content.

Table 7.5 UR ratios (urine urea-nitrogen concentration/total urine nitrogen concentration) for grey kangaroo and wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	0.786 \pm 0.014(43)	0.776 \pm 0.013(45)	0.620 \pm 0.034(16)	0.808 \pm 0.032(13)
Summer	0.756 \pm 0.027(9)	0.747 \pm 0.022(10)	0.648 \pm 0.039(5)	0.770 \pm 0.030(5)
Autumn	0.765 \pm 0.013(10)	0.757 \pm 0.015(9)	-	-
Winter 1	0.853 \pm 0.016(7)	0.851 \pm 0.021(9)	0.574 \pm 0.077(5)	0.763 \pm 0.060(4)
Winter 2	0.818 \pm 0.052(8)	0.748 \pm 0.033(10)	0.635 \pm 0.063(6)	0.900 \pm 0.064(4)
Spring	0.761 \pm 0.029(9)	0.783 \pm 0.036(7)		

WALLAROO TO GREY KANGAROO

<u>LANA</u> overall	NS	<u>NEWHOLME</u> overall	***
S	NS	S	*
A	NS	W1	NS
W1	NS	W2	*
W2	NS		
SP	NS		

LANA TO NEWHOLME

<u>WALLAROO</u> overall	NS	<u>GREY KANGAROO</u> overall	***
S	NS	S	*
W1	NS	W1	**
W2	*	W2	*

SEASONAL COMPARISON

LANA

Wallaroo

S-A	NS
A-W1	**
W1-SP	NS
W1-W2	*
SP-S	NS
A-W2	NS
W2-SP	NS

Grey Kangaroo

S-A	NS
A-W1	**
W1-SP	*
W1-W2	NS
SP-S	NS
A-W2	NS
W2-SP	NS

NEWHOLME

Wallaroo

S-W1	NS
W1-W2	NS
S-W2	NS (p = 0.08)

Grey Kangaroo

S-W1	NS
W1-W2	NS
S-W2	NS

and Lana except in the winter 2 sample where UR ratios for wallaroo on Newholme (0.90) were significantly greater than for wallaroo on Lana (0.75). Grey kangaroo had significantly lower mean UR ratios in all seasons on Newholme than on Lana. On Lana both species had the lowest mean UR ratio in summer and the highest mean UR ratio for the winter 1 sample. On Newholme there were no significant seasonal differences in UR ratios for the grey kangaroo. There were also no significant seasonal changes for the wallaroo on Newholme. However, when the individual with a high level of stomach nitrogen was excluded, the mean UR ratio for wallaroo in winter 2 on Newholme was 0.96 which was significantly higher than in summer ($p < 0.01$) or winter 1 ($p < 0.05$).

A number of authors (e.g., Preston *et al.*, 1975; Torrell *et al.*, 1974; Seal *et al.*, 1978) have found a correlation between plasma urea-nitrogen levels and protein intake for animals with forestomach fermentation. In the present study there was no significant correlation between plasma urea-nitrogen and nitrogen levels of stomach contents. This may have been partly due to a lag between the intake of nitrogen as animals began to feed and any affect on plasma urea-nitrogen levels. However there was also no significant correlation between plasma urea-nitrogen levels and faecal nitrogen. There was however a significant correlation between plasma urea-nitrogen and the UR ratio for both species (grey kangaroo, $r = 0.44$, $p < 0.001$, Fig. 7.13; wallaroo, $r = 0.29$, $p < 0.05$, Fig. 7.14).

(c) Quantity of food eaten

It is possible that an animal may try to compensate for a drop in the quality of food available by increasing the amount of food eaten. It was thus thought necessary to measure the quantity of food eaten in order to assess the total intake of nitrogen and energy. Although there are techniques available for measuring the actual amount of food ingested (e.g., Storr, 1963; Alldredge *et al.*, 1974) they were beyond the scope of the present study. Instead, an index of stomach fill was used to assess the quantity of food eaten. The stomach fill index used in the present study was the ratio of the wet weight of stomach contents to the empty stomach weight. Adjusting the weight of the stomach contents for differences in the weight of the stomach enabled a comparison of stomach fill in individuals of different size. Stomach weight was used to adjust for differences in size rather than using body weight, as in many previous studies (e.g., Short *et al.*, 1969; Laws *et al.*, 1975), because a drop in body weight, due to a decline in condition, will cause an increase in the stomach fill index which is not associated with an increase in the quantity of food eaten.

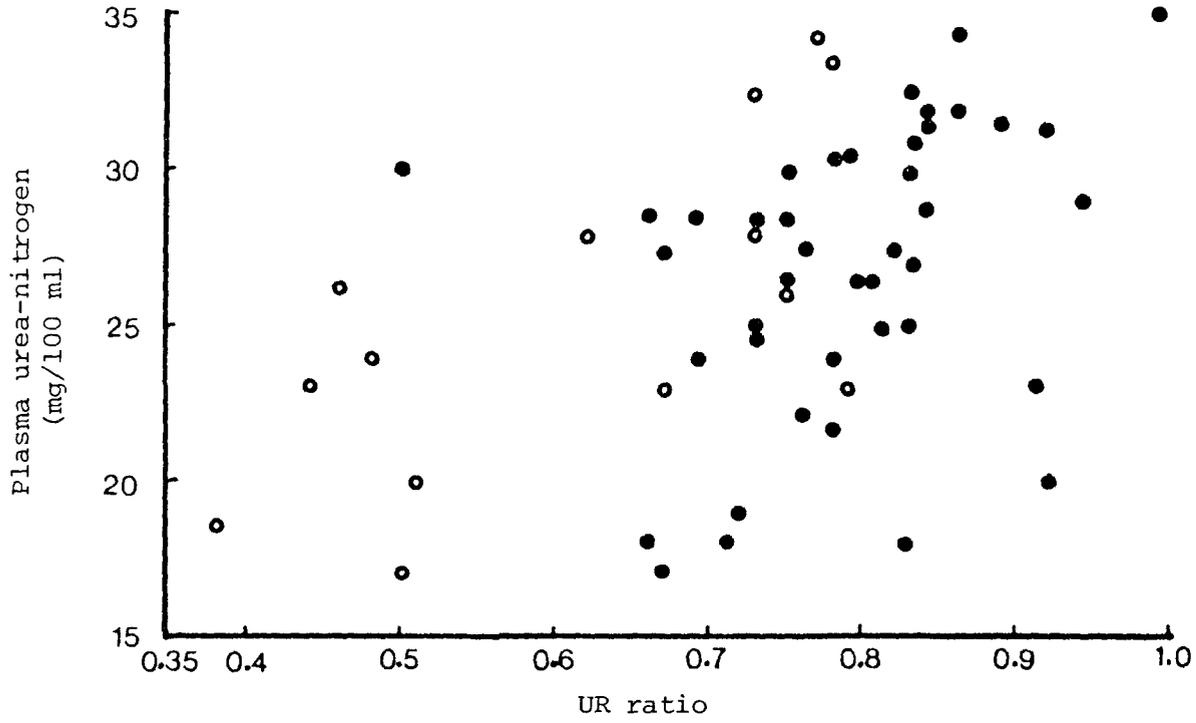


Fig. 7.13. Relationship between plasma urea-nitrogen and the UR ratio for grey kangaroo.

- Lana
- Newholme

$$\text{Plasma urea-nitrogen} = 16.38 \text{ UR ratio} + 14.33$$

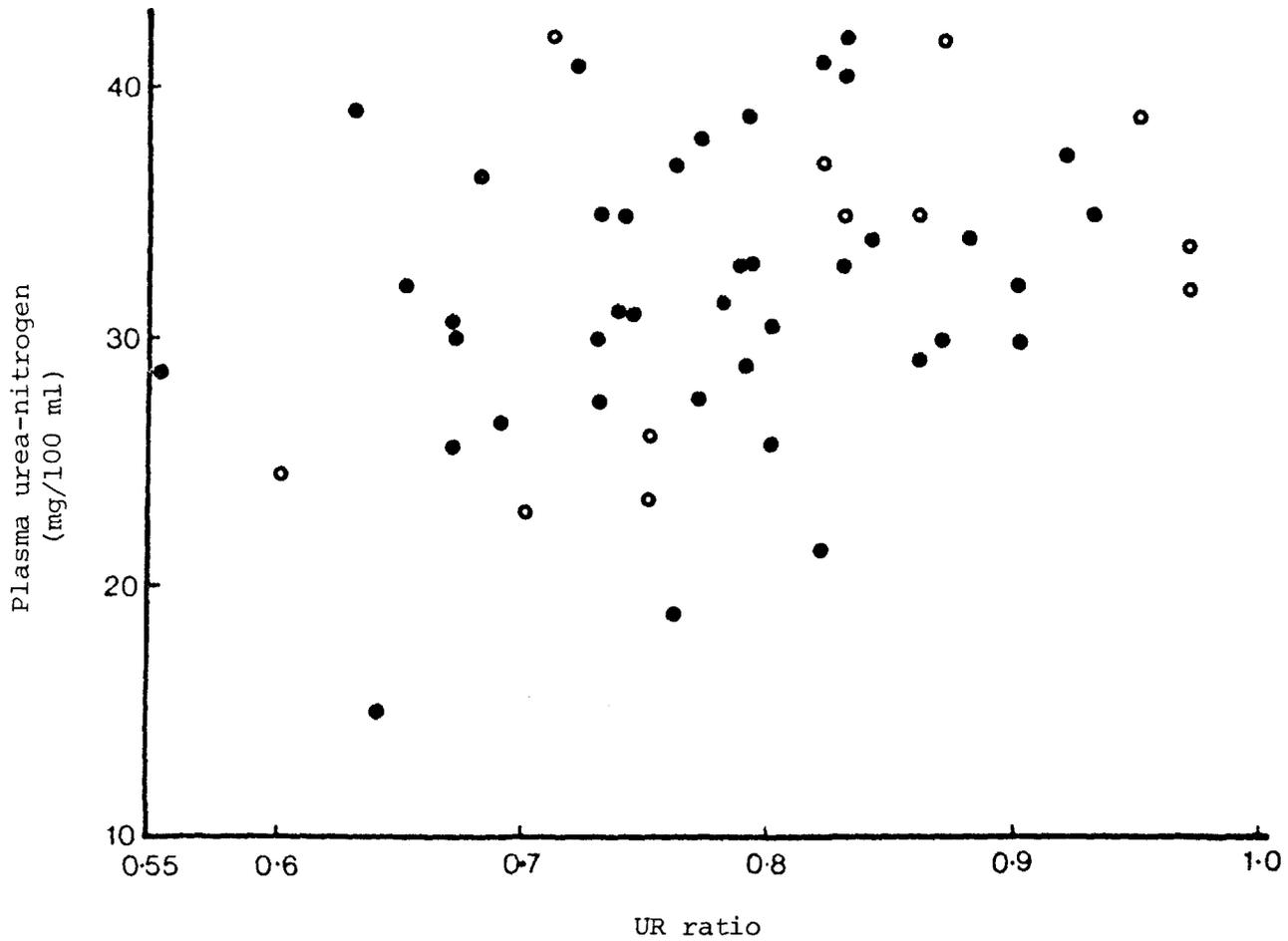


Fig. 7.14. Relationship between plasma urea-nitrogen and the UR ratio for wallaroo.

- Lana
- Newholme

$$\text{Plasma urea-nitrogen} = 19.91 \text{ UR ratio} + 16.24$$

A comparison of the empty stomach weight in relation to body weight, with the stomach contents weight subtracted, for the grey kangaroo and wallaroo is shown in Fig. 7.15. An analysis of co-variance showed no significant difference between the species in the slopes of the regression lines, but a significant difference in intercepts ($F(1,124) = 29.8$, $p < 0.001$). For a given body weight grey kangaroo had a greater stomach organ weight. The stomach fill index will thus not be directly comparable between the species.

All wallaroo and some grey kangaroo were shot before dark on Newholme whereas all animals on Lana were shot during the night. Since kangaroos begin feeding in the late afternoon, the effects of the length of time which kangaroos had been feeding before being shot on the stomach fill index was examined to investigate whether the stomach fill levels for animals on the two study areas were comparable. The time of commencement of feeding was estimated from observations of kangaroos on the two properties. The time of commencement of feeding varied seasonally. On Lana there was no correlation between the stomach fill index and the length of time which kangaroos had been feeding before being shot for either species. On Newholme there was a significant correlation for both species (grey kangaroo, $r = 0.38$, $p = 0.055$, Fig. 7.16; wallaroo, $r = 0.59$, $p < 0.05$, Fig. 7.17). When only grey kangaroo shot during the night on Newholme were included there was no significant correlation for this species on Newholme. Hence for grey kangaroo on Newholme only individuals shot during the night were included in the stomach fill indices results.

The stomach fill indices are given in Table 7.6. There was a trend for wallaroo on Newholme to have higher mean stomach fill indices during all seasons in comparison to Lana, but the difference was not statistically significant. Had the wallaroos on Newholme been shot at night it is possible that these differences might have been significant. In order to adjust the stomach fill indices for wallaroo on Newholme so that they were more comparable to the Lana values, the stomach fill index for wallaroo on Newholme (estimated from the regression line relating stomach fill to number of feeding hours for wallaroo on Newholme) at three hours after feeding commenced (the time of first sampling of a wallaroo on Lana) was used as an estimate of stomach fill. This estimate of stomach fill for wallaroo on Newholme (4.80) was significantly greater than the mean stomach fill index for wallaroo on Lana during common sampled seasons (3.98) ($t = 6.95$, $df = 28$, $p < 0.001$). Grey kangaroo had a significantly greater stomach fill

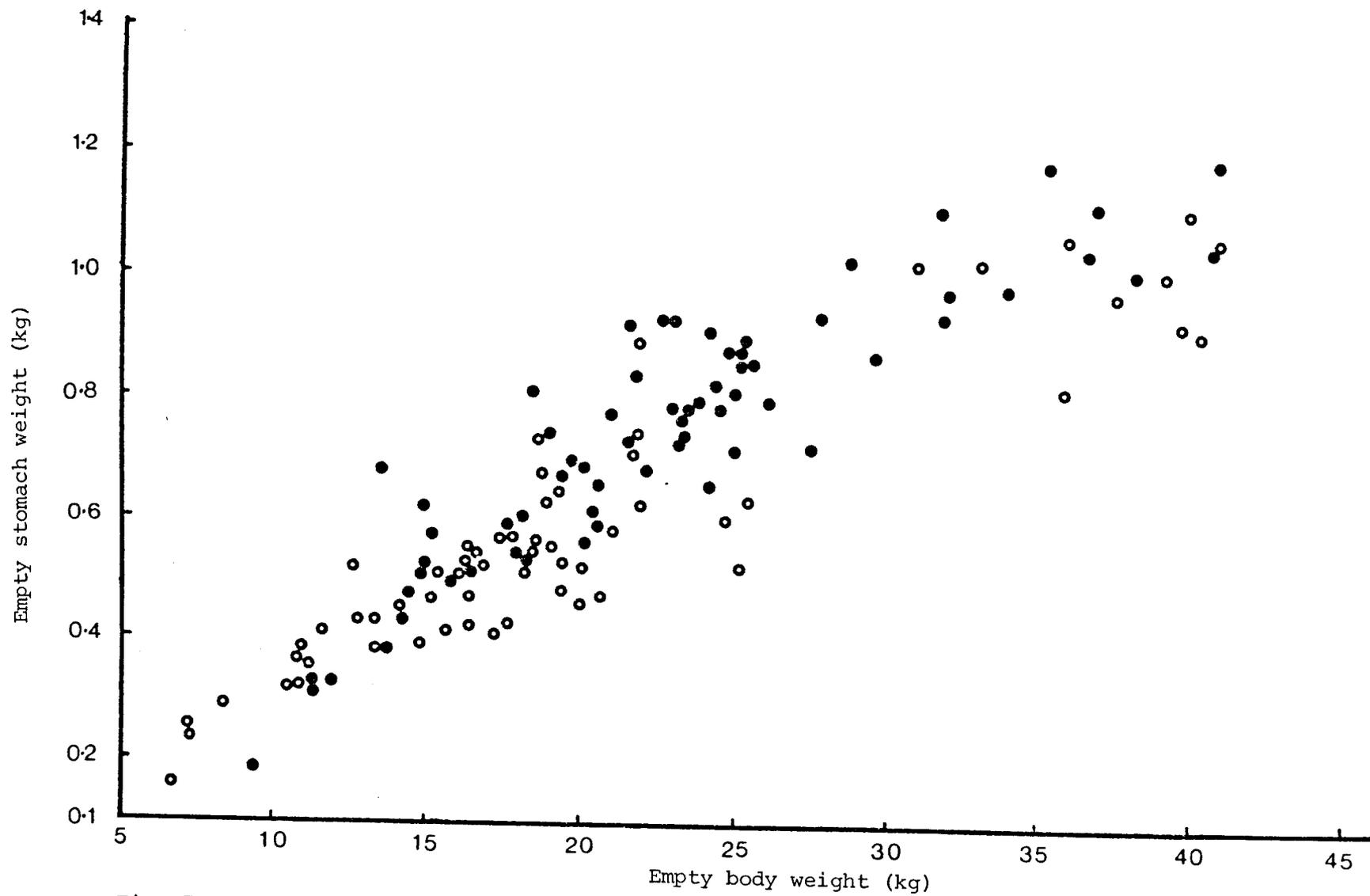


Fig. 7.15. Relationship between the empty stomach weight and the empty body weight for the grey kangaroo and wallaroo.

● Grey kangaroo

○ Wallaroo

Grey kangaroo: $Y = 27.203X + 122.562$;

Wallaroo: $Y = 23.958X + 103.449$

where Y = empty stomach weight and X = empty body weight

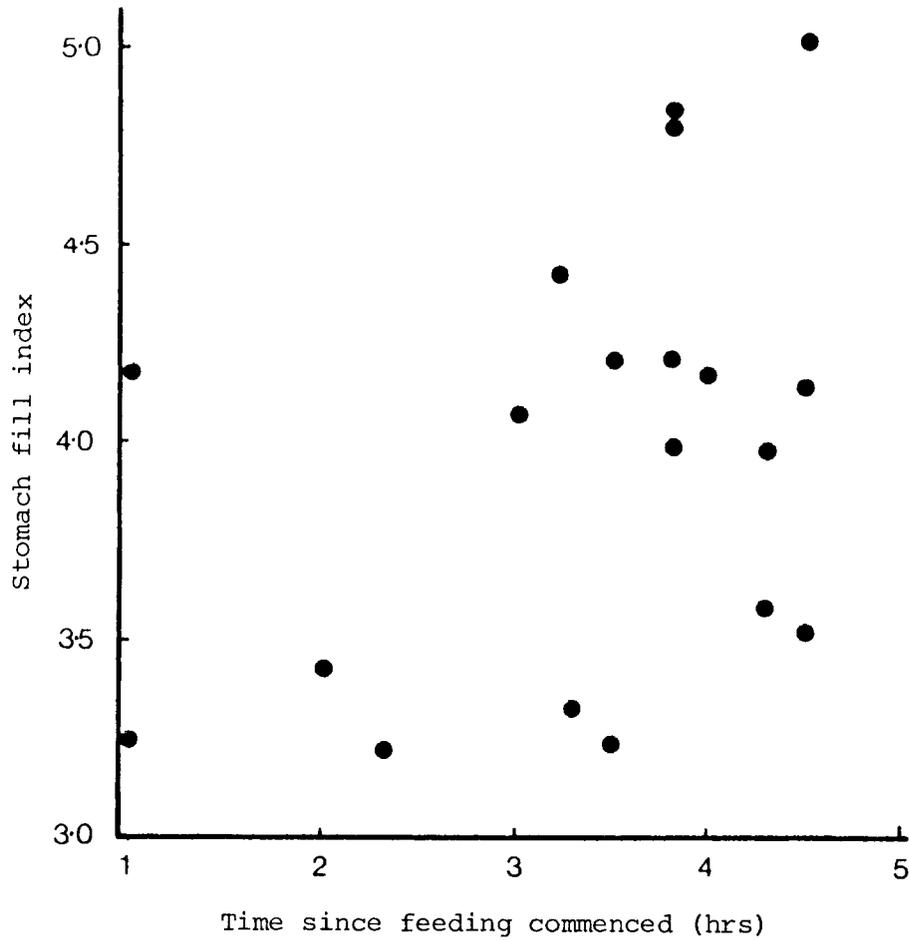


Fig. 7.16. Relationship between the stomach fill index and the time since feeding commenced for grey kangaroo on Newholme.

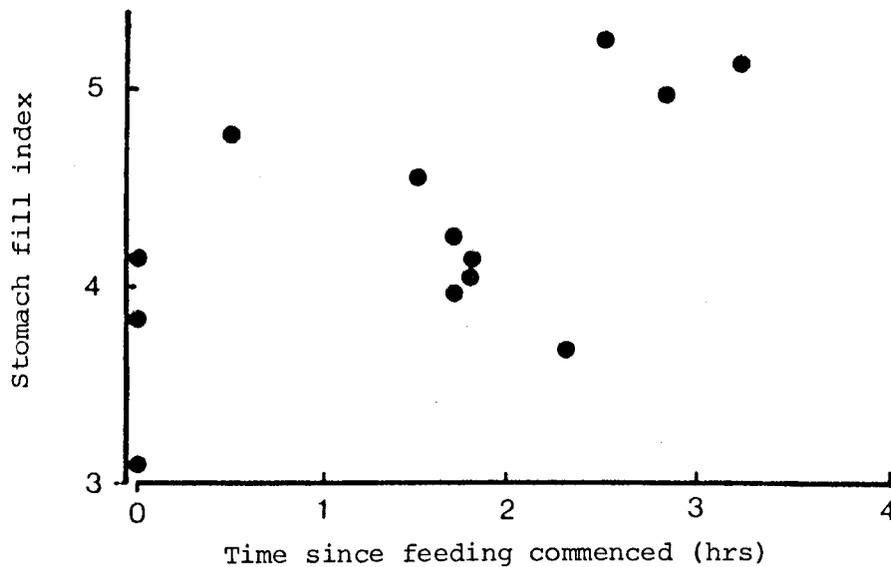


Fig. 7.17. Relationship between the stomach fill index and the time since feeding commenced for wallaroo on Newholme.

$$\text{Stomach fill index} = 0.339 \text{ time since feeding commenced} + 3.781$$

Table 7.6 Stomach fill indices for the grey kangaroo and wallaroo on Lana and Newholme. For grey kangaroo on Newholme only individuals shot during the night are included. Values are means \pm standard errors. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	3.38 \pm 0.12 (49)	3.95 \pm 0.10 (48)	4.11 \pm 0.14 (15)	4.30 \pm 0.17 (13)
Summer	2.80 \pm 0.17 (9)	3.75 \pm 0.23 (10)	4.23 \pm 0.44 (3)	3.95 \pm 0.23 (6)
Autumn	3.20 \pm 0.14 (10)	4.32 \pm 0.21 (10)	-	-
Winter 1	3.14 \pm 0.27 (10)	4.11 \pm 0.21 (9)	3.78 \pm 0.20 (4)	4.40 \pm 0.23 (4)
Winter 2	4.47 \pm 0.22 (10)	4.07 \pm 0.17 (10)	4.23 \pm 0.18 (8)	4.88 \pm 0.33 (3)
Spring	3.24 \pm 0.12 (10)	3.43 \pm 0.17 (9)	-	-

LANA TO NEWHOLME

<u>WALLAROO</u> overall	NS	<u>GREY KANGAROO</u> overall	*
S	NS	S	**
W1	NS	W1	NS
W2	*	W2	NS

SEASONAL COMPARISON

LANA

Wallaroo

S-A	NS (p = 0.08)
A-W1	NS
W1-SP	*
W1-W2	NS
SP-S	NS
A-W2	NS
W2-SP	*

Grey Kangaroo

S-A	NS (p = 0.08)
A-W1	NS
W1-SP	NS
W1-W2	**
SP-S	*
A-W2	***
W2-SP	***

NEWHOLME

Wallaroo

S-W1	NS
W1-W2	NS
W2-S	*

Grey Kangaroo

S-W1	NS
W1-W2	NS
W2-S	NS

on Newholme compared to Lana only during summer. Significant differences in stomach fill occurred on Lana between some seasons for both species. The lowest mean stomach fill occurred in summer, and the highest in winter 2 for the grey kangaroo on Lana. For the wallaroo on Lana the lowest mean stomach fill occurred in spring and the highest in winter 1. There were no significant seasonal changes in stomach fill on Newholme for the grey kangaroo. For the wallaroo on Newholme the winter 2 mean stomach fill index was significantly greater than the summer level.

In order to examine the effects of different energy requirements of different sex and reproductive classes on the level of stomach fill, males and females were divided up into sexually mature and immature animals according to criteria given in Chapter 6. Mature females were further subdivided into individuals with (a) small or (b) large pouch young or (c) suckling young-at-foot or (d) in anoestrus. For the grey kangaroo, pouch young were classified as small if they were 200 days old or less and as large if they were older than 200 days. For the wallaroo, pouch young 160 days old or less were classed as small and pouch young older than 160 days were classed as large. The age at which pouch young were classified as large instead of small was based on the age at which a rapid increase in growth rate occurred as judged from Figures 6.3 and 6.4.

The stomach fill indices of each sex and reproductive class are given in Table 7.7. Since sample sizes are small, only the overall mean stomach fill of different sex and reproductive classes were compared. For the wallaroo on Lana and Newholme and for the grey kangaroo on Newholme there were no significant differences between reproductive classes in level of stomach fill. For the grey on Lana, however, differences between reproductive classes did occur. Immature males had a significantly lower stomach fill than did mature males ($p < 0.05$). Immature females were not significantly different from mature female classes taken as a whole. Immature females were not significantly different from immature males. Females with large pouch young had a significantly greater stomach fill overall compared to females with small pouch young ($p < 0.05$). However, if the winter 2 sample is excluded as no females with small pouch young were sampled then, these two female classes do not differ significantly in stomach fill. Adult female grey kangaroo with suckling young-at-foot were only collected in winter 2 so they were compared to other females in winter 2 only. At this season adult females with young-at-foot did not have a significantly greater stomach fill than females with large pouch young or immature females. However, a larger sample

Table 7.7 Comparison of the stomach fill indices for different sex and reproductive classes for the grey kangaroo and wallaroo on Lana and Newholme. For grey kangaroo on Newholme only individuals shot during the night are included. Values are means (\pm standard errors for overall figures). Values in brackets are the number of kangaroos in each sample.

(A) WALLAROO LANA

SEASON	FEMALE				MALE			
	Immature	With small pouch young	With large pouch young	With young- at-foot	Immature	Mature		
Overall	3.61 _{+0.29} (5)	3.89 _{+0.13} (13)	3.83 _{+0.28} (7)	3.88 _{+0.23} (3)	4.24 _{+0.21} (10)	3.99 _{+0.30} (10)		
Summer	3.12 (2)	3.59 (2)	3.86 (2)	-	4.22 (1)	4.05 (3)		
Autumn	-	4.18 (3)	-	3.94 (1)	5.02 (2)	4.18 (4)		
Winter 1	4.43 (1)	3.79 (3)	-	3.46 (1)	4.73 (2)	4.13 (2)		
Winter 2	3.70 (2)	4.29 (3)	4.55 (2)	4.24 (1)	3.59 (2)	-		
Spring	-	3.31 (2)	3.32 (3)	-	3.85 (3)	2.77 (1)		

(B) WALLAROO NEWHOLME

SEASON	FEMALE				MALE			
	Immature	With small pouch young	With large pouch young	With young- at-foot	Immature	Mature		
Overall	-	3.58 _{+0.26} (3)	5.14 (1)	4.18 (1)	4.43 _{+0.35} (2)	4.49 _{+0.23} (6)		
Summer	-	3.38 (2)	-	4.18 (1)	4.78 (1)	3.96 (2)		
Winter 1	-	3.98 (1)	-	-	4.07 (1)	4.77 (2)		
Winter 2	-	-	5.14 (1)	-	-	4.74 (2)		

(C) GREY KANGAROO LANA

SEASON	FEMALE					MALE	
	Immature	With small pouch young	With large pouch young	With young-at-foot	Anoestrus	Immature	Mature
Overall	3.28±0.34 (5)	2.83±0.11 (11)	3.42±0.25 (9)	5.30±0.06 (2)	2.17 (1)	3.10±0.22 (8)	3.83±0.19 (13)
Summer	2.87 (3)	2.15 (1)	2.92 (1)	-	-	2.92 (3)	2.77 (1)
Autumn	-	3.06 (5)	2.75 (2)	-	-	-	3.76 (3)
Winter 1	-	2.58 (3)	3.67 (2)	-	2.17 (1)	2.11 (1)	4.02 (3)
Winter 2	4.24 (1)	-	4.18 (3)	5.30 (2)	-	3.46 (1)	4.64 (3)
Spring	3.57 (1)	3.00 (2)	2.51 (3)	-	-	3.50 (3)	3.27 (3)

(D) GREY KANGAROO NEWHOLME

SEASON	FEMALE			MALE	
	Immature	With small pouch young	With large pouch young	Immature	Mature
Overall	4.56±0.47 (2)	3.90±0.20 (5)	4.09±0.25 (5)	4.22 (1)	4.18±0.65 (2)
Summer	5.03 (1)	4.15 (1)	4.22 (1)	-	3.52 (1)
Winter 1	-	3.64 (3)	4.06 (4)	-	-
Winter 2	4.09 (1)	4.44 (1)	-	4.22 (1)	4.83 (1)

size might have shown differences between these classes as there was no overlap in the stomach fill indices between females with young-at-foot and females with large pouch young, and females with young-at-foot and immature females. Similarly, in winter 1 the anoestrous female's stomach fill index was not significantly different from females with small pouch young or females with large pouch young. Yet there was no overlap in values and hence a larger sample might have shown significant differences between these classes. Mature males had a significantly greater stomach fill in comparison with all mature females ($p = 0.05$). The low value for the mean stomach fill index for the grey kangaroo on Lana during summer was probably due to the large proportion of immature animals sampled in this season. Similarly, the high value for the stomach fill index for grey kangaroo on Lana during winter 2 was due partly to females with suckling young-at-foot being present in this sample and not in other seasons. However, if the females with suckling young-at-foot from the winter 2 sample and the anoestrous female from the winter 1 sample are excluded (because of these classes not being represented in both samples) the mean stomach fill index for grey kangaroo on Lana is still significantly greater ($p < 0.05$) in winter 2 than in winter 1.

7.3.2 Assessment of condition

In the following section various measurements were used to assess differences in the physical condition of kangaroos (1) between seasons and (2) between the two study areas. In good seasons, when an animal's intake of food exceeds its daily requirements, deposits of protein, fat and other metabolites (e.g., glycogen) are built up and body weight increases. As the food resources of an area decrease, or as an animal's requirements increase, and the intake of food of adequate quality falls below maintenance level, animals must utilize the fat deposits laid down during good seasons in order to meet their energy requirements. As fat deposits are diminished animals must turn to catabolism of their body protein to meet their energy demands. The drop in physical condition which is associated with a suboptimal diet also affects parameters other than fat and muscle deposits. Thus changes in organ weights and blood characteristics have also been shown to occur with changes in condition (e.g., Myers and Bults, 1977; Franzmann and Le Resche, 1978; Wilson and Hirst, 1978).

Part of the condition assessment was based on techniques used by Dr. Peter Jarman (i.e., body measurements, organ weights, muscle to bone ratios). The measurement of leg length was included as a result of discussions with Dr. Martin Denny.

Since many of the parameters used to assess condition were related to age and/or size, it was necessary to adjust these parameters so that the condition of animals of different sizes could be directly compared. The method adopted for correcting for size or age was based upon that used by Bakker and Main (1980). The slope of the straight line of best fit was used to calculate an intercept for each point. If the intercepts so calculated were all positive and greater than one then these values were used as an index for that parameter adjusted for age and/or size. If the values for the intercepts were very small and/or negative, all values were adjusted by multiplying and/or adding a constant number. This was done for the sake of convenience when examining the index. Thus this treatment adjusted values so that a large change in condition did not result in a minute change in the condition index and so that the absolute value of an index went up and not down as a result of an increase in condition.

Age and sex classes will differ in their growth rate. Individuals will also differ in the nutritional burdens placed upon them as a result of their reproductive status. Different population classes will thus have different energy requirements and the pattern of changes in their physical condition over the year could be expected to differ. One of the limitations of the present study was that the small sample size did not allow an adequate comparison to be made of population classes over the seasons and between the two study areas.

(a) Body weight

A drop in body weight has been shown to be associated with a decline in condition in many studies (e.g., Warren and Kirkpatrick, 1978; Myers *et al.*, 1976; Barker *et al.*, 1974). Studies using body weight as a condition index have sometimes only compared animals of the same skeletal size (e.g., Main, 1970), however most studies have related body weight to age or size to develop a condition index for body weight (e.g., Bailey, 1968; Bakker and Main, 1980). In the present study leg length was found to be the best size predictor of body weight. The best straight line relationship was between the cube root of empty body weight and leg length for both the grey kangaroo ($r = 0.93$, $df = 67$, $p < 0.001$) and wallaroo ($r = 0.93$, $df = 53$, $p < 0.001$). The empty body weight is the body weight minus the stomach contents weight. The empty body weight was used instead of body weight because of the possible effects of differences in the quantity of food eaten between properties on the weight-length index. The equations used to calculate the weight-length condition index were (calculating the intercepts and adjusting

their value as discussed above):

$$\text{for grey kangaroo } 20(\sqrt[3]{X} - 0.0516Y)$$

$$\text{and for wallaroo } 20(\sqrt[3]{X} - 0.0667Y) + 5$$

where X = empty body weight (kg)

and Y = leg length (cm)

One of the grey kangaroo shot on Lana in winter 1 was obviously in very poor condition. Its weight (16.2 kg) was very low compared to that predicted from its size (23.6 kg). It was the only mature female found to be in anoestrus during the study. Since this female was obviously in poor condition it was omitted from the analysis in order to see whether the other animals in this sample were also in poor condition compared to other seasons and compared to animals on Newholme. For the grey kangaroo on Lana there was a significant difference over all seasons between males and females ($p < 0.01$). The sexes were thus treated separately. Bakker and Main (1980) found differences between the weight-length condition indices of male and female quokka maintained on a high quality diet in captivity. Differences between males and females in the present study in the weight-length condition index may thus not necessarily mean that the sexes were different in condition. The weight-length condition indices for grey kangaroo are given in Table 7.8. Although for both sexes in all seasons the mean weight-length condition index was greater for animals on Lana than for those on Newholme none of the differences were statistically significant. There were also no significant seasonal changes in the weight-length condition index.

For the wallaroo the proportion of large adult males in a sample appeared to be influencing the mean weight-length condition index so the sexes were treated separately. The results are given in Table 7.9. There were no significant differences between Lana and Newholme for either sex in any season. However the mean weight-length condition index on Lana during summer was around double the value on Newholme for both sexes. Hence an increased sample size might have shown a significant difference between properties during summer. For females on Lana the mean weight-length index was lowest in winter 1. Weight in winter 2 was lower than in autumn and weight in winter 1 was lower than in winter 2. For males on Lana weight was also lowest in winter 1 but there were no significant differences between seasons. The large value for males on Newholme in winter 2 may have been due to both the animals in this sample being large adults. There were no significant seasonal

Table 7.8 Body weight condition indices for male and female grey kangaroo on Lana and Newholme each season. Weight was body weight minus the stomach contents weight. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Male	Female	Male	Female
Overall	10.58 \pm 0.33 (20)	9.10 \pm 0.28 (27)	9.06 \pm 0.86 (7)	8.22 \pm 0.57 (14)
Summer	10.07 \pm 0.83 (4)	9.56 \pm 0.80 (5)	8.73 \pm 1.50 (4)	9.09 \pm 0.70 (2)
Autumn	10.71 \pm 0.64 (3)	9.75 \pm 0.33 (7)	-	-
Winter 1	9.66 \pm 1.39 (3)	8.96 \pm 1.57 (5)	-	8.23 \pm 0.63 (6)
Winter 2	10.43 \pm 0.63 (4)	8.69 \pm 0.80 (6)	9.55 \pm 0.51 (3)	7.91 \pm 1.21 (6)
Spring	11.42 \pm 0.44 (6)	8.19 \pm 0.26 (4)	-	-

LANA TO NEWHOLME

MALE

overall NS
S NS
W2 NS

FEMALE

overall NS
S NS
W1 NS
W2 NS

SEASONAL COMPARISON

LANA

Male

S-A NS
A-W1 NS
W1-SP NS
W1-W2 NS
SP-S NS
A-W2 NS
W2-SP NS

Female

S-A NS
A-W1 NS
W1-SP NS
W1-W2 NS
SP-S NS
A-W2 NS
W2-SP NS

NEWHOLME

Male

S-W2 NS

Female

S-W1 NS
W1-W2 NS
S-W2 NS

Table 7.9 Body weight condition indices for male and female wallaroo on Lana and Newholme each season. Weight was body weight minus the stomach contents weight. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA		NEWHOLME	
	Male	Female	Male	Female
Overall	7.03 \pm 0.71 (19)	7.07 \pm 0.53 (28)	6.00 \pm 1.07 (8)	4.75 \pm 0.97 (5)
Summer	9.41 \pm 1.91 (4)	8.17 \pm 1.52 (6)	4.36 \pm 1.07 (3)	3.99 \pm 1.52 (3)
Autumn	6.43 \pm 1.08 (6)	9.33 \pm 1.61 (4)	-	-
Winter 1	4.69 \pm 1.29 (3)	4.42 \pm 0.76 (5)	5.00 \pm 1.38 (3)	5.25 (1)
Winter 2	8.32 \pm 1.98 (2)	6.48 \pm 0.65 (8)	9.97 \pm 1.18 (2)	6.43 (1)
Spring	6.69 \pm 1.64 (4)	7.53 \pm 0.61 (5)	-	-

LANA TO NEWHOLME

MALE

overall NS
S NS
W1 NS
W2 NS

FEMALE

overall NS
S NS
W1 NS
W2 NS

SEASONAL COMPARISON

LANA

Male

S-A NS
A-W1 NS
W1-SP NS
W1-W2 NS
SP-S NS
A-W2 NS
W2-SP NS

Female

S-A NS
A-W1 *
W1-SP *
W1-W2 NS (p = 0.07)
SP-S NS
A-W2 NS (p = 0.07)
W2-SP NS

NEWHOLME

Male

S-W1 NS
W1-W2 NS (p = 0.08)
S-W2 *

Female

S-W1 NS
W1-W2 only 1 individual in each sample
S-W2 NS

differences in weight for females on Newholme.

(b) Kidney fat index

The kidney fat index was expressed as the weight of fat associated with the kidney as a percentage of the weight of the kidney. The kidney fat index has been used for many mammalian herbivores as an index to body fat reserves (e.g., Riney, 1955; Hanks *et al.*, 1976; Caughley, 1962, 1970, 1971). Batcheler and Clark (1970) have found that for red deer *Cervus elaphus* in New Zealand kidney weight fluctuates throughout the year giving distorted values for estimates of seasonal variation in fat reserves. However, despite possible variations in kidney weight, both Bamford (1970) (for brushtail possum *Trichosurus vulpecula*) and Smith (1970) (for a range of African ungulate species) have shown that the kidney fat index is correlated with the total body fat.

The kidney fat indices are given in Table 7.10. There was no difference between Lana and Newholme in kidney fat for either species. There were no significant seasonal differences on Newholme for either grey kangaroo or wallaroo. For the wallaroo on Lana the lowest kidney fat levels were in winter 1. For the grey kangaroo on Lana the lowest kidney fat levels were also in winter 1, however the summer level was also low.

Differences in kidney fat index have been shown to exist between sexes and reproductive classes for other herbivores (e.g., Riney, 1955; Caughley, 1970). The kidney fat indices for different sex and reproductive classes for the grey kangaroo and wallaroo on the two properties are given in Table 7.11. There were too few kangaroos sampled to allow an adequate statistical comparison of sex and reproductive classes for each season. From an examination of the data it appears that immature animals had lower kidney fat indices than adults and that adult females with pouch young or young-at-foot had higher kidney fat indices than adult males. When immature animals, females with pouch young and mature males were each compared between study areas for the grey kangaroo and wallaroo there were no significant differences in any season. The low level of kidney fat for the grey kangaroo on Lana during summer in Table 7.10 was probably due to the high proportion of immature animals in this sample compared to other seasons.

(c) Bone marrow fat

It has been found that the kidney fat index is not a reliable indicator of body fat at low levels of fat storage (e.g., Ransom, 1965; Bamford, 1970). At low levels of kidney fat large changes occur in

Table 7.10 Kidney fat indices for the grey kangaroo and wallaroo on Lana and Newholme each season. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA				NEWHOLME			
	Grey Kangaroo		Wallaroo		Grey Kangaroo		Wallaroo	
Overall	34.85 \pm 4.79(49)	56.83 \pm 9.63(49)	33.84 \pm 10.51(21)	30.68 \pm 7.07(18)				
Summer	17.47 \pm 4.63(9)	41.99 \pm 16.94(10)	16.87 \pm 4.79(6)	31.12 \pm 13.08(6)				
Autumn	57.09 \pm 14.66(10)	75.21 \pm 30.42(10)	-	-				
Winter 1	15.68 \pm 2.86(10)	22.91 \pm 4.12(10)	27.92 \pm 9.04(6)	23.36 \pm 5.78(7)				
Winter 2	41.95 \pm 9.42(10)	64.66 \pm 20.62(10)	49.11 \pm 23.33(9)	40.42 \pm 19.90(5)				
Spring	40.34 \pm 11.63(10)	81.89 \pm 25.25(9)	-	-				

WALLAROO TO GREY KANGAROO

<u>LANA</u>		<u>NEWHOLME</u>	
overall	*	overall	NS
S	NS	S	NS
A	NS	W1	NS
W1	NS	W2	NS
W2	NS		
SP	NS		

NEWHOLME TO LANA

<u>WALLAROO</u>		<u>GREY</u>	
overall	NS	overall	NS
S	NS	S	NS
W1	NS	W1	NS
W2	NS	W2	NS

SEASONAL COMPARISON

<u>LANA</u>		<u>GREY KANGAROO</u>	
Wallaroo		Grey Kangaroo	
S-A	NS	S-A	*
A-W1	NS	A-W1	*
W1-SP	*	W1-SP	NS (p = 0.054)
W1-W2	NS (p = 0.06)	W1-W2	*
SP-S	NS	SP-S	NS
A-W2	NS	A-W2	NS
W2-SP	NS	W2-SP	NS
<u>NEWHOLME</u>		<u>GREY KANGAROO</u>	
Wallaroo		Grey Kangaroo	
S-W1	NS	S-W1	NS
W1-W2	NS	W1-W2	NS
S-W2	NS	S-W2	NS

Table 7.11 Kidney fat indices for each sex and reproductive class for each season. Values are means. Overall values are means + standard error. Values in brackets are the number of kangaroos in each sample.

(A) WALLAROO LANA

SEASON	FEMALE				MALE			
	Immature	With small pouch young	With large pouch young	With young-at-foot	Immature	Mature		
Overall	16.38+5.90 (5)	98.41+22.56(14)	88.39+19.52(7)	48.47+13.20(10)	14.48+3.32(10)	41.62+22.84(10)		
Summer	9.10 (2)	92.30 (2)	65.45 (2)	-	17.00 (1)	23.07 (3)		
Autumn	-	127.40 (3)	-	59.20 (1)	7.20 (2)	74.08 (4)		
Winter 1	16.00 (1)	34.75 (4)	-	22.20 (1)	11.25 (2)	14.70 (2)		
Winter 2	23.85 (2)	120.13 (3)	54.25 (2)	64.00 (1)	33.00 (2)	-		
Spring	-	155.75 (2)	126.43 (3)	-	8.30 (3)	21.30 (1)		

(B) WALLAROO NEWHOLME

SEASON	FEMALE				MALE			
	Immature	With small pouch young	With large pouch young	With young-at-foot	Immature	Mature		
Overall	-	36.65+19.07(4)	51.98+23.91(4)	10.30 (1)	9.25+3.05(2)	24.14+3.32(7)		
Summer	-	51.90 (2)	-	10.30 (1)	12.30 (1)	30.15 (2)		
Winter 1	-	21.40 (2)	37.30 (2)	-	6.20 (1)	19.95 (2)		
Winter 2	-	-	66.65 (2)	-	-	22.93 (3)		

(C) GREY KANGAROO LANA

SEASON	FEMALE						MALE	
	Immature	With small pouch young	With large pouch young	With young- at-foot	Anoestrus	Immature	Mature	
Overall	14.70+3.26 (5)	46.11+11.86 (12)	58.32+13.43 (9)	45.25+41.14 (2)	0 (1)	17.24+4.47 (7)	26.53+5.60 (13)	
Summer	10.53 (3)	14.45 (2)	37.80 (1)	-	-	27.40 (2)	4.10 (1)	
Autumn	-	69.36 (5)	67.55 (2)	-	-	-	29.67 (3)	
Winter 1	-	19.10 (3)	16.15 (2)	-	0 (1)	26.10 (1)	13.70 (3)	
Winter 2	24.40 (1)	-	67.43 (3)	45.25 (2)	-	9.80 (1)	30.83 (3)	
Spring	17.50 (1)	60.15 (2)	117.40 (1)	-	-	10.00 (3)	39.40 (3)	

(D) GREY KANGAROO NEWHOLME

SEASON	FEMALE				MALE	
	Immature	With small pouch young	With large pouch young	With young- at-foot	Immature	Mature
Overall	11.85+6.24 (2)	28.86+6.13 (5)	58.61+25.54 (8)	-	7.10 (1)	13.34+3.11 (5)
Summer	5.60 (1)	36.60 (1)	-	-	-	14.75 (4)
Winter 1	-	25.17 (3)	30.67 (3)	-	-	-
Winter 2	18.10 (1)	32.20 (1)	75.38 (5)	-	7.10 (1)	7.70 (1)

the bone marrow fat content. Both Riney (1955) and Ransom (1965) have observed that small amounts of fat remain on the kidney of deer during the final stages of starvation. The percentage dry weight of bone marrow has been shown to be closely correlated with the fat content (e.g., Neiland, 1970; Hunt, 1979; Hanks *et al.*, 1965) and so in this study the percentage dry weight of bone marrow was used as an index of its fat content. However, at very low levels of marrow fat, non-fat residues may form a large part of the dry weight.

The percentage dry weights recorded for bone marrows are given in Table 7.12. On Lana the grey kangaroo had significantly higher marrow fat levels than the wallaroo in autumn. This may have simply been a reflection of the presence of a female with a suckling young-at-foot and two immature animals in the wallaroo sample compared to neither of these categories occurring in the grey kangaroo sample in autumn. There were no differences between the grey kangaroo and wallaroo on Newholme. There were no significant differences between Lana and Newholme for either species in any season. There were no significant seasonal differences for the grey kangaroo or wallaroo on Newholme. For the grey kangaroo on Lana winter 1 marrow fat levels were close to being significantly lower than autumn levels. There were two grey kangaroo in the winter 1 sample on Lana with very low marrow fat levels. The dry weight of these marrows was probably mainly non-fat residue. One of these individuals was the anoestrous female with a very low body weight mentioned in section 7.3.2a. The other individual was a female with a pouch young nearing the end of its pouch life. For the wallaroo on Lana the bone marrow fat levels were lowest in autumn and winter 1. Winter 1 levels were significantly lower than winter 2 levels. The two lowest marrow fat levels recorded for wallaroo were for two young-at-foot in winter 1. One of these was shot on Lana and the other on Newholme. Both of these individuals would have been born during autumn and hence would have been faced with poor quality food since the end of their pouch life. Young-at-foot of equivalent age sampled in other seasons had high marrow fat levels.

(d) Leg muscle to bone ratio

The use of muscle to bone ratios as indices of muscle bulk was developed in ecological studies of antelope in Africa (P.J. Jarman, pers. comm.). The leg muscle to bone ratio used in the present study to assess changes in muscle bulk was developed by Dr. Peter Jarman. The leg muscle weight was divided by bone weight in order to enable a comparison of muscle bulk in animals of different size. Leg bone (i.e., tibia and

Table 7.12 Bone marrow fat content (% dry weight) for the grey kangaroo and wallaroo on Lana and Newholme. Values are means + standard errors. Values in brackets are the number of kangaroos in each sample. The summer sample for grey kangaroo on Lana was lost due to an oven malfunction.

SEASON	LANA		NEWHOLME	
	Grey Kangaroo	Wallaroo	Grey Kangaroo	Wallaroo
Overall	79.7+ 3.1 (40)	78.0+2.4 (48)	83.5+2.2 (21)	77.4+5.0 (18)
Summer	-	87.6+1.4 (9)	82.1+4.4 (6)	75.9+7.9 (6)
Autumn	88.6+ 0.7 (10)	76.3+4.2 (10)	-	-
Winter 1	68.4+10.4 (10)	61.8+6.6 (10)	80.9+5.4 (6)	74.6+9.4 (7)
Winter 2	79.9+ 5.1 (10)	85.0+5.1 (10)	86.2+2.8 (9)	83.0+9.4 (5)
Spring	81.9+ 2.3 (10)	80.5+2.9 (9)	-	-

NEWHOLME TO LANA

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

GREY KANGAROO TO WALLAROO

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

SEASONAL COMPARISON

LANA

Grey Kangaroo

A-W1	NS (p = 0.067)
W1-P	NS
W1-W2	NS
A-W2	NS
W2-SP	NS

Wallaroo

S-A	*
A-W1	NS
W1-SP	*
W1-W2	*
SP-S	*
A-W2	NS
W2-SP	NS

NEWHOLME

Grey Kangaroo

S-W1	NS
W1-W2	NS
S-W2	NS

Wallaroo

S-W1	NS
W1-W2	NS
S-W2	NS

fibula) weight was significantly correlated with empty body weight (i.e., size) for both wallaroo ($r = 0.96$, $df = 57$, $p < 0.001$) and grey kangaroo ($r = 0.96$, $df = 64$, $p < 0.001$). A drop in muscle bulk may reflect increased protein catabolism brought on by depletion of fat reserves and a continued suboptimal diet.

The males and females of each species were examined separately as the sexes differed in the relationship between the muscle to bone ratio and age. The muscle to bone ratios were plotted against age and molar index[†] and the best straight line relationship (if such a relationship existed) was used to calculate an index adjusted for age (using the method described above).

The line of best fit relating leg muscle to bone ratio to age for female wallaroo was a quadratic the equation of which is given in Fig. 7.18. The P.V. Sakhatani text (Fisher and Yates, 1963) showed there was no difference between the line of best fit for animals on Lana and Newholme. Sample sizes were too small to test seasonal differences.

The equation used to calculate an index of the leg muscle to bone ratio corrected for age for male wallaroo was:

$$5(\text{Leg muscle to bone ratio} - 0.1345 \text{ Molar index}).$$

The leg muscle to bone indices are given in Table 7.13. There were no significant differences between seasons or between Lana and Newholme. The lowest values were recorded during winter 1 on both Lana and Newholme.

The equation used to calculate an index of the leg muscle to bone ratio corrected for age for female grey kangaroo was:

$$5(\text{Leg muscle to bone ratio} - 0.1041 \text{ Molar index}).$$

The anoestrous female in poor condition on Lana in winter 1 had a low leg muscle to bone ratio (2.2) compared to that predicted from its age (2.8) and was not included in the analysis. This was done in order to compare the other individuals in the winter 1 sample for differences in the leg muscle to bone index to other seasons and to Newholme. The female grey kangaroo leg muscle to bone indices are given in Table 7.14. There were no differences between Lana and Newholme and no seasonal differences on Newholme. On Lana the largest mean leg muscle to bone

† Molar index is related logarithmically to age (see Kirkpatrick, 1965b).

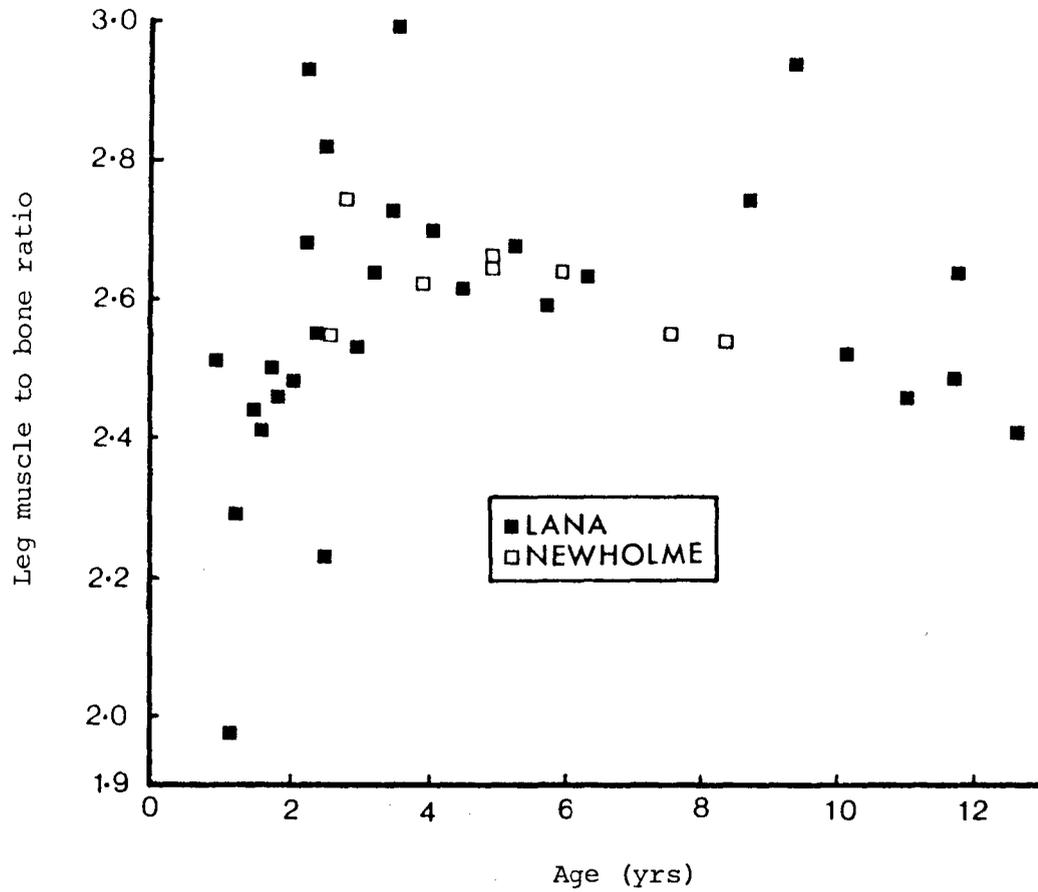


Fig. 7.18. Relationship between the leg muscle to bone ratio and age for female wallaroo.

$$\text{Leg muscle to bone ratio} = 2.266 + 0.126 \text{ Age} - 0.009 \text{ Age}^2$$

Table 7.13 Leg muscle to bone indices for male wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA	NEWHOLME
Overall	10.78 \pm 0.23 (19)	10.82 \pm 0.31 (9)
Summer	10.69 \pm 0.16 (4)	11.33 \pm 0.70 (3)
Autumn	11.12 \pm 0.49 (6)	-
Winter 1	9.98 \pm 0.84 (3)	10.34 \pm 0.37 (3)
Winter 2	11.32 \pm 0.41 (2)	10.80 \pm 0.49 (3)
Spring	10.68 \pm 0.42 (4)	-

LANA TO NEWHOLME

overall	NS
S	NS
W1	NS
W2	NS

SEASONAL COMPARISON

<u>LANA</u>		<u>NEWHOLME</u>	
S-A	NS	S-W1	NS
A-W1	NS	W1-W2	NS
W1-SP	NS	S-W2	NS
W1-W2	NS		
SP-S	NS		
A-W2	NS		
W2-SP	NS		

Table 7.14 Leg muscle to bone indices for female and male grey kangaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	FEMALE		MALE	
	Lana	Newholme	Lana	Newholme
Overall	12.49 \pm 0.21 (26)	12.43 \pm 0.31 (14)	11.71 \pm 0.16 (20)	11.46 \pm 0.18 (6)
Summer	12.29 \pm 0.35 (5)	13.36 \pm 0.52 (2)	11.66 \pm 0.20 (4)	11.39 \pm 0.27 (4)
Autumn	12.19 \pm 0.21 (7)	-	11.06 \pm 0.05 (2)	-
Winter 1	12.27 \pm 0.32 (5)	12.34 \pm 0.32 (6)	11.24 \pm 0.21 (4)	-
Winter 2	13.50 \pm 0.64 (6)	12.21 \pm 0.63 (6)	12.75 \pm 0.33 (4)	11.60 \pm 0.03 (2)
Spring	11.88 \pm 0.35 (3)	-	11.60 \pm 0.22 (6)	-

LANA TO NEWHOLME

FEMALE

overall NS
S NS
W1 NS
W2 NS

MALE

overall NS
S NS
W2 NS (p = 0.08)

SEASONAL COMPARISON

LANA

Female

S-A NS
A-W1 NS
W1-SP NS
W1-W2 NS
SP-S NS
A-W2 NS (p = 0.06)
W2-SP NS

Male

S-A NS
A-W1 NS
W1-SP NS
W1-W2 **
SP-S NS
A-W2 *
W2-SP *

NEWHOLME

Female

S-W1 NS
W1-W2 NS
S-W2 NS

Male

S-W2 NS

index was recorded in winter 2.

The equation used to calculate the leg muscle to bone index adjusted for age for male grey kangaroo was:

$$5(\text{Leg muscle to bone ratio} - 0.1767 \text{ Molar Index}).$$

The results are given in Table 7.14. The greatest mean leg muscle to bone index was recorded in winter 2 on Lana as for females. The mean leg muscle to bone index was close to being significantly greater on Lana than on Newholme during winter 2. There were no significant seasonal differences on Newholme.

(e) Haematocrit and haemoglobin

Differences in the haematocrit and haemoglobin levels of blood have been related to differences in condition in many mammalian herbivore studies (e.g., Dudzinski *et al.*, 1962; Seal *et al.*, 1978; Farrell *et al.*, 1972; Ealey and Main, 1967; Barker *et al.*, 1974; Franzman, 1972). Since a relationship between haematocrit and haemoglobin levels and condition had been found in so many different species, the haematocrit and haemoglobin levels for kangaroos in the present study were measured in order to check for any differences in these parameters over seasons and between properties which might be related to changes in condition.

Franzmann and Le Resche (1978), Seal and Hoskinson (1978), Seal *et al.* (1972) and others have shown the excitability affects haemoglobin and haematocrit levels. In this study assessing the affects of excitability on haematocrit and haemoglobin levels proved difficult. Some kangaroos had to be shot twice before being killed, also some kangaroos were disturbed by the sound of the vehicle or by the sound of a shot before they were themselves shot. These events could have led to increased haematocrit and haemoglobin levels. After a kangaroo was shot a blood sample was obtained as soon as possible. Sometimes, however, it took a while to find shot kangaroos because of tall grass. As the time since death increases, the cell content of the blood decreases due to settling out of the cells. Any cases where the haematocrit and haemoglobin levels were particularly low and time after death before a blood sample was taken was great, or cases where the levels were high and the animals were known to have been greatly disturbed were excluded from the analysis. Cases where haematocrit and haemoglobin levels were normal despite possible disturbance were included. These assessments were subjective however and the results should thus be interpreted with care.

For female wallaroo there was no significant correlation between haematocrit and age or molar index. The equation used to calculate an index of haematocrit adjusted for age for male wallaroo was:

$$\text{Haematocrit} - 1.7852 \text{ Molar Index.}$$

The results for male and female wallaroo are given in Table 7.15. For females there was no significant difference in haematocrit levels between animals on Lana and Newholme. There were no significant seasonal changes on Newholme. On Lana the lowest haematocrit levels occurred in winter. For male wallaroo haematocrit levels were significantly higher on Lana overall and during summer than on Newholme. On Lana the lowest mean haematocrit level was recorded in spring. On Newholme haematocrit levels were lower in summer than in winter 1 but sample sizes were small and excitability levels may have been affecting the results.

The equations used to calculate an index of haematocrit adjusted for age for grey kangaroo were:

(for females) Haematocrit - 2.3 Molar Index.
and (for males) Haematocrit - 1.2381 Age (yrs).

The haematocrit indices for male and female grey kangaroo are given in Table 7.16. For female grey kangaroo haematocrit levels were higher on Lana than on Newholme during all seasons. There were no significant seasonal changes on Lana. On Newholme haematocrit levels in winter 1 may have been slightly higher than in winter 2. For male grey kangaroo haematocrit levels were higher on Lana than on Newholme in winter 2. The number of kangaroos in Newholme samples were too low to assess seasonal changes. On Lana for male grey kangaroo, as for male wallaroo, the lowest haematocrit levels occurred in spring. Levels during winter 1 may have been lower than in winter 2.

Haemoglobin levels were not analysed for blood samples collected in winter 2. For female wallaroo there was no significant correlation between age (or molar index) and haemoglobin level. However some young animals (i.e., below 2.5 years of age) appeared to have lower values than other age classes (see Fig. 7.19). The equation used to calculate an index of haemoglobin corrected for age for male wallaroo was:

$$\text{Haemoglobin (g/100 ml)} - 1.2224 \text{ Molar Index.}$$

The results for male and female wallaroo are given in Table 7.17. For female wallaroo haemoglobin levels were not significantly different

Table 7.15 Haematocrit levels (% by volume) for female wallaroo and haematocrit indices (adjusted for age) for male wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	FEMALE		MALE	
	Lana	Newholme	Lana	Newholme
Overall	41.67 \pm 1.05 (28)	37.30 \pm 3.12 (6)	40.06 \pm 0.79 (20)	33.94 \pm 1.52 (7)
Summer	45.42 \pm 2.81 (6)	39.43 \pm 5.29 (3)	42.70 \pm 1.15 (4)	30.49 \pm 0.32 (3)
Autumn	44.45 \pm 1.09 (4)	-	40.06 \pm 1.89 (6)	-
Winter 1	39.77 \pm 2.34 (6)	41.00 (1)	40.10 \pm 0.70 (4)	38.91 \pm 0.50 (2)
Winter 2	38.51 \pm 1.38 (8)	32.25 \pm 4.75 (2)	39.91 \pm 2.20 (2)	34.14 \pm 2.32 (2)
Spring	42.45 \pm 2.75 (4)	-	37.46 \pm 1.87 (4)	-

LANA TO NEWHOLME

<u>FEMALE</u>		<u>MALE</u>	
overall	NS	overall	***
S	NS	S	***
W1	NS	W1	NS
W2	NS	W2	NS

SEASONAL COMPARISON

<u>LANA</u>			
Female		Male	
S-A	NS	S-A	NS
A-W1	NS	A-W1	NS
W1-SP	NS	W1-SP	NS
W1-W2	NS	W1-W2	NS
SP-S	NS	SP-S	NS (p = 0.054)
A-W2	*	A-W2	NS
W2-SP	NS	W2-SP	NS
<u>NEWHOLME</u>			
Female		Male	
S-W1	NS	S-W1	***
W1-W2	NS	W1-W2	NS
S-W2	NS	S-W2	NS

Table 7.16 Haematocrit indices for male and female grey kangaroo on Lana and Newholme. Values are means + standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	FEMALE		MALE	
	Lana	Newholme	Lana	Newholme
Overall	38.99+0.86(28)	33.06+1.12(8)	39.30+0.85(20)	36.21+2.88(3)
Summer	37.33+1.30(6)	-	42.68+1.49(3)	38.87+1.90(2)
Autumn	39.87+2.03(7)	-	40.15+2.23(3)	-
Winter 1	42.33+2.03(5)	35.09+1.19(4)	36.95+2.15(4)	-
Winter 2	37.25+2.18(6)	31.02+1.29(4)	42.28+1.45(4)	30.90(1)
Spring	38.39+0.91(4)	-	36.76+0.74(6)	-

LANA TO NEWHOLME

FEMALE		MALE	
overall	**	overall	NS
W1	*	S	NS
W2	NS (p = 0.06)	W2	*

SEASONAL COMPARISON

<u>LANA</u>			
Female		Male	
S-A	NS	S-A	NS
A-W1	NS	A-W1	NS
W1-SP	NS	W1-SP	NS
W1-W2	NS	W1-W2	NS (p = 0.08)
SP-S	NS	SP-S	**
A-W2	NS	A-W2	NS
W2-SP	NS	W2-SP	**
<u>NEWHOLME</u>			
Female		Male	
W1-W2	NS (p = 0.059)	S-W2	NS

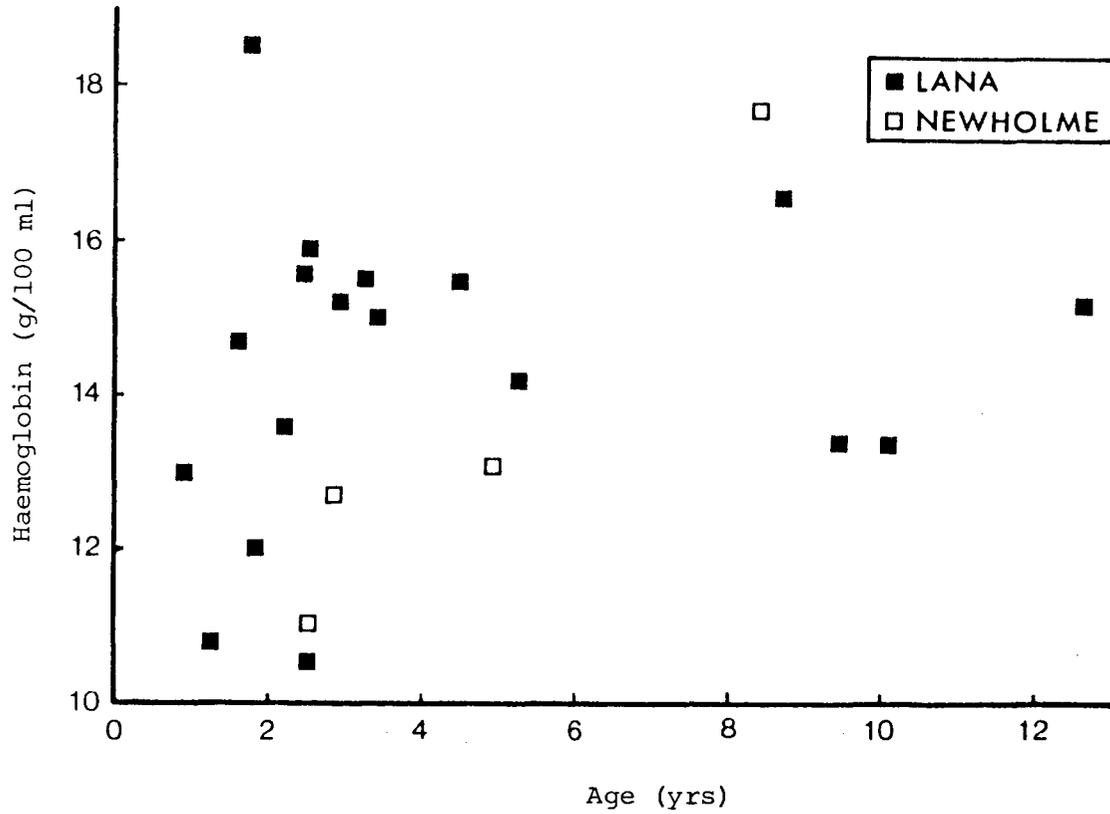


Fig. 7.19. Relationship between haemoglobin concentration of blood and age for female wallaroo.

Table 7.17 Haemoglobin levels (g/100 ml) for female wallaroo and haemoglobin indices for male wallaroo on Lana and Newholme. Values are means + standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	FEMALE		MALE	
	Lana	Newholme	Lana	Newholme
Overall	14.37+0.47(18)	13.63+1.43(4)	12.59+0.40(17)	9.96+0.67(3)
Summer	14.75+0.46(5)	13.80+2.01(3)	13.83+1.31(4)	9.43+0.70(2)
Autumn	14.43+0.56(3)	-	12.13+0.60(5)	-
Winter 1	13.02+0.95(6)	13.10 (1)	11.91+0.23(4)	11.04 (1)
Spring	15.88+1.09(4)	-	12.59+0.69(4)	-

LANA TO NEWHOLME

<u>FEMALE</u>		<u>MALE</u>	
overall	NS	overall	*
S	NS	S	NS (p = 0.09)
W1	NS	W1	NS

SEASONAL COMPARISON

<u>LANA</u>			
Female		Male	
S-A	NS	S-A	NS
A-W1	NS	A-W1	NS
W1-SP	NS (p = 0.087)	W1-SP	NS
SP-S	NS	SP-S	NS
<u>NEWHOLME</u>			
Female		Male	
S-W1	NS	S-W1	NS

between Lana and Newholme. Haemoglobin levels were lowest during winter 1 on Lana. Sample sizes were too small to assess seasonal differences on Newholme. For male wallaroo haemoglobin levels overall were lower on Newholme than on Lana. Although levels were lowest during winter 1 on both Newholme and Lana there were no significant seasonal differences.

For the grey kangaroo there was no significant age effect on haemoglobin levels for either females or males. A t-test showed no differences between the sexes on Lana or Newholme and so the data for both sexes were pooled. The results are shown in Table 7.18. There were no differences between haemoglobin levels on Lana and Newholme. On Lana the lowest mean haemoglobin level was recorded in winter 1. There were no significant seasonal differences on Newholme.

Haemoglobin and haematocrit levels were significantly correlated for both grey kangaroo (Fig. 7.20) and wallaroo (Fig. 7.21).

(f) Spleen weight

Since the spleen acts as reservoir for red blood cells and since changes have been shown to occur in haematocrit and haemoglobin levels with changes in condition in other mammalian herbivores, the spleen weights were recorded to examine differences between seasons and between properties. Changes in spleen weight have been shown to occur with changes in condition in other studies (e.g., Myers and Bults, 1977; Myers *et al.*, 1976). However Dawson and Denny (1968) have found that excitement causes splenic emptying. Thus differences in the degree of arousal of kangaroos may affect spleen weight in the same way as haematocrit and haemoglobin are affected.

The equation used to calculate an index of spleen weight corrected for body size for wallaroo was:

$$10 (\log. \text{ spleen weight (gm)} - 0.0358 \text{ Leg length (cm)}).$$

A t-test revealed no significant difference between male and female wallaroo on either Lana or Newholme so the data for both sexes were pooled. The results are given in Table 7.19. Spleen weight indices were significantly greater on Lana than on Newholme overall and during summer and possibly also during winter 1. On Lana the highest mean spleen weight index was recorded during summer and the lowest during winter 1. On Newholme there were no significant seasonal differences although the highest mean spleen weight index may have occurred in winter 2.

The equation used to calculate an index of spleen weight corrected

Table 7.18 Haemoglobin levels (g/100 ml) for grey kangaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA	NEWHOLME
Overall	15.36 \pm 0.27 (37)	15.00 \pm 0.41 (6)
Summer	15.54 \pm 0.61 (10)	14.65 \pm 0.45 (2)
Autumn	15.74 \pm 0.59 (8)	-
Winter 1	14.38 \pm 0.45 (9)	15.18 \pm 0.60 (4)
Spring	15.76 \pm 0.48 (10)	-

LANA TO NEWHOLME

overall	NS
S	NS
W1	NS

SEASONAL COMPARISON

<u>LANA</u>		<u>NEWHOLME</u>	
S-A	NS	S-W1	NS
A-W1	NS (p = 0.08)		
W1-SP	NS (p = 0.052)		
SP-S	NS		

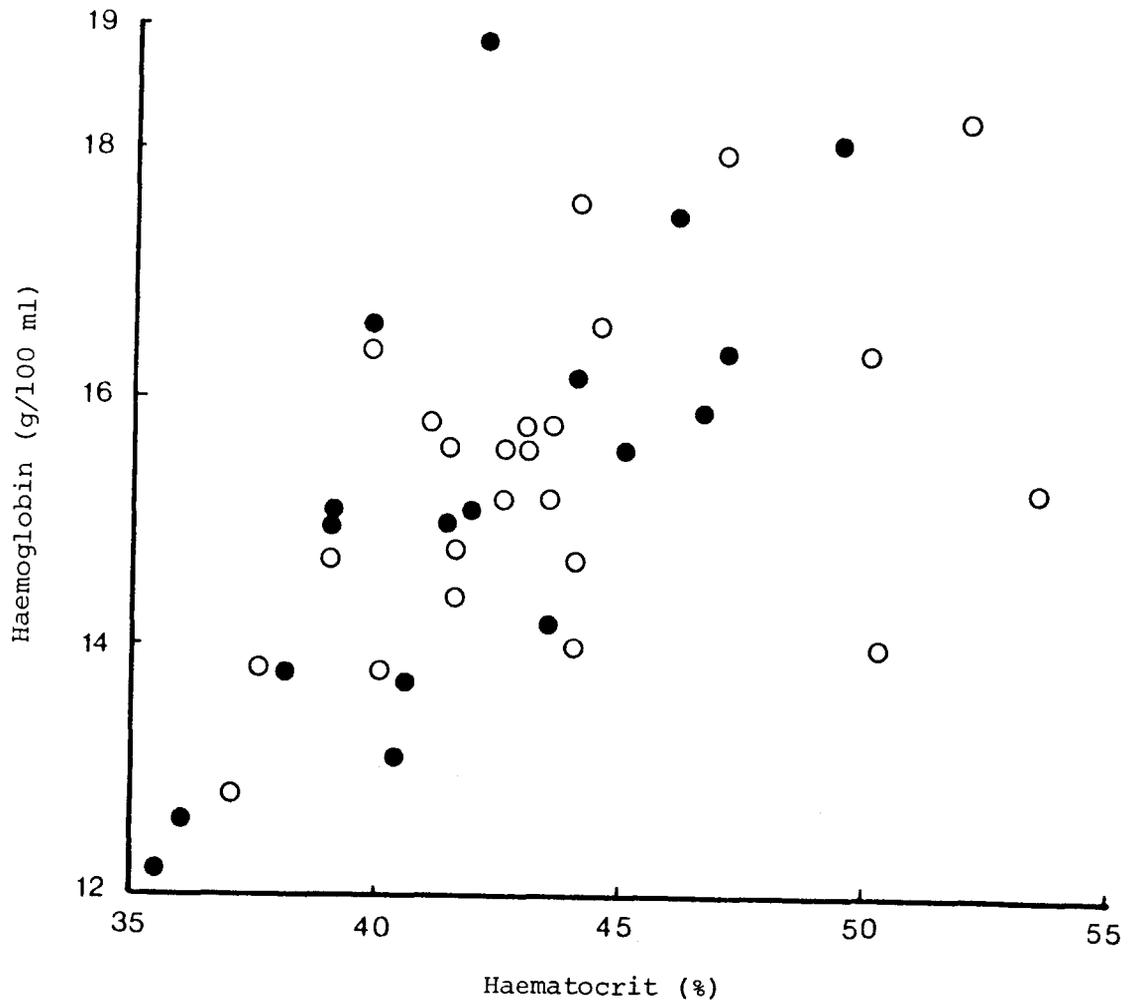


Fig. 7.20. Relationship between haemoglobin and haematocrit levels for grey kangaroo. $r = 0.57$, $p < 0.001$

● Male

○ Female

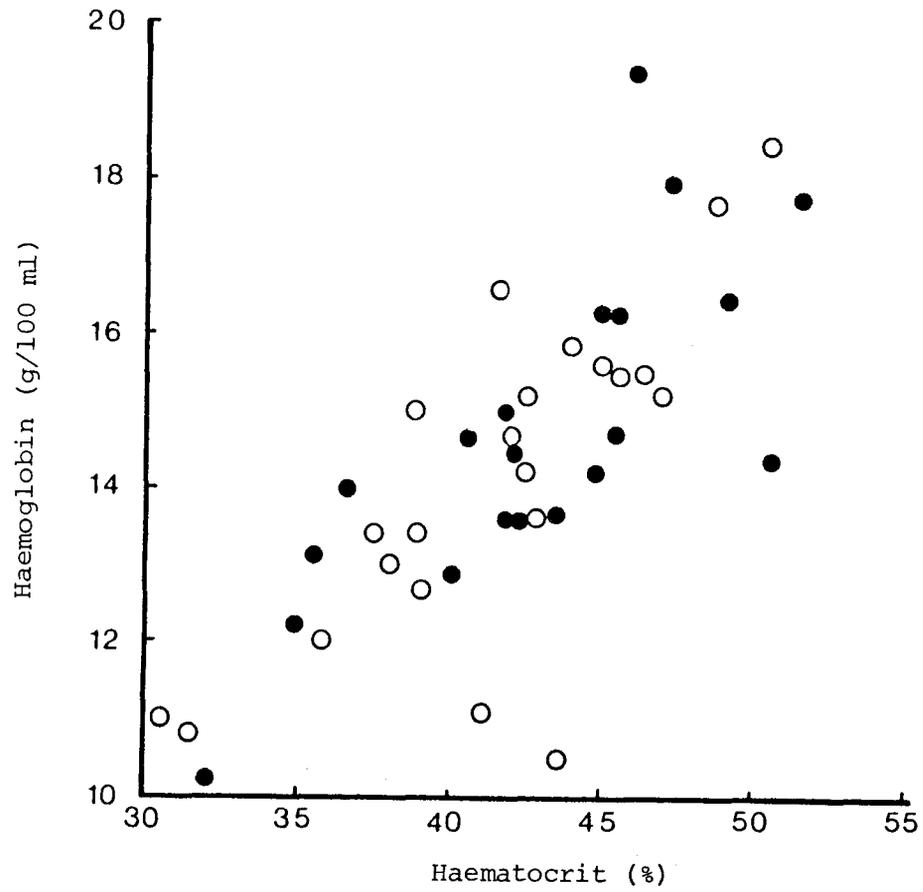


Fig. 7.21. Relationship between haemoglobin and haematocrit levels for wallaroo. $r = 0.78$, $p < 0.001$.

● Male

○ Female

Table 7.19 Spleen weight indices for wallaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA	NEWHOLME
Overall	3.96 \pm 0.19 (48)	2.76 \pm 0.25 (18)
Summer	5.05 \pm 0.53 (10)	2.43 \pm 0.58 (6)
Autumn	3.53 \pm 0.49 (10)	-
Winter 1	3.37 \pm 0.30 (9)	2.53 \pm 0.24 (7)
Winter 2	3.78 \pm 0.24 (10)	3.47 \pm 0.42 (5)
Spring	3.99 \pm 0.23 (9)	-

LANA TO NEWHOLME

overall **
 S **
 W1 NS (p = 0.055)
 W2 NS

SEASONAL COMPARISON

<u>LANA</u>		<u>NEWHOLME</u>	
S-A	*	S-W1	NS
A-W1	NS	W1-W2	NS (p = 0.065)
W1-SP	NS	S-W2	NS
W1-W2	NS		
SP-S	NS (p = 0.09)		
A-W2	NS		
W2-SP	NS		

for body size for grey kangaroo was:

$$10 \left(\sqrt[3]{\text{Spleen weight (gm)} - 0.0557 \text{ Leg length (cm)}} \right).$$

The anoestrous female in poor condition (spleen weight = 20 g, expected spleen weight = 61 g) was not included in the analysis for reasons given previously. A t-test showed no significant difference between the sexes on Lana or Newholme and so the data for both sexes were pooled. The results are given in Table 7.20. Spleen weight indices were significantly greater on Lana than on Newholme overall and during summer. The lowest mean spleen weight index occurred during winter 2 on Lana. On Newholme there were no significant seasonal differences.

(g) Liver weight

Since one of the functions of the liver is the storage of food substances assimilated in the gut, animals in poor condition (i.e., on an inadequate food intake) may have a lower liver weight than an animal in good condition. Changes in liver weight have been shown to occur with changes in condition in other studies (e.g., Myers and Bults, 1977; Myers *et al.*, 1976).

The equation used to calculate an index of liver weight corrected for body size for wallaroo was:

$$\left((\text{Liver weight (gm)} - 27.42 \text{ Forearm length (cm)}) + 400 \right) \div 5$$

There were no significant differences between the sexes and so data for males and females were pooled. The results are shown in Table 7.21. The mean liver weight index was larger on Lana than on Newholme during all seasons although only significantly higher for the overall comparison. The lowest mean liver weight index occurred during winter 1 on both properties.

The equation used to calculate an index of liver weight corrected for body size for grey kangaroo was:

$$\left((\text{Liver weight (gm)} - 29.26 \text{ Forearm length (cm)}) + 300 \right) \div 3$$

There were no significant differences between males and females and so the data for both sexes were pooled. The results are given in Table 7.22. Although the mean liver weight indices were greater on Lana than on Newholme during all seasons these differences are not statistically significant. The lowest mean index was recorded in winter 2 on Lana and in winter 1 on Newholme.

Table 7.20 Spleen weight indices for grey kangaroo on Lana and Newholme. Values are means + standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA	NEWHOLME
Overall	13.95 \pm 0.33 (48)	12.40 \pm 0.45 (20)
Summer	15.53 \pm 0.81 (10)	13.13 \pm 0.51 (6)
Autumn	14.04 \pm 0.52 (10)	-
Winter 1	13.98 \pm 0.49 (8)	12.71 \pm 1.13 (6)
Winter 2	11.98 \pm 0.77 (10)	11.63 \pm 0.63 (8)
Spring	14.22 \pm 0.61 (10)	-

LANA TO NEWHOLME

overall	*
S	*
W1	NS
W2	NS

SEASONAL COMPARISON

<u>LANA</u>		<u>NEWHOLME</u>	
S-A	NS	S-W1	NS
A-W1	NS	W1-W2	NS
W1-SP	NS	S-W2	NS
W1-W2	NS (p = 0.056)		
SP-S	NS		
A-W2	*		
W2-SP	*		

Table 7.21 Liver weight indices for wallaroo on Lana and Newholme. Values are means + standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA	NEWHOLME
Overall	50.79 \pm 1.80 (48)	39.83 \pm 2.68 (18)
Summer	58.76 \pm 4.87 (10)	44.41 \pm 4.29 (6)
Autumn	48.88 \pm 4.41 (10)	-
Winter 1	44.42 \pm 2.62 (9)	35.19 \pm 4.10 (7)
Winter 2	49.09 \pm 3.39 (10)	40.82 \pm 5.72 (5)
Spring	52.32 \pm 3.41 (9)	-

LANA TO NEWHOLME

overall	**
S	NS (p = 0.065)
W1	NS (p = 0.068)
W2	NS

SEASONAL COMPARISON

<u>LANA</u>		<u>NEWHOLME</u>	
S-A	NS	S-W1	NS
A-W1	NS	W1-W2	NS
W1-SP	NS (p=0.085)	S-W2	NS
W1-W2	NS		
SP-S	NS		
A-W2	NS		
W2-SP	NS		

Table 7.22 Liver weight indices for the grey kangaroo on Lana and Newholme. Values are means \pm standard error. Values in brackets are the number of kangaroos in each sample.

SEASON	LANA	NEWHOLME
Overall	44.17 \pm 2.52 (49)	32.82 \pm 5.08 (17)
Summer	42.67 \pm 5.19 (10)	39.59 \pm 12.90 (5)
Autumn	40.99 \pm 6.37 (10)	-
Winter 1	48.14 \pm 6.35 (9)	27.97 \pm 0.30 (4)
Winter 2	36.38 \pm 4.51 (10)	31.02 \pm 6.42 (8)
Spring	53.09 \pm 5.18 (10)	-

LANA TO NEWHOLME

overall	NS
S	NS
W1	NS
W2	NS

SEASONAL COMPARISON

<u>LANA</u>		<u>NEWHOLME</u>	
S-A	NS	S-W1	NS
A-W1	NS	W1-W2	NS
W1-SP	NS	S-W2	NS
W1-W2	NS		
SP-S	NS		
A-W2	NS		
W2-SP	*		

(h) Relationship between condition indices

The relationship between the kidney fat index and the level of bone marrow fat is shown in Fig. 7.22 for the grey kangaroo and Fig. 7.23 for the wallaroo. For both species at high levels of kidney fat the level of bone marrow fat remained constantly high. At low levels of kidney fat the bone marrow fat content decreased rapidly with the kidney fat rarely disappearing entirely. Thus the bone marrow fat deposits were not utilized by the kangaroos unless most of the kidney fat (and other fat deposits in the body cavity (pers. obs.)) had been utilized. This is similar to that found for other mammalian herbivores (e.g., Ransom, 1965; Sinclair and Duncan, 1972).

The kidney fat index was not significantly correlated with the body weight condition index for male or female wallaroo or male grey kangaroo. The kidney fat index was however significantly correlated with the body weight condition index for female grey kangaroo ($r = 0.36$, $df = 40$, $p < 0.05$). This was probably related to the fact that the animals in the poorest condition were female grey kangaroo. Thus only when the kidney fat index dropped to very small values did a significant drop in weight occur. This is even more evident for the bone marrow fat. Thus there was no significant correlation between the bone marrow fat level and the body weight condition index for male grey kangaroo or male wallaroo but a significant correlation for female wallaroo ($r = 0.33$, $df = 30$, $p < 0.05$) and female grey kangaroo ($r = 0.50$, $df = 35$, $p < 0.001$) probably because females were recorded in poorest condition in both species. Thus the animals with very low bone marrow fat levels also had a low body weight condition index. The leg muscle to bone index (an index of muscle bulk) was also only correlated with the body weight condition index for female grey kangaroo ($r = 0.49$, $df = 37$, $p < 0.001$). It thus appears that only after all fat reserves have been depleted do animals start to catabolize body protein thus causing a significant drop in body weight.

The liver and spleen weight indices were significantly correlated for both grey kangaroo ($r = 0.32$, $df = 64$, $p < 0.01$) and wallaroo ($r = 0.62$, $df = 64$, $p < 0.001$). The spleen weight index was significantly correlated with the body weight condition index for both grey kangaroo ($r = 0.48$, $df = 65$, $p < 0.001$) and wallaroo ($r = 0.66$, $df = 58$, $p < 0.001$). The liver weight index was significantly correlated with the body weight condition index for wallaroo ($r = 0.38$, $df = 58$, $p < 0.01$) and was close to being significant for the grey kangaroo ($p = 0.07$).

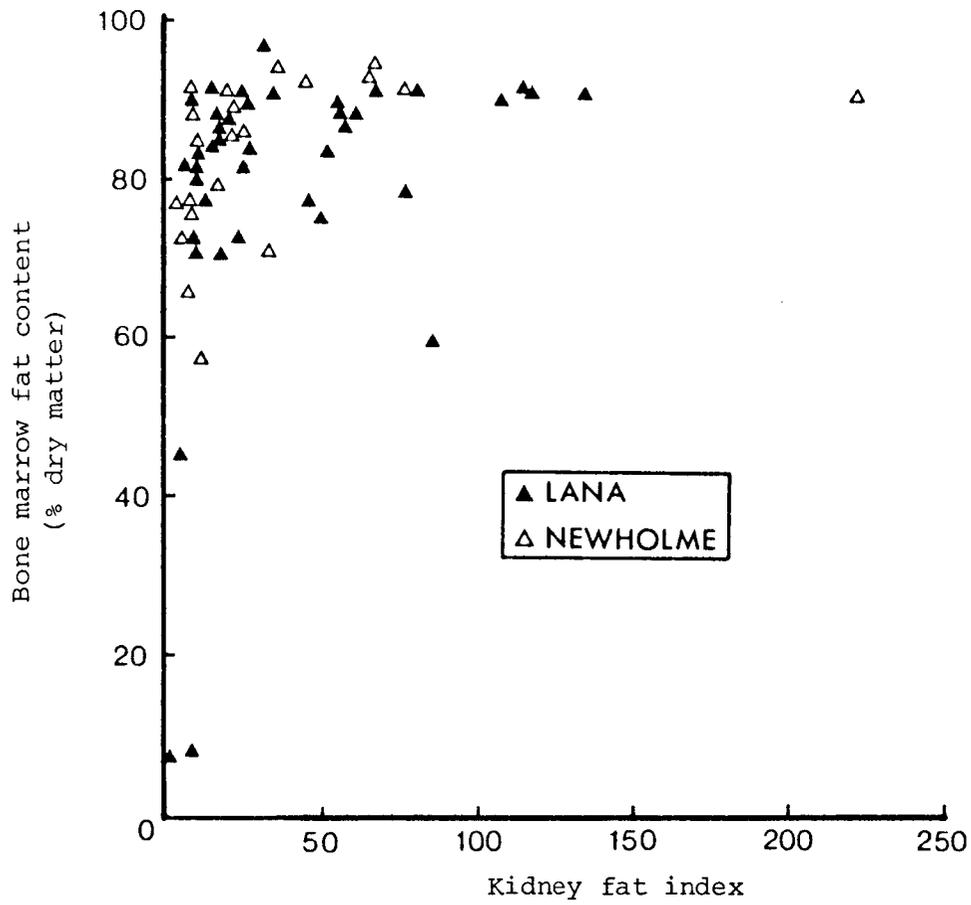


Fig. 7.22. Relationship between the bone marrow fat content and the kidney fat index for grey kangaroo.

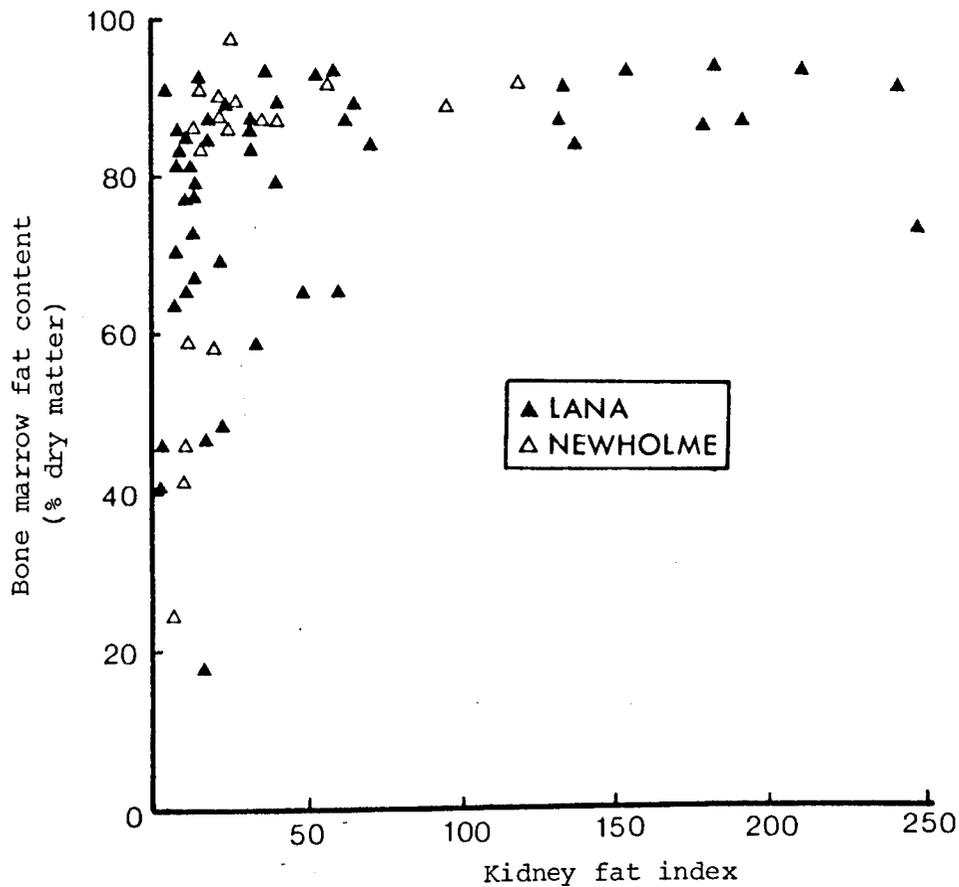


Fig. 7.23. Relationship between the bone marrow fat content and the kidney fat index for wallaroo.

7.4 Discussion

The analysis of changes in condition of kangaroos over seasons and between Lana and Newholme has been hampered by the differences in condition which occur between sex and reproductive classes. These differences are brought about by differences in the energy requirements of sex and reproductive classes and differences in their cycle of condition changes over seasons. Immature animals have high growth rates and very little of their assimilated energy is stored as fat. Mature males engage in interactions with other males in ritualized fighting and encounters over the "ownership" of oestrous females. As oestrous females will occur most frequently in spring and early summer due to most pouch young emerging during spring (Chapter 6), mature males' energy expenditure may be greatest at this time. The low levels of haematocrit in the blood during spring for both wallaroo and grey kangaroo males may be related to this increased competition. Mature females' energy requirements will differ depending on the size of pouch young or young-at-foot which they are suckling. Many mature females will be carrying large pouch young during winter and suckling young-at-foot during spring. The largest fat reserves occurred in mature females with pouch young. Such reserves are probably necessary to ensure adequate nutrition of the pouch young during winter. These differences in energy requirements may also be associated with differences in the amount of food eaten (i.e., stomach fill levels) by different sex and reproductive classes. Thus significant differences were found between some sex and reproductive classes of grey kangaroo on Lana and larger sample sizes might have shown that these differences exist for both species.

Despite the small sample sizes and the difficulty of comparing samples with different sex and reproductive class combinations, the condition of both grey kangaroo and wallaroo on Lana does appear in general to be higher than on Newholme. The possible exception to this is winter 1. Thus on Lana during winter 1 two females were sampled in very poor condition. They were probably in poorer condition than the other grey kangaroo sampled in winter 1 on Lana due to the extra nutritional burden of suckling large pouch young (or young-at-foot). One of the females was carrying a fully developed joey and the other was in anoestrus. This anoestrous female could have lost a large pouch young due to malnutrition or could have finished feeding a young-at-foot. There was no difference in the quality of food eaten by these individuals in comparison to the others sampled which could account for

their poor condition. The condition of grey kangaroo females with large pouch young on Newholme in winter 1 did not drop to the low levels of the two females on Lana. There was no significant drop in the quality of food eaten by grey kangaroo on Lana in winter 1 compared to winter 2. However there was a significant decrease in the level of stomach fill in winter 1 compared to winter 2. On Lana grey kangaroo had a lower intake of low-fibre grass leaf and a greater intake of tussock grass in winter 1 compared to winter 2 (Chapter 4). It was hypothesized in Chapter 4 that the effects of the wet conditions in winter 1 on Lana was to reduce the biomass of low-fibre grass (principally *Danthonia racemosa*) present. Thus, although the quality of the diet was similar in both winters, in winter 1 grey kangaroo may have been affected by a drop in the quantity of low-fibre grass available. This shortage was reflected in a drop in condition in animals with the highest energy requirements at that time (i.e., females suckling young-at-foot or large pouch young). On Newholme the diets of the kangaroos were similar during winter 1 and winter 2 (Chapter 4) and there was no significant difference in the level of stomach fill in the two winters.

The wallaroo on Lana during winter 1 appeared to be somewhat less affected by the reduced low-fibre grass biomass than were grey kangaroo. Thus the female wallaroo with a suckling young-at-foot in the winter 1 sample on Lana had not dropped in condition to as great an extent as had the two female grey kangaroo. It can be hypothesized that differences in the digestive strategy of the two species account for at least part of this difference in condition during winter 1. The grey kangaroo stomach is more elongated and cylindrical in comparison to the wallaroo stomach (Dellow, 1979). It was shown in the present study that the stomach of the grey kangaroo makes up a greater proportion of the body weight in comparison to wallaroo. Hume (1978) argued that the elongation of the stomach in the Macropodidae evolved to enable them to utilize high-fibre grass. On high-fibre diets the Macropodidae strategy is based on an increase in food intake and passage through the stomach at the expense of a high unit digestive efficiency. Since the grey kangaroo stomach is more elongated and has a greater capacity than wallaroo, on low quality diets the grey kangaroo's digestive strategy may be based on a larger intake and an increased rate of passage in comparison to wallaroo. Grey kangaroo may thus be more susceptible to a drop in the quantity of food available during periods of reduced availability of good quality food. The stomach fill index for grey kangaroo on Lana was significantly lower during winter 1 compared to winter 2 whereas the stomach fill index for wallaroo on Lana in winter 1

was similar to the winter 2 level. Experimental work is needed on captive animals to confirm that these differences in digestive strategy do exist between the two species. The work that has been done comparing the grey kangaroo and wallaroo has all been done with high quality diets (Dellow, 1979). Future work should be aimed at examining differences between the two species fed (a) diets of lower quality and (b) amounts less than *ad libitum*.

The diet of the wallaroo was shown to contain a higher proportion of grasses (and legumes in spring) of high nitrogen content than the grey kangaroo (Chapter 4). The greater proportion of non-plant nitrogen in wallaroo stomachs should also increase the differences in the nitrogen content of unwashed stomachs. There were however no significant differences in nitrogen content of the stomach between grey kangaroo and wallaroo on either Lana or Newholme. Reasons for this lack of a difference between the stomach nitrogen levels of the two species are not known. Both kangaroo species' stomachs usually contained large quantities of nematodes. No effort was made to exclude these worms from the stomach samples other than avoiding large dense clumps with little plant material. The greater level of animal-derived nitrogen in wallaroo stomachs may have been due to more nematodes in wallaroo stomachs. However in the absence of any measurement of the size of the nematode populations in the two species it is not possible to confirm this.

Differences in the level of ash in the stomach of the grey kangaroo and wallaroo during spring on Lana are probably related to differences in the intake of silica or other minerals from the soil as they grazed. For the grey kangaroo on Lana the lowest levels of ash in the stomach contents occurred in spring whereas for the wallaroo the highest levels occurred in spring. During spring grey kangaroo diets contained the highest proportion of grass stem and inflorescence (see Chapter 4) and they probably tended to graze higher from ground level than in other seasons. Wallaroo also take most stem and inflorescence during spring. However, their use of *Microlaena* from sheep camps was greatest at this time. Since the grass in sheep camps was very short in spring, wallaroo may take in more soil as they feed at this time than in other seasons.

Apart from the two adult female grey kangaroo on Lana during winter 1, the only other animals found to be in very poor condition were two young-at-foot, one on Lana and the other on Newholme, during winter 1. These animals would have finished pouch life during autumn and hence

would always have been faced with a scarcity of good quality food. It was argued in Chapter 6 that most pouch young finish pouch life in spring/summer in both species in order to maximise the time available to the young before periods of reduced food availability ensue. The poor condition of the two young-at-foot that finished pouch life in autumn is evidence of the detrimental effects of pouch young emergence during periods of reduced availability of good quality food.

The quality of food contained in the stomach was higher on Lana than on Newholme for both grey kangaroo and wallaroo. The intake of higher quality food by kangaroos on Lana was probably responsible for the better condition of kangaroos on Lana compared to Newholme. The present study has indicated at least two strategies used by kangaroos on Newholme to increase the amount of energy assimilated. The stomach fill index for both the wallaroo and grey kangaroo was significantly greater on Newholme than on Lana in some seasons. If all of the animals on Newholme had been shot at night so that the stomach fill indices on the two properties were more comparable and if sample sizes were greater, the number of seasons in which the stomach fill levels were significantly greater on Newholme would probably have been greater. Also the UR ratios for grey kangaroo were significantly lower on Newholme than on Lana, indicating that grey kangaroo on Newholme may have been recycling a greater proportion of the synthesized urea than were grey kangaroo on Lana. Recycling of urea to the stomach can increase production of bacterial protein (if energy is not limiting) which can then be used as a source of protein by the kangaroo.

Energy appears to be an important limiting factor in the diet on both properties. When the nitrogen content of the food eaten drops, if nitrogen is limiting, there should be an increase in the proportion of synthesized urea recycled to the gut. The UR ratio for grey kangaroo on Lana was greater during both winters than in summer, indicating that a lower proportion of urea was recycled to the gut during winter. The UR ratio for wallaroo on Lana was significantly greater in winter 1 than in other seasons and the same level in winter 2 as in spring, summer and autumn. The UR ratios for the grey kangaroo on Newholme were not significantly different between seasons. The UR ratios for wallaroo on Newholme were similar in winter 1 and summer and significantly greater (i.e., less recycling) in winter 2 than in other seasons. Food intake during winter must have been below the maintenance requirements as condition dropped during winter. Therefore some factor other than nitrogen must have been limiting. It is possible that the energy content

of food is critical during winter. If energy is in short supply recycling of urea will not increase the production of bacterial protein.

The most extreme case of energy shortage may have been on Newholme for wallaroo during winter 2. The stomach nitrogen levels were below the summer levels for these wallaroo yet the faecal nitrogen levels were increased markedly. This may have indicated that the wallaroo were unable to assimilate a lot of the protein being eaten. A lack of energy could limit the bacterial production and thus limit their breakdown of plant fibre and hence limit the amount of protein able to be assimilated by wallaroo. The mean fibre content of wallaroo stomachs on Newholme in winter 2 was the highest recorded during the study. The UR ratios of these wallaroo, with the exception of one individual, were extremely high indicating virtually no recycling of urea was occurring. Very high UR ratios occur in animals on diets with a very high nitrogen content. However, these wallaroo were not feeding on a high nitrogen diet. To my knowledge no study has measured UR ratios of animals fed a diet with an adequate protein content but an inadequate energy content. I would predict that animals in this situation would have high UR ratios. One of the wallaroo on Newholme in winter 2 had a UR ratio comparable to other seasons. This same animal had the highest stomach nitrogen level recorded for a wallaroo during this study. The level of tussock grass and good quality grass (i.e. *Microlaena*) in the diet of this individual was comparable to other wallaroo in the Newholme winter 2 sample. This individual must have therefore been selecting individual plants (or plant parts) of high quality rather than plant species of high quality. The only difference in the diet of this wallaroo compared to other wallaroo in the winter 2 sample on Newholme was the presence of a small amount of mushroom in its stomach. How or whether this mushroom affected the nutritional status of this individual is not known.

Some studies have found a significant correlation between plasma urea-nitrogen and protein intake for herbivores with forestomach fermentation (e.g., Preston *et al.*, 1965; Torell *et al.*, 1974; Nolan *et al.*, 1970; Franzmann, 1972). However, energy intake has also been shown to affect plasma urea levels (e.g., Kirkpatrick *et al.*, 1975). The lack of a significant correlation between stomach nitrogen or faecal nitrogen and plasma urea levels may be the result of the interacting effects of energy and protein on the plasma urea levels.

Klein and Schonheyder (1970) found that for several deer species there was a decrease in the animal-derived nitrogen component of the

stomach contents as the vegetative nitrogen component increased. There was no evidence of this source of variation for either the grey kangaroo or wallaroo. Thus there was a highly significant correlation between washed and unwashed stomach contents over a wide range of nitrogen levels for both species. The lack of an increase in the animal-derived nitrogen component of the diet as the vegetative nitrogen component decreases may be due to the lack of a substantial increase in the proportion of urea recycled to the gut as the vegetative nitrogen drops. As previously noted, this lack of an increase in the proportion of urea recycled is probably due to a shortage of energy.

The kidney fat index and the bone marrow fat content have been found to be adequate indices of condition over the full range of condition encountered. Other indices of condition measured were in general agreement with these. However the kidney index may be inadequate for assessing good condition in young animals because very little fat is stored in these animals since most excess energy goes into growth. The condition indices based on blood parameters (i.e., haematocrit and haemoglobin) proved the least satisfactory as they were probably influenced by an animal's level of excitement and the time taken before a blood sample was obtained. Rigid standardization would be necessary to ensure the accuracy of these measurements as an index to condition. The weight-length index would be the best index of condition if measurements were to be made on live animals. The length parameter needs to be chosen with care to ensure the best correlation with weight and accurate measurement of the length parameter is essential. Differences in the degree of stomach fill could also affect the accuracy of this measurement as a condition index. Although only a few measurements need to be taken on an individual to assess its condition, in order to explain any changes in condition one needs to monitor many physiological parameters as well as changes in the quality, quantity and composition of the food eaten. Sample sizes also need to be adequate to assess accurately the condition of each sex and reproductive class as these classes can differ markedly in condition during the same season.

CHAPTER 8GENERAL DISCUSSION

In the New England Tablelands of New South Wales properties with improved pasture (i.e., fertilizer added and sometimes also new pasture species introduced) support higher densities of kangaroos than do properties with unimproved pasture (provided adequate shelter for kangaroos remain). Graziers in the district claim an increase in the number of kangaroos occurs on a property after pasture improvement measures are adopted. The ecology of the eastern grey kangaroo and wallaroo was studied on two areas, one with improved pasture and one with unimproved pasture, in order to compare the ecology of these species on areas with different levels of food resources but where other resources were similarly available.

It has been shown that a greater proportion of the pasture biomass on Lana was made up of grasses of lower fibre content than on Newholme. From a comparison of the quality of the same plant species on each property it was shown that plants are of a higher quality on Lana. Thus pasture improvement increases the quality of grasses (and other pasture plants) and the quantity of low-fibre grasses present in comparison to unimproved areas. It was shown that the density of grey kangaroo and wallaroo on Lana was greater than on Newholme and that the condition of animals on Lana was generally higher than for animals on Newholme. The animals on Lana did not eat a greater quantity of food than animals on Newholme, however, their stomachs did contain food of a higher quality. It was suggested that the better condition of animals on Lana was a result of this intake of higher quality food. It was also found that for a given quantity of low-fibre grass leaf (the main dietary item of kangaroos) the density of both wallaroo and grey kangaroo on Lana was greater than on Newholme. Thus higher quality food appears to be able to support a larger population of kangaroos, although increased productivity on improved pasture could also be playing a role.

The question still remains as to how increased food quality leads to a greater population density. The fecundity of females was similar on both properties. The only female found to be in anoestrus was a grey kangaroo on Lana in winter 1978. This was probably brought about by the effects of an unusually wet winter and would not be a regular

occurrence on Lana. Thus it is probably unlikely that differences in birth rate between the properties will be influencing population densities.

The examination of condition of animals showed that the most likely population classes to suffer from the effects of reduced availability of good quality food during autumn and winter would be young animals and adult females with large pouch young or suckling young-at-foot. Young animals have a high growth rate and do not store large fat reserves. All energy extracted from their food must go into growth and maintenance. Thus young animals have no fat reserves which they can utilize during periods when energy intake is below that required for maintenance. In adult animals, females with large pouch young or suckling young-at-foot are most likely to suffer the effects of food shortage due to the additional energy demands of lactation. Poor condition in these females is likely to affect the condition of pouch young through a reduced milk supply or even through the drying up of the mother's milk during periods of acute food shortage.

No difference in the condition of pouch young on Lana and Newholme could be shown. However, it was found that the proportion of adult female wallaroo accompanied by young-at-foot was 2.6 times greater on Lana than on Newholme. Thus, since fecundity on the two properties was similar, the mortality rate of pouch young and/or young-at-foot must have been 2.6 times greater on Newholme than on Lana for wallaroo. This could result from a poor nutritional status for young animals on Newholme due to poor milk supplies because of the lower nutritional status of adult females on Newholme. Alternatively, young-at-foot mortality rates may be greater on Newholme due to poor quality pasture available to these animals on Newholme. The importance of nutrition to the survival of young-at-foot is highlighted by the distribution of births over the year. Thus the majority of young are born at a time which ensures they will emerge from the pouch so that the length of time for which adequate food resources are available is maximised before periods of reduced food availability ensue (i.e., autumn and winter). This strategy also means that most adult females are faced with heavy lactation demands during the period of lowest food availability. Thus it is essential for adult females to build up large fat reserves to enable them to cope with these extra demands during winter. The poor condition during winter of the two young-at-foot which had emerged from the pouch during autumn highlights the importance of time of exit from the pouch on the survival of young-at-foot.

Although no data were obtained on the percentage of adult female grey kangaroo that were accompanied by young-at-foot on the two properties, it is hypothesized that a greater proportion of adult female grey kangaroo will be accompanied by young-at-foot on Lana than on Newholme. However culling of grey kangaroo on Lana is responsible for maintaining the population below the carrying capacity. Thus it would be difficult to separate the effects of differences in the level of the two populations on Lana and Newholme in relation to the carrying capacity from the effects of differences in the quality of food available on the mortality rates for young grey kangaroo on the two properties.

From the condition of animals on the two properties it appears unlikely that the natural mortality rate (i.e., excluding human predation) of adult animals differs much between the properties. A higher mortality of pouch young and/or young-at-foot is probably responsible for maintenance of a higher density of both grey kangaroo and wallaroo on Lana compared to Newholme.

Other studies on kangaroos have also concluded that pouch young mortality is an important factor in the regulation of numbers. In the red kangaroo as food becomes scarce during drought conditions mortality of pouch young increases and many females enter anoestrus (e.g., Newsome, 1964, 1966; Newsome *et al.*, 1967). Frith and Sharman (1964) found that 83% of red kangaroo pouch young failed to reach maturity in areas affected by drought compared to 15% in more favourable areas. In one of their study areas Frith and Sharman (1964) found a lower percentage of sexually mature females in anoestrus compared to that found by Newsome (1964) even though drier conditions probably prevailed during Frith and Sharman's study than during Newsome's study. Russell (1974) has suggested that these differences may be related to differences in the quality of food available to the two populations. Bayliss (1980) concluded that late pouch young and young-at-foot survival was responsible for changes in density of red kangaroo in Kinchega National Park in western New South Wales. These changes in density were correlated with an index of plant growth as were kidney fat levels in the female red kangaroo. Bayliss (1980) hypothesized that the amount of stored kidney fat reflected the female's ability to carry out the burdens of advanced lactation thus determining juvenile survival. Newsome (1977) concluded that a run of good years in central Australia was necessary to ensure adequate red kangaroo pouch young survival to maintain the population. Kirkpatrick (1965c) found in the eastern grey kangaroo population he studied that 50% of young failed to reach

independence. During drought conditions Kirkpatrick and McEvoy (1966) found that grey kangaroo pouch young mortality increased until a point was reached where all female kangaroos sampled were anoestrus and without young. Increased mortality of young animals and cessation of breeding have both been found for euros during a succession of dry years (Russell, 1974; Ealey, 1962; Sadleir, 1965).

Studies on the mortality of pouch young and young animals have mainly concentrated on showing increases in mortality during exceptionally poor conditions as a result of drought. In the present study it appears that increased mortality of pouch young and/or young-at-foot may occur on areas of lower quality pasture during normal yearly seasonal conditions and that this increased mortality probably leads to lower population densities on areas of lower quality pasture.

Although Newholme has had no pasture improvement, the actions of sheep are responsible for creating small areas with high quality food which the kangaroos, especially the wallaroo, utilize extensively. Thus the study area chosen as an unimproved area still had some pasture improvement due to the actions of domestic stock. It is possible that an even greater difference in density of kangaroos and mortality of pouch young and young-at-foot would be found if an improved area with domestic stock were compared to an unimproved area without domestic stock. The presence of some high quality pasture during winter in sheep camps may increase survival rates of young animals on Newholme greatly in comparison to areas without such a resource.