

CHAPTER 3

GENERAL METHODS

3.1 FIELD METHODS

Commercial shooters, non-commercial shooters and officers from the Department of Parks, Wildlife and Heritage were used to obtain samples of Bennett's wallabies and Tasmanian pademelons. Sampling occurred in winter (May-September) and summer (November-February) of 1988 and 1989. The actual timing of sampling within these periods depended on the availability of shooters and weather conditions. At the View Point study area, deer trapping also restricted sampling times.

Unless otherwise stated, all shooters were instructed to shoot wallabies regardless of sex or size in order to minimize any sampling bias imposed by the hunters themselves.

In most cases, shooting occurred from a vehicle with the aid of a spotlight. The exception to this was those samples collected on foot in the Nunamara study area. Shooting normally commenced once it was dark and usually continued for three hours, but ranged from one to five hours. In most cases the wallabies were examined after the shooting period. However, if large numbers were shot or the vehicle was small, shooting and examination occurred alternately.

All animals had their sex determined and were weighed with a Salter 25 kg spring balance. Head lengths were measured using 210 mm vernier callipers. Skulls, testes, pouch young, kidneys and their associated fat were removed, placed in labelled plastic bags and were placed in a freezer within 24 hours of collection. The size of all four teats and whether the teats were lactating or not was also recorded.

3.2 AGING

Ages of pouch young were calculated from head length using the following equations.

Tasmanian pademelon (McCartney 1978)	$\text{Age (days)} = \frac{\text{Head Length (mm)} - 8.03}{0.347}$
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Bennett's wallaby (derived from J.Merchant, unpublished data)	$\text{Age (days)} = \frac{\text{Head Length (mm)} - 16.75}{0.310}$
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The ages of animals which had left the pouch were estimated by molar eruption (Sharman *et al.* 1964). The stages of eruption were given decimal notations accumulating in fifths, as described by Newsome *et al.* (1977). There are two potential sources of error when using this method. Firstly, molar progression is a direct function of the amount of chewing (Sanson 1982). Hence, the relationship between age and molar eruption may differ between captive and free-ranging animals and between populations with different diets. Secondly, some sex-related differences in molar eruption have been shown to occur in the agile wallaby, *M. agilis*, (Newsome *et al.* 1977) and these differences may occur in the wallabies used in this study. As a consequence of these potential sources of error the data derived from this technique must be viewed conservatively.

The relationship between molar eruption and age of Bennett's wallabies (J. Merchant, unpublished data) is shown in Figure 3.1. This method is limited by the fact that animals cannot be aged once all the molar teeth have erupted. Thus for Bennett's wallabies, individuals could not be aged beyond six years.

Up until the present study there was no means of determining the age of Tasmanian pademelons after pouch vacation. McCartney (1978) examined the relationship between age and cementum annulation in the teeth but found no consistent relationship.

In an effort to determine a relationship between age and molar eruption; known age, hand reared young held by wildlife parks and private individuals were examined. Molar eruption stages were determined by examining the teeth of the live animal with the aid of an ophthalmoscope. The results are presented in Figure 3.2. Tasmanian pademelons could not be aged beyond 30 months using this method.

During the winter sampling period of 1988 a reference collection of 281 Bennett's wallaby and 251 Tasmanian pademelon skulls was established. Skulls were boiled, cleaned and then aged. In the remaining sampling periods the semi-thawed skulls were aged after prising open the jaw.

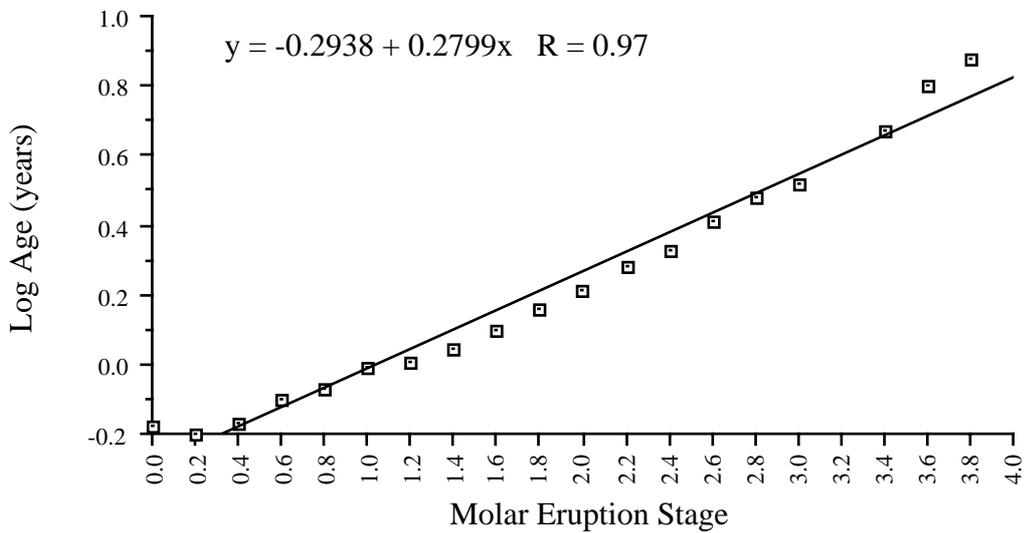
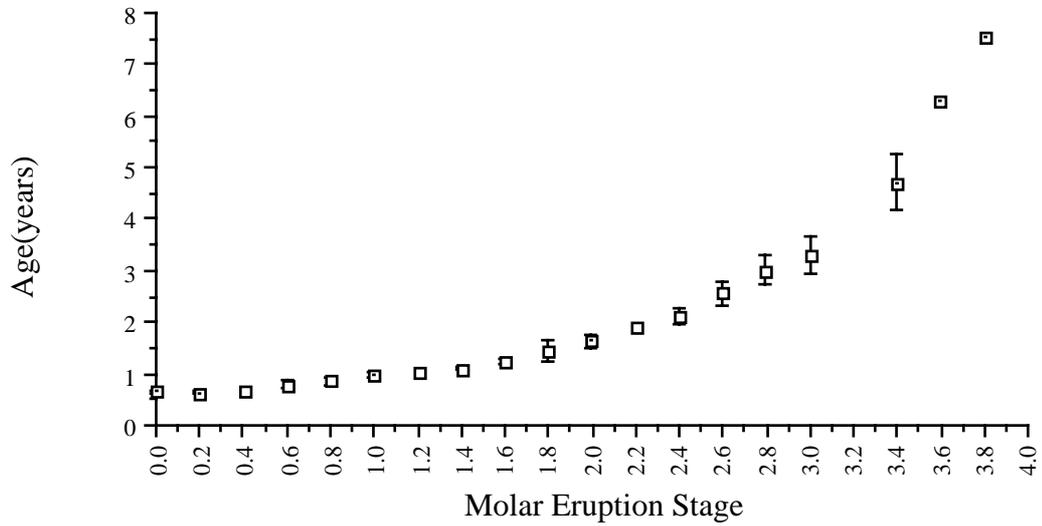


Figure 3.1 Relationship between age and molar eruption stage for Bennett's wallabies. Data supplied by Dr. J.Merchant, CSIRO, Canberra.

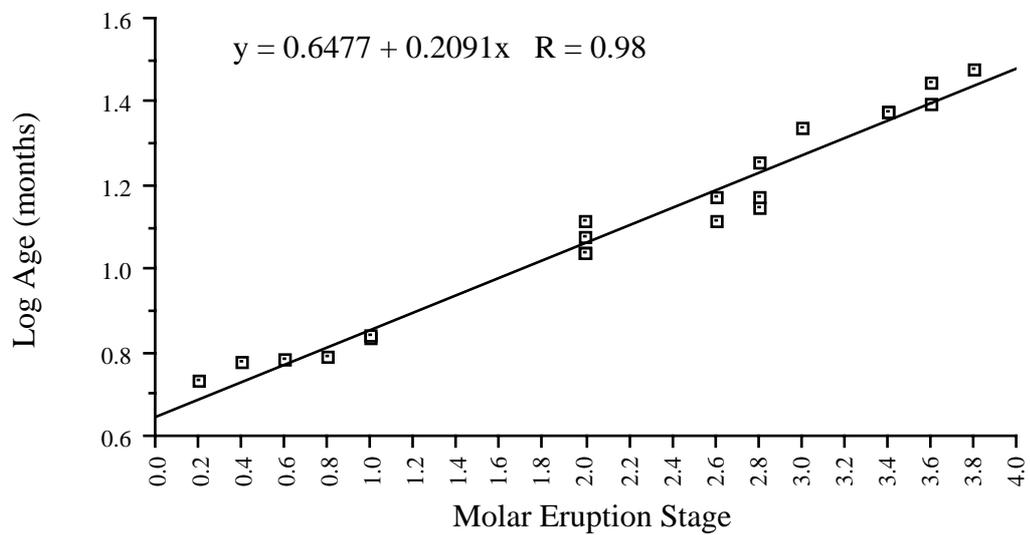
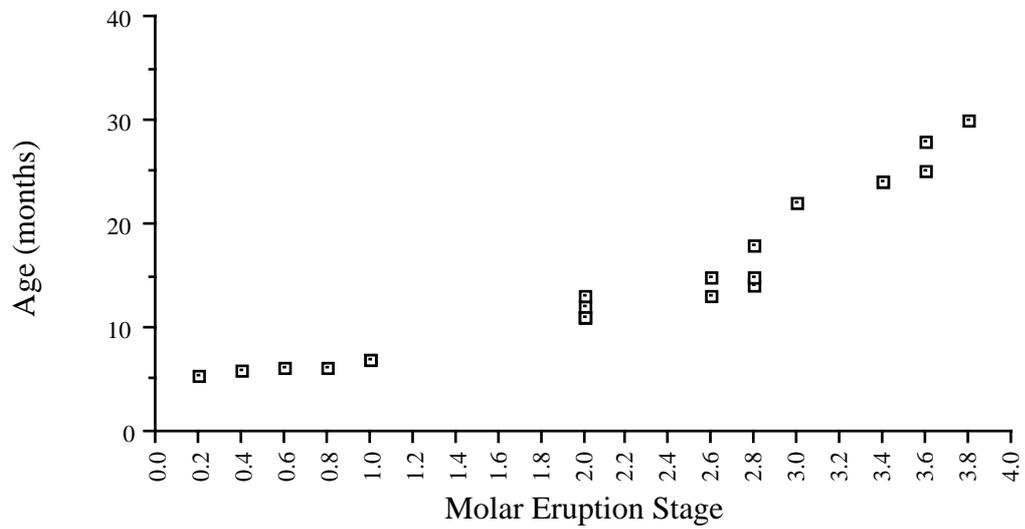


Figure 3.2 Relationship between age and molar eruption stage for the Tasmanian pademelon. Data was obtained from examination of hand reared young of known age.

CHAPTER 4

BODY CONDITION

4.1 INTRODUCTION

The body condition of members of a population reflects the quality of the environment in which that population lives (Klein 1970; Riney 1982; Bailey 1984; Shepherd 1987). Inferred in the use of this term is the idea that body condition is closely related to the chances of an animal's survival (Caughley 1971a). The most common measures of body condition are body size, usually body weight, and measures of fat reserves (Bailey 1984). This follows from the knowledge that when environmental conditions are favourable and an animal's intake of food exceeds its daily requirements, deposits of protein, fat and other metabolites are built up and body weight increases. This does not necessarily imply that fat animals are in good health, but the assumption is normally made that animals with relatively high levels of fat also have adequate levels of other resources within the body (Johns *et al.* 1984). Shepherd (1987) found that body condition in red and western grey kangaroos was linked to some components of rate of increase such as fecundity and survival, and concluded that body condition was a useful summary statistic of a kangaroo's response to their environment.

There have been numerous studies investigating the body condition of a wide range of mammal species. Some studies have shown that within a population there are differences in body condition between adults and juveniles (Riney 1955; Dunham and Murray 1982; Lindstrom 1983; Henderson and Clarke 1986; Pepin 1987) and between males and females (Johns *et al.* 1984; Anderson 1985; Boyd and Myhill 1987). The body condition of animals will also vary throughout a year (Caughley 1962, 1970, 1971a; Flux 1971; Attwell 1982; Dunham and Murray 1982; Johns *et al.* 1984; Waid and Warren 1984; Boyd and Myhill 1987; DeLiberto *et al.* 1989) and has often been shown to be related to the reproductive cycle which, in turn, is influenced by environmental conditions.

Rainfall has been shown to be a significant factor influencing the body condition of animals (Sinclair 1977; Anderson 1985; Shepherd 1987) due to its effect on food availability and quality. Shepherd (1987) was able to show that body condition of red and western grey kangaroos was correlated with rainfall, pasture biomass and dietary quality.

Few studies have compared body condition of populations in relation to hunting pressure. Studies on red deer, *Cervus elaphus*, (Challies 1973), white-tailed deer, *Odocoileus virginianus*, (Kie *et al.* 1983) and chamois, *Rupicapra rupicapra*, (Storch (1989) have shown that populations subject to hunting are in better condition than those which are not hunted. This has

been attributed to the lower density of animals in the hunted areas and hence greater resources for the survivors.

The body condition of Bennett's wallabies and Tasmanian pademelons has not been previously studied. The aim of this chapter is to assess the body condition of these two species and to determine whether hunting and rainfall influences their body condition. The Kidney Fat Index or KFI (Riney 1955) was used to assess the short term response of wallabies to the quality of their environment and growth in body weight was used to assess the longer term response.

4.2 METHODS

The routine measurement of body weight and the collection of kidneys and their associated fat has been described in Chapter 2. KFI was calculated for the left and right kidney using the formula below and then averaged.

$$\text{KFI} = \frac{\text{kidney fat weight}}{\text{kidney weight}} \times 100$$

There are two assumptions in using KFI. Firstly, the amount of kidney fat is proportional to total body fat and, secondly, kidney weight is proportional to body weight. The first assumption is assumed to be true for both wallaby species based on other studies on macropods (Caughley 1962) as well as other mammal species (Smith 1970; Havera 1977). The second assumption will be tested in section 4.3.1.

The frequency distribution of KFIs for both species showed a Poisson distribution and consequently a variance stabilising transformation (square root) was applied to the data (Zar 1984).

For both species, at each study area, mean KFIs were calculated for adult females, adult males and juveniles over winter (June-August) and summer (November-February) of 1988 and 1989.

Mean KFIs for male and female juvenile Tasmanian pademelons were combined as they were not significantly different ($F_{(1,348)}=2.43$, $P>0.1$). Mean KFI for juvenile male Bennett's wallabies was slightly higher (3 KFI units) than that of females ($F_{(1,386)}=8.24$, $P>0.005$). However, in order to reduce the number of comparisons, the juveniles of both sexes were combined.

In all comparisons using adult females, only those which showed evidence of successful reproduction were used as those which failed to produce a pouch young or had lost a pouch young had much lower KFIs (see results in Section 4.3.2).

The effect of variation in hunting pressure and rainfall between study areas on KFI was tested by correlation analysis. Total rainfall for the 12 months prior to collection of KFIs was used for the correlation. As hunting pressure could not be quantified on a parametric scale, a non-parametric test, Kendall's Rank Correlation Coefficient, was used to investigate the effect of this factor on KFI. Annual hunting pressure was ranked from very low to very high (refer to Table 2.4 in Section 2.5).

4.3 RESULTS

4.3.1 Variation in Kidney Weight to Body Weight Ratio

The use of kidney weight (KW) in KFI allows for comparison between animals of different size. The underlying assumption is that kidney weight is proportional to body weight (BW). This assumption is tested below for different sexes, age groups, seasons and study areas.

Variation between sexes and age groups

The regressions given in Figure 4.1 shows that there are linear relationships between kidney weight and body weight for Bennett's wallaby ($r^2=0.82$, $p<0.001$) and for the Tasmanian pademelon ($r^2=0.85$, $p<0.001$). There were no significant differences between males and females for either species (Bennett's wallaby: slope, $t=0.71$, $p>0.50$, elevation, $t=0.01$, $p>0.90$; Tasmanian pademelon: slope, $t=0.27$, $p>0.50$, elevation, $t=1.77$, $p>0.05$).

For both species, the Y-intercept was not equal to zero (Bennett's wallaby: $t=6.4$, $p<0.001$; Tasmanian pademelon: $t=14.6$, $p<0.001$). This indicates that young wallabies have proportionally larger kidneys than old wallabies. This is clearly demonstrated in Table 4.1 where mean kidney weight to body weight (KW/BW) ratios are given. Thus, there were no significant differences in mean KW/BW ratios for Bennett's wallabies older than 2 years ($F_{(4,656)} = 2.02$, $p>0.05$) or Tasmanian pademelons older than 30 months ($F_{(2,506)} = 0.04$, $P>0.90$).

Variation between study areas

As KW/BW ratios varied between age groups, only adult age classes (>2 years for Bennett's wallabies and >18 months for Tasmanian pademelons) will be used to compare variation in mean KW/BW ratios between study areas and months.

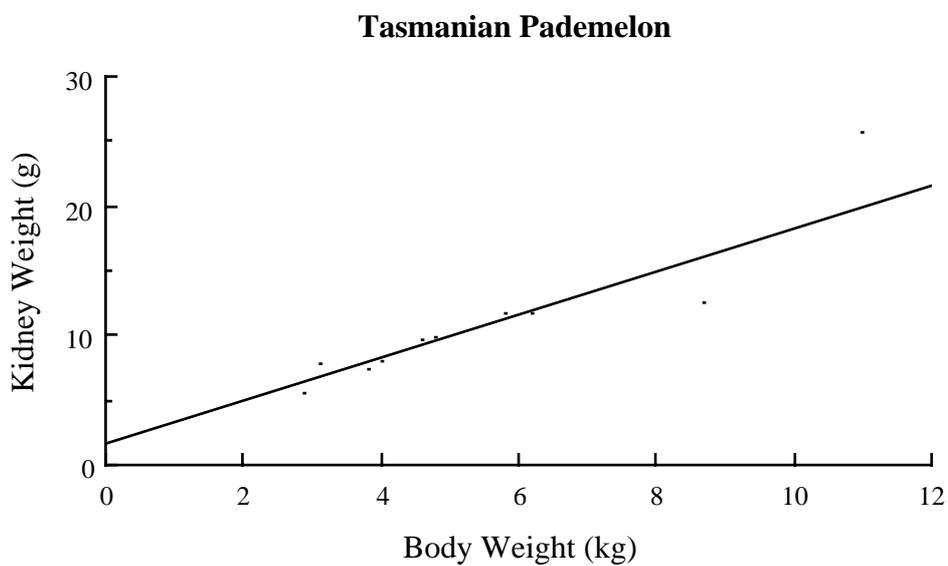
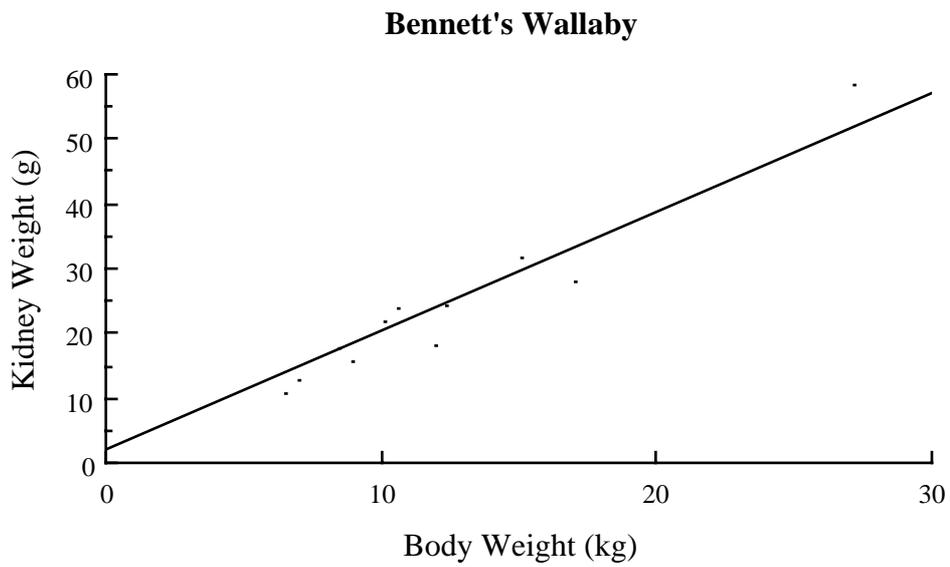


Figure 4.1 Relationship between kidney weight and body weight for Bennett's wallaby ($y = 1.851 + 1.842x$, $R = 0.91$) and the Tasmanian pademelon ($y = 1.672 + 1.660x$, $R = 0.92$).

Table 4.1. Variation in mean kidney weight (KW) to body weight (BW) ratios (\pm s.d.) by age. Numbers in rounded parentheses indicate sample size.

Bennett's Wallaby			Tasmanian Pademelon		
Age	KW / BW Ratio		Age	KW / BW Ratio	
(years)	(g/kg)		(months)	(g/kg)	
0.75-1	2.23 \pm 0.27	(45)	6-12	2.33 \pm 0.35	(202)
1-2	2.18 \pm 0.30	(343)	12-18	2.14 \pm 0.31	(265)
2-3	1.99 \pm 0.28	(300)	18-24	1.96 \pm 0.26	(189)
3-4	1.91 \pm 0.26	(121)	24-30	1.92 \pm 0.26	(144)
4-5	1.94 \pm 0.30	(119)	30+	1.93 \pm 0.26	(164)
5-6	1.98 \pm 0.27	(34)			
6+	1.98 \pm 0.33	(87)			
F-test	F [6,1041] = 23.81			F [4,959] = 71.58	
Significance	p < 0.001			p < 0.001	

For both wallaby species, mean KW/BW ratios varied significantly between study areas (Table 4.2). The maximum difference in mean KW/BW ratios between study areas was 23% for Bennett's wallabies and 12% for Tasmanian pademelons.

Variation between months

As mean KW/BW ratios varied between study areas, only those study areas which were not significantly different from each other will be used to compare variation in KW/BW ratios between months. Thus for Bennett's wallaby, Soldiers Marsh and the Florentine Valley study areas were used, and for the Tasmanian pademelon, Rushy Lagoon, Florentine Valley, Lagoon of Islands and Buckland study areas were used.

Mean KW/BW ratios varied between months for both Bennett's wallaby ($F_{(13,205)} = 3.63$, $p < 0.001$) and the Tasmanian pademelon ($F_{(14,267)} = 2.46$, $p < 0.005$) (Figure 4.2). For Bennett's wallaby this variation was attributed to the decrease in the ratio in June 1988 and May 1989. When these two months were excluded from the analysis there was no difference between months ($F_{(11,161)} = 1.14$, $p > 0.25$). For the Tasmanian pademelon the ratio was less in June and July of 1988. When these two months were excluded from the analysis there was no significant difference between months ($F_{(12,224)} = 1.14$, $p > 0.25$). The mean KW/BW ratio for Tasmanian pademelons in April 1989 was low but was not significantly different from other months.

Table 4.2. Variation in mean kidney weight (KW) to body weight (BW) ratios between study areas. Solid lines indicate study areas which were not significantly different from each other at the 0.05 level. Numbers in rounded parentheses indicate sample size.

Bennett's Wallaby

Study Areas	KW / BW Ratio	No Significant Differences
Western Lakes	2.17 ± 0.27 (113)	
Florentine Valley	2.07 ± 0.26 (118)	
Soldiers Marsh	2.02 ± 0.24 (95)	
Lagoon of Islands	1.96 ± 0.29 (77)	
Maria Island	1.93 ± 0.25 (51)	
Rushy Lagoon	1.87 ± 0.22 (96)	
View Point	1.78 ± 0.25 (38)	
Buckland	1.66 ± 0.17 (61)	
F-test Significance	F [7,641] = 33.17 p < 0.001	

Tasmanian Pademelon

Study Areas	KW / BW Ratio	No Significant Differences
Soldiers Marsh	2.09 ± 0.24 (47)	
Granville Harbour	2.07 ± 0.23 (58)	
Maria Island	2.07 ± 0.23 (20)	
Rushy Lagoon	1.99 ± 0.21 (50)	
Lagoon of Islands	1.95 ± 0.29 (81)	
Florentine Valley	1.93 ± 0.24 (116)	
Buckland	1.91 ± 0.25 (35)	
View Point	1.83 ± 0.21 (76)	
F-test Significance	F [7,471] = 54.65 p < 0.001	

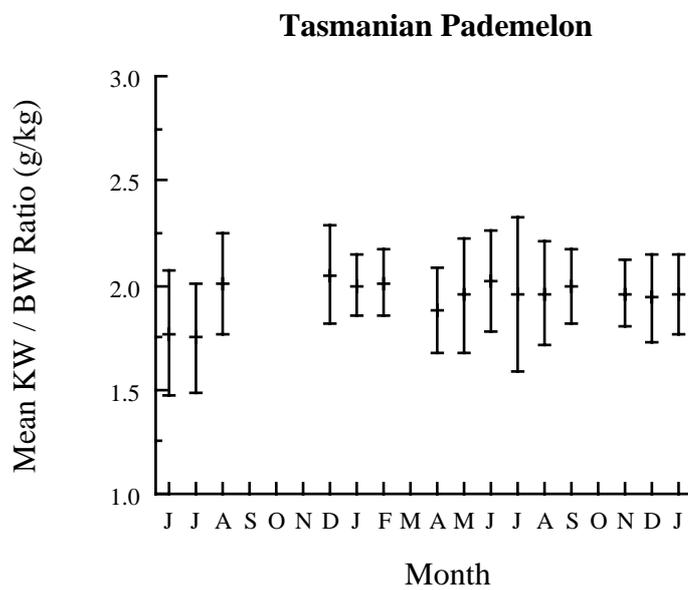
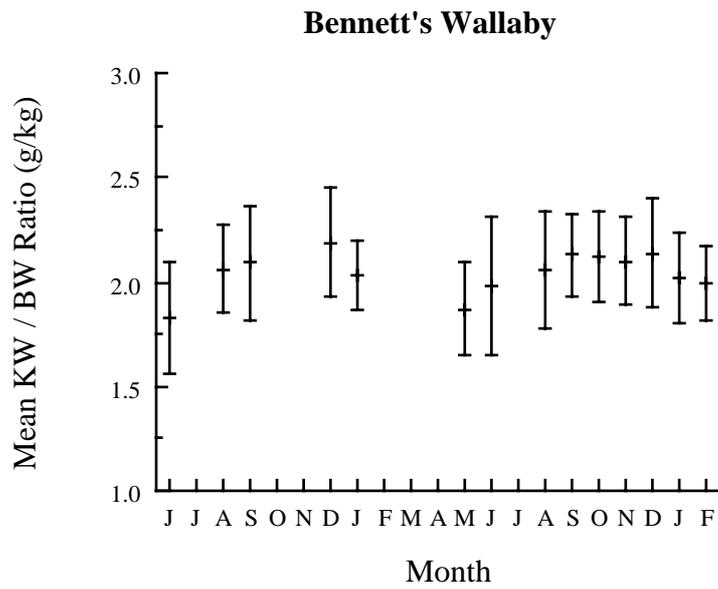


Figure 4.2 Monthly variation in mean kidney weight (KW) to body weight (BW) ratios from June 1988 to February 1990. Standard deviations are given.

4.3.2 Kidney Fat Index

Bennett's wallaby

Comparison between sexes, age groups and seasons

Mean KFIs for adult females, adult males and juveniles in winter and summer are shown in Table 4.3. The data have been pooled over all study areas and both years.

For adult females, adult males and juveniles, mean KFIs in winter were significantly higher than in summer. During winter, mean KFIs for adult females were 17% higher than adult males and 40% higher than juveniles. During summer, mean KFIs for adult males were 13% higher than adult females and 26% higher than juveniles.

Comparison between study areas

Mean KFIs for adult females, adult males and juveniles at each study area are shown in Table 4.4. During winter of 1988 mean KFIs differed significantly between study areas for adult females, adult males and juveniles. Mean KFIs were lower in low rainfall study areas than in high rainfall study areas. Mean KFIs were positively correlated with total rainfall for the 12 months prior to the sampling period (adult females: $r=0.95$, $df=5$, $p=0.0009$; adult males: $r=0.79$, $df=4$, $p=0.05$; juveniles $r=0.84$, $df=4$, $p=0.04$) (Figure 4.3).

During winter of 1989 mean KFIs did not differ significantly between study areas for adult females, adult males or juveniles. Furthermore, there were no significant correlations between mean KFIs and total rainfall for the 12 months prior to the sampling period (adult females: $r=0.08$, $df=6$, $p=0.8$; adult males: $r=0.39$, $df=5$, $p=0.4$; juveniles: $r=0.22$, $df=5$, $p=0.6$).

Table 4.3 Comparison of mean KFIs between sexes, age groups and seasons for Bennett's wallabies (\pm s.d.) (square root transformed). The data were pooled over all study areas and both years. Numbers in rounded parentheses indicate sample size.

	Winter	Summer	F-Test	Significance
Adult Female	5.6 \pm 2.3 (159)	3.9 \pm 1.6 (114)	F _[1,271] =43.19	p<0.0001
Adult Male	4.8 \pm 1.5 (156)	4.4 \pm 1.5 (176)	F _[1,330] =5.18	p<0.05
Juvenile	4.0 \pm 1.1 (149)	3.5 \pm 1.1 (142)	F _[1,289] =13.28	p<0.001
F-Test	F _[2,461] =31.31	F _[2,429] =17.34		
Significance	p<0.0001	p<0.0001		

Table 4.4 Comparison of mean KFIs between study areas for Bennett's wallabies (\pm s.d.) (square root transformed). Numbers in rounded parentheses indicate sample size. ns=not significant.

WINTER 1988					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
Lemont	Low	High	3.8 \pm 1.0 (7)	3.1 \pm 0.3 (6)	2.9 \pm 0.4 (5)
View Point	Low	Medium	4.7 \pm 0.7 (6)	-	3.5 \pm 0.6 (8)
Buckland	Low	Low	4.8 \pm 0.6 (6)	4.0 \pm 0.6 (7)	3.5 \pm 0.1 (5)
Soldiers Marsh	Medium	Low	4.8 \pm 0.3 (5)	4.9 \pm 1.2 (12)	-
Lagoon of Islands	Medium	High	5.0 \pm 1.3 (6)	4.2 \pm 1.0 (6)	3.5 \pm 1.0 (11)
Western Lakes	High	Low	6.9 \pm 2.2 (8)	5.8 \pm 2.1 (22)	4.6 \pm 1.1 (15)
Florentine Valley	High	Low	5.9 \pm 0.9 (7)	4.3 \pm 1.3 (5)	3.7 \pm 1.1 (11)
F-Test			F [6,38]=5.11	F [5,52]=3.65	F [5,49]=3.76
Significance			p < 0.002	p < 0.02	p < 0.02
SUMMER 1988					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	low	Medium	-	5.8 \pm 1.6 (6)	3.5 \pm 0.6 (8)
Lagoon of Islands	Medium	High	3.8 \pm 1.4 (10)	4.3 \pm 1.5 (18)	2.8 \pm 0.4 (13)
Western Lakes	High	Low	2.9 \pm 0.9 (13)	3.1 \pm 1.1 (12)	3.0 \pm 0.9 (8)
Florentine Valley	High	Low	4.6 \pm 1.3 (16)	5.2 \pm 1.7 (28)	3.6 \pm 0.8 (16)
F-Test			F [2,36]=6.96	F [3,60]=6.61	F [3,41]=3.58
Significance			p < 0.01	p < 0.002	p < 0.05
WINTER 1989					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	Low	High	5.1 \pm 1.9 (7)	-	-
Buckland	Low	Low	7.1 \pm 2.0 (11)	5.3 \pm 1.1 (10)	4.3 \pm 1.1 (15)
Maria Island	Low	Very Low	5.5 \pm 2.0 (29)	4.0 \pm 1.0 (15)	3.8 \pm 1.2 (23)
Rushy Lagoon	Medium	Very High	7.1 \pm 3.2 (18)	4.7 \pm 1.3 (25)	4.0 \pm 1.1 (9)
Soldiers Marsh	Medium	Low	6.0 \pm 1.8 (17)	5.4 \pm 0.8 (11)	4.2 \pm 0.9 (19)
Lagoon of Islands	Medium	High	6.3 \pm 1.7 (8)	4.8 \pm 1.4 (11)	4.3 \pm 1.2 (7)
Western Lakes	High	Low	5.7 \pm 2.4 (10)	5.1 \pm 2.0 (15)	4.0 \pm 1.3 (9)
Florentine Valley	High	Low	6.7 \pm 2.2 (14)	5.0 \pm 2.1 (7)	4.5 \pm 1.3 (12)
F-Test			F [7,106]=1.52	F [6,87]=1.49	F [6,87]=0.59
Significance			ns	ns	ns
SUMMER 1989					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	Low	Medium	4.0 \pm 1.0 (8)	5.1 \pm 1.1 (9)	3.4 \pm 1.1 (11)
Buckland	Low	Low	3.3 \pm 0.3 (10)	4.5 \pm 1.1 (16)	3.6 \pm 0.6 (17)
Rushy Lagoon	Medium	Very High	4.6 \pm 2.9 (10)	4.9 \pm 1.6 (11)	-
Soldiers Marsh	Medium	Low	3.3 \pm 0.6 (10)	4.3 \pm 1.4 (19)	3.1 \pm 0.3 (7)
Lagoon of Islands	Medium	High	3.8 \pm 1.0 (9)	4.0 \pm 1.0 (11)	3.4 \pm 0.6 (11)
Western Lakes	High	Low	3.5 \pm 1.6 (11)	3.4 \pm 0.6 (21)	3.3 \pm 1.3 (16)
Florentine Valley	High	Low	4.9 \pm 1.8 (17)	5.0 \pm 1.3 (25)	4.2 \pm 1.5 (35)
F-Test			F [6,68]=1.99	F [6,105]=4.67	F [5,91]=2.34
Significance			ns	p < 0.001	ns

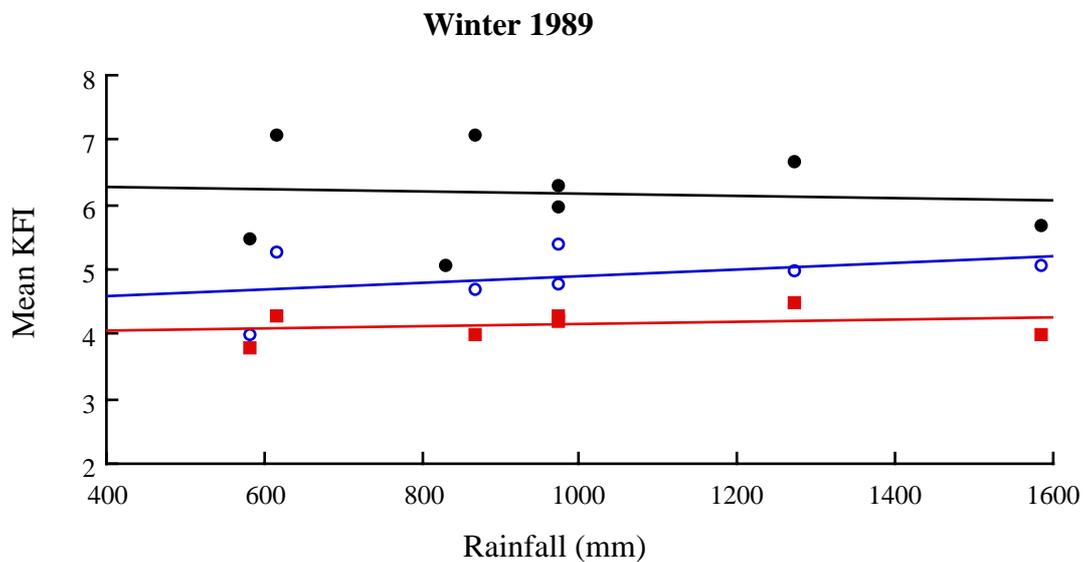
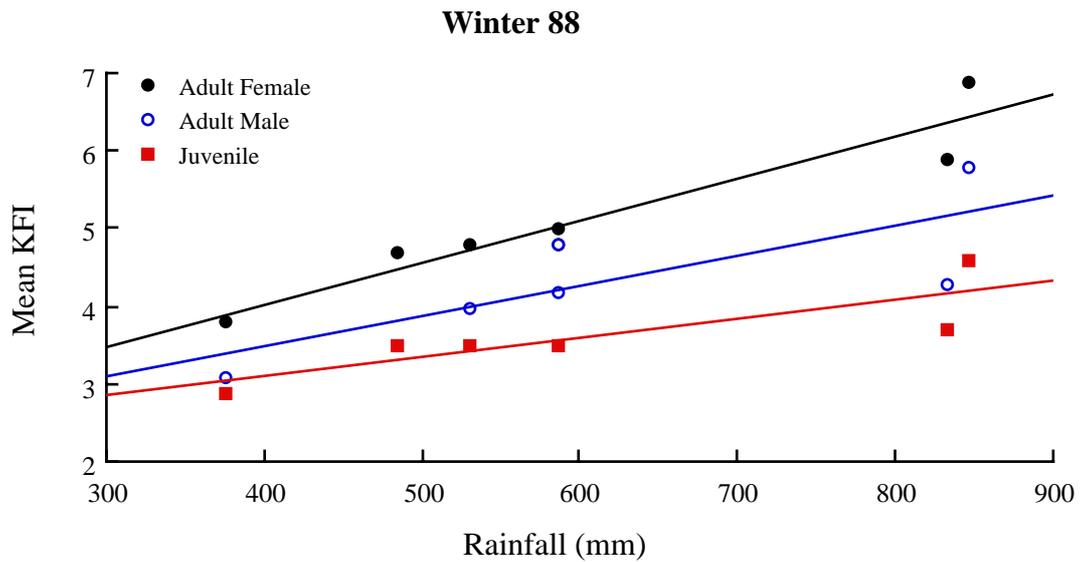


Figure 4.3. Correlation between mean KFI and rainfall (12 months prior to sampling periods) for Bennett's wallaby during winter 1988 (adult females: $r=0.95$, $df=5$, $p=0.0009$; adult males: $r=0.79$, $df=4$, $p=0.05$; juveniles $r=0.84$, $df=4$, $p=0.04$) and 1989 (adult females: $r=0.08$, $df=6$, $p=0.8$; adult males: $r=0.39$, $df=5$, $p=0.4$; juveniles: $r=0.22$, $df=5$, $p=0.6$). Means and standard deviations are given in Table 4.4.

During summer of 1988 mean KFIs differed significantly between study areas for adult males, adult females and juveniles (Table 4.4). For adult males and females this can be attributed to the low mean KFIs at the Western Lakes study area. For juveniles, KFIs were lowest at Lagoon of Islands and Western Lakes. No correlations were undertaken between rainfall and mean KFI during summer of 1988 due to insufficient data.

During summer of 1989 mean KFIs for adult males differed significantly between study areas. This can be attributed to the low mean KFI at Western Lakes. Mean KFIs for adult females and juveniles did not differ significantly between study areas. However, it should be noted that mean KFIs for Western Lakes were amongst the lowest for these groups. There were no significant correlations between mean KFI and total rainfall for the 12 months prior to the sampling period (adult females: $r=0.09$, $df=5$, $p=0.8$; adult males: $r=0.69$, $df=5$, $p=0.08$; juveniles: $r=0.28$, $df=4$, $p=0.6$).

No correlations were found between annual hunting pressure and mean KFI in winter 1988 (adult females: $\text{Tau}=-0.47$, $z=1.5$, $p=0.07$; adult males: $\text{Tau}=-0.35$, $z=1.1$, $p=0.1$, juveniles: $\text{Tau}=-0.53$, $z=1.5$, $p=0.07$), winter 1989 (adult females: $\text{Tau}=0.29$, $z=1.0$, $p=0.2$; adult males: $\text{Tau}=-0.17$, $z=0.53$, $p=0.3$, juveniles: $\text{Tau}=-0.18$, $z=.56$, $p=0.3$) or summer 1989 (adult females: $\text{Tau}=0.40$, $z=1.28$, $p=0.1$; adult males: $\text{Tau}=0.17$, $z=0.53$, $p=0.3$, juveniles: $\text{Tau}=0.0$, $z=0.0$, $p=0.5$). No correlations were undertaken for summer 1988 data.

It should be noted that mean KFIs for Rushy Lagoon, which was the most heavily hunted study area, were amongst the highest of all study areas.

Comparison between years

Comparisons of mean KFIs between years are given in Table 4.5. Only winter data were compared due to insufficient sampling in summer 1988. Mean KFIs were significantly lower in 1988 than in 1989.

Table 4.5 Comparison of mean KFIs between years for Bennett's wallabies (\pm s.d.) (square root transformed). The data were pooled over study areas which were sampled in both years and which were not significantly different from each other. Numbers in rounded parentheses indicate sample size.

	Winter 88	Winter 89	F-Test	Significance
Adult Female	5.1 \pm 0.9 (30)	5.9 \pm 0.8 (39)	$F_{[1,67]}=15.89$	$p<0.001$
Adult Male	4.4 \pm 1.1 (30)	5.1 \pm 1.3 (39)	$F_{[1,67]}=5.41$	$p<0.05$
Juvenile	3.6 \pm 0.9 (27)	4.3 \pm 1.4 (35)	$F_{[1,60]}=5.91$	$p<0.05$

Tasmanian pademelon

Comparison between sexes, age groups and seasons

Mean KFIs for adult females, adult males and juveniles in winter and summer are shown in Table 4.6. The data have been pooled over all study areas and both years.

For adult females, adult males and juveniles, mean KFIs in winter were significantly higher than in summer. During winter, mean KFIs for adult females were 18% higher than adult males and 45% higher than juveniles. During summer, mean KFIs for adult females were 19% higher than adult males and 47% higher than juveniles.

Table 4.6 Comparison of mean KFIs between sexes, age groups and seasons for Tasmanian pademelons (\pm s.d.) (square root transformed). The data were pooled over all study areas and both years. Numbers in rounded parentheses indicate sample size.

	Winter	Summer	F-Test	Significance
Adult Female	7.7 \pm 3.1 (191)	5.6 \pm 3.1 (107)	F _[1,296] =31.06	p<0.0001
Adult Male	6.5 \pm 2.1 (242)	4.7 \pm 1.6 (123)	F _[1,363] =67.80	p<0.0001
Juvenile	5.3 \pm 2.0 (217)	3.8 \pm 1.2 (104)	F _[1,319] =48.62	p<0.0001
F-Test	F _[2,647] =50.50	F _[2,331] =20.05		
Significance	p<0.0001	p<0.0001		

Comparison between study areas

Mean KFIs for adult females, adult males and juveniles at each study area are shown in Table 4.7. During winter of 1988 mean KFIs differed significantly between study areas for adult females and adult males. Mean KFIs were lower in low rainfall study areas than in high rainfall study areas. Mean KFIs were positively correlated with the total rainfall for the 12 months prior to the sampling period (Figure 4.4). For adult females ($r=0.99$, $df=3$, $p=0.002$) and adult males ($r=0.99$, $df=2$, $p=0.002$) the results were statistically significant. Mean KFIs did not vary between study areas for juveniles and there was no correlation between mean KFI and rainfall for juveniles ($r=0.58$, $df=2$, $p=0.4$).

Table 4.7 Comparison of mean KFIs between study areas for Tasmanian pademelons (\pm s.d.) (square root transformed). Numbers in rounded parentheses indicate sample size. ns=not significant.

WINTER 1988					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	Low	Medium	4.8 \pm 0.5 (8)	4.5 \pm 0.7 (15)	4.6 \pm 1.2 (22)
Buckland	Low	Low	6.0 \pm 1.8 (5)	4.6 \pm 1.0 (7)	-
Lagoon of Islands	Medium	High	6.8 \pm 1.4 (7)	5.6 \pm 1.3 (8)	5.5 \pm 2.4 (12)
Florentine Valley	High	Low	9.7 \pm 3.1 (7)	7.8 \pm 2.2 (26)	6.4 \pm 1.6 (10)
Styx	High	Very Low	9.2 \pm 4.6 (8)	8.0 \pm 2.6 (16)	5.0 \pm 1.4 (8)
F-Test			F [4,30]= 28	F [4,67]=11.33	F [3,48]=2.89
Significance			p < 0.02	p < 0.001	ns
SUMMER 1988					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	Low	Medium	-	3.6 \pm 0.9 (6)	3.9 \pm 1.1 (8)
Lagoon of Islands	Medium	High	4.7 \pm 2.0 (15)	4.4 \pm 1.5 (27)	3.4 \pm 0.8 (12)
Florentine Valley	High	Low	4.3 \pm 0.8 (19)	4.5 \pm 2.0 (8)	3.3 \pm 0.5 (8)
F-Test			F [1,32]=5.44	F [2,38]=0.74	F [2,25]=1.41
Significance			ns	ns	ns
WINTER 1989					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	Low	Medium	7.9 \pm 2.5 (22)	6.4 \pm 1.8 (22)	4.4 \pm 1.2 (21)
Buckland	Low	Low	7.4 \pm 3.7 (7)	5.3 \pm 1.2 (15)	3.9 \pm 1.2 (8)
Maria Island	Low	Very Low	7.0 \pm 2.5 (14)	5.4 \pm 0.8 (5)	5.9 \pm 1.3 (6)
Rushy Lagoon	Medium	Very High	9.8 \pm 3.4 (26)	6.2 \pm 2.1 (43)	4.8 \pm 2.0 (21)
Soldiers Marsh	Medium	Low	5.9 \pm 1.7 (10)	4.9 \pm 1.3 (12)	3.9 \pm 1.4 (8)
Lagoon of Islands	Medium	High	6.5 \pm 3.3 (23)	6.3 \pm 1.8 (26)	4.7 \pm 1.2 (23)
Florentine Valley	High	Low	8.7 \pm 2.7 (25)	7.2 \pm 2.1 (26)	6.4 \pm 2.4 (23)
Granville Harbour	High	Low	8.4 \pm 2.2 (18)	7.4 \pm 1.8 (24)	6.1 \pm 2.4 (58)
F-Test			F [7,137]=3.77	F [7,165]=3.99	F [7,160]=4.74
Significance			p < 0.002	p < 0.001	p < 0.001
SUMMER 1989					
Study Area	Rainfall	Hunting	Adult Female	Adult Male	Juvenile
View Point	Low	Medium	7.2 \pm 2.7 (14)	4.5 \pm 1.0 (28)	4.7 \pm 1.2 (14)
Buckland	Low	Low	5.3 \pm 2.9 (8)	4.3 \pm 0.8 (9)	3.4 \pm 0.6 (5)
Rushy Lagoon	Medium	Very High	8.1 \pm 3.2 (11)	4.8 \pm 1.1 (7)	3.7 \pm 1.0 (12)
Soldiers Marsh	Medium	Low	5.0 \pm 2.5 (5)	4.0 \pm 1.1 (10)	3.9 \pm 1.1 (8)
Lagoon of Islands	Medium	High	5.5 \pm 3.0 (6)	-	3.6 \pm 0.3 (5)
Florentine Valley	High	Low	4.9 \pm 1.4 (7)	4.8 \pm 1.6 (8)	-
Granville Harbour	High	Low	8.3 \pm 3.5 (11)	7.0 \pm 1.9 (11)	3.8 \pm 1.4 (32)
F-Test			F [6,55]=2.03	F [5,67]=8.41	F [5,70]=1.82
Significance			ns	p < 0.001	ns

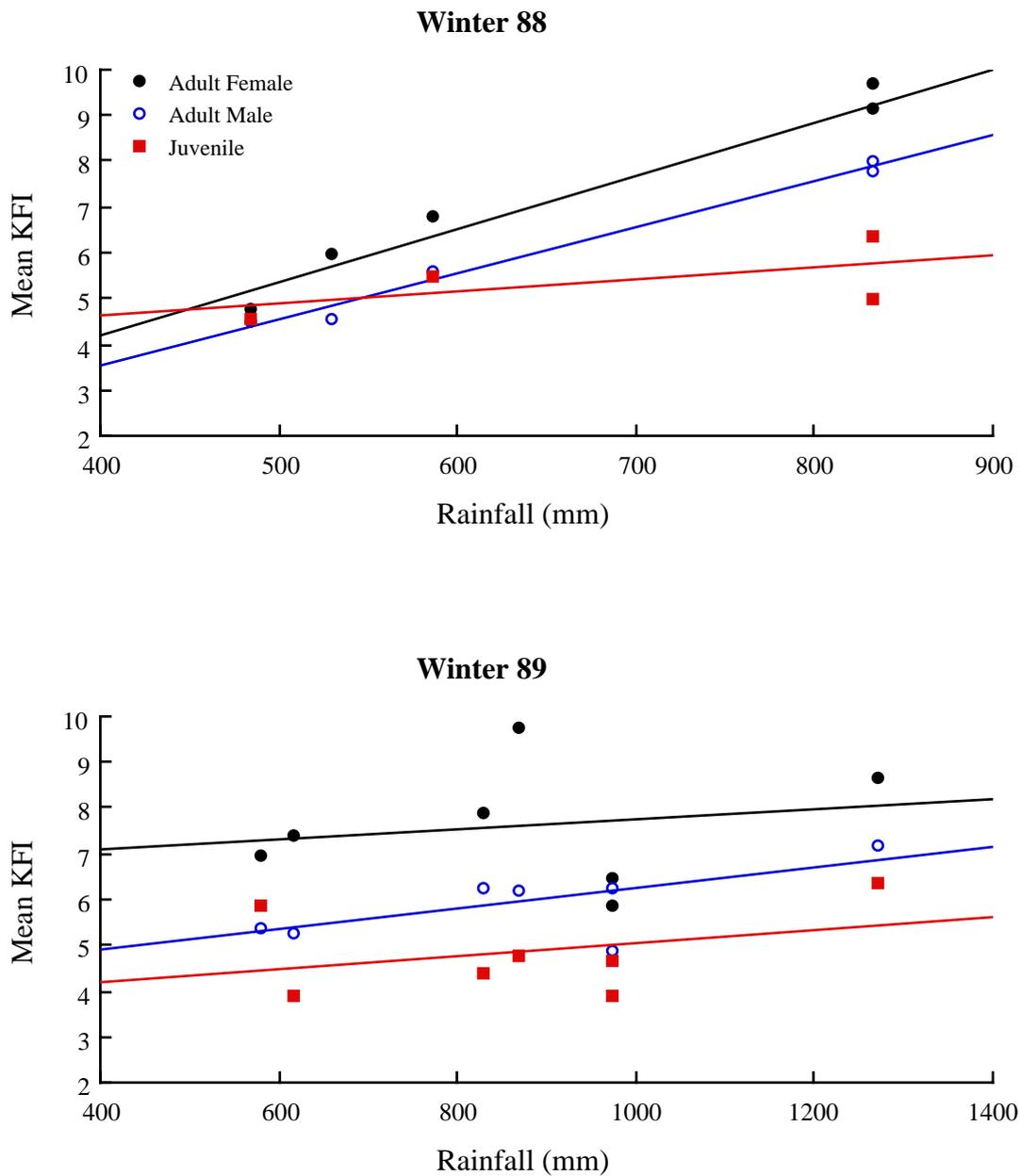


Figure 4.4. Correlation between mean KFI and rainfall (12 months prior to sampling periods) for the Tasmanian pademelon during winter 1988 (adult females: $r=0.99$, $df=3$, $p=0.002$; adult males: $r=0.99$, $df=3$, $p=0.0005$; juveniles: $r=0.58$, $df=2$, $p=0.4$) and 1989 (adult females: $r=0.19$, $df=5$, $p=0.7$; adult males: $r=0.67$, $df=5$, $p=0.1$; juveniles: $r=0.34$, $df=5$, $p=0.5$). Means and standard deviations are given in Table 4.7.

During winter of 1989 mean KFIs differed significantly between study areas for adult females, adult males and juveniles. For adult females the mean KFI at Rushy Lagoon was significantly higher than those for other study areas; for adult males the mean KFI for Granville Harbour was significantly higher; and for juveniles mean KFIs for Granville Harbour and the Florentine Valley were significantly higher. Mean KFIs were not correlated with total rainfall for the 12 months prior to the sampling period (adult females: $r=0.19$, $df=5$, $p=0.7$; adult males: $r=0.67$, $df=5$, $p=0.1$; juveniles: $r=0.34$, $df=5$, $p=0.5$) (Figure 4.4).

During summer of 1988 mean KFIs did not differ between study areas for adult females, adult males or juveniles (Table 4.7). No correlations were undertaken between rainfall and mean KFI during summer of 1988 due to insufficient data.

During summer of 1989 mean KFIs did not differ between study areas for adult females and juveniles. For adult males, the mean KFIs for Granville Harbour were significantly higher than those for other study areas. There were no significant correlations between mean KFI and total rainfall for the 12 months prior to the sampling period (adult females: $r=0.11$, $df=4$, $p=0.8$; adult males: $r=0.22$, $df=3$, $p=0.7$; juveniles: $r=0.34$, $df=3$, $p=0.6$).

There was no evidence of a correlation between annual hunting pressure and mean KFI for the Tasmanian pademelon in winter 1988 (adult females: $\text{Tau}=-0.32$, $z=0.8$, $p=0.2$; adult males: $\text{Tau}=-0.67$, $z=1.4$, $p=0.09$, juveniles: $\text{Tau}=0.0$, $z=0.0$, $p=0.5$), winter 1989 (adult females: $\text{Tau}=0.24$, $z=0.8$, $p=0.2$; adult males: $\text{Tau}=0.0$, $z=0.0$, $p=0.5$, juveniles: $\text{Tau}=-0.0$, $z=0.0$, $p=0.5$) or summer 1989 (adult females: $\text{Tau}=0.39$, $z=1.2$, $p=0.1$; adult males: $\text{Tau}=0.17$, $z=0.5$, $p=0.3$, juveniles: $\text{Tau}=0.0$, $z=0.0$, $p=0.5$). No correlations were undertaken for summer 1988 data.

Comparison between years

Comparisons of mean KFIs between years are given in Table 4.8. Only winter data were compared due to insufficient sampling in summer 1988. For adult males, mean KFIs were significantly lower in winter 1988 than in winter 1989. Mean KFIs for females in the winter of 1988 were 24% lower than in 1989, however, this difference was not statistically significant at the 0.05 level. There was no evidence that mean KFIs for juveniles differed between years.

Table 4.8 Comparison of mean KFIs between years for Tasmanian pademelons (\pm s.d.) (square root transformed). The data were pooled over study areas which were sampled in both years and which were not significantly different from each other. Numbers in rounded parentheses indicate sample size. ns=not significant.

	Winter 88	Winter 89	F-Test	Significance
Adult Female	5.8 \pm 1.5 (20)	7.2 \pm 3.1 (52)	F _[1,70] =4.78	ns (p=0.07)
Adult Male	4.8 \pm 1.1 (30)	6.1 \pm 1.7 (63)	F _[1,91] =13.23	p<0.001
Juvenile	4.9 \pm 1.7 (34)	4.5 \pm 1.2 (44)	F _[1,76] =1.31	ns

Comparison of mean KFIs between successful and unsuccessful breeders

Mean KFIs for adult females that were successful or unsuccessful in breeding are given in Table 4.9. Females which were unsuccessful in breeding had lower mean KFIs than those successful in breeding.

4.3.3 Growth

The increase in mean body weight with age for males and females of both species are shown in Figure 4.5. Mean body weights and statistical comparisons are given in Tables 4.10 and 4.11.

Both species showed strong sexual dimorphism. In the oldest age class male Bennett's wallabies were 48% heavier than females. Similarly, male Tasmanian pademelons in the oldest age class were 52% heavier than females. Female Bennett's wallabies attained maximum weight around 4-5 years of age whereas males continue growing at this age, albeit slowly. Female Tasmanian pademelons attained maximum weight by 2-3 years of age whereas males continue to increase in weight after this age. For both species, the greatest rate of growth occurred at a young age.

Tables 4.12 and 4.13 show the mean body weight of both species in each age class for each study area. There were significant differences in mean body weight and hence growth between study areas for both species.

Table 4.9 Mean KFIs (\pm s.d.) (square root transformed) for successful (females with pouch young) and unsuccessful breeders (females which failed to breed or had lost pouch young). Numbers in parentheses indicate sample size.

Bennett's Wallaby

	Winter 88		Winter 89	
	Successful	Unsuccessful	Successful	Unsuccessful
Buckland	4.8 \pm 0.6 (6)	3.6 (1)	-	-
Maria Island	-	-	5.5 \pm 2.0 (29)	3.4 (1)
Rushy Lagoon	-	-	7.1 \pm 3.2 (18)	4.4 \pm 1.0 (3)
Soldiers Marsh	4.8 \pm 0.3 (5)	3.5 \pm 0.3 (4)	6.0 \pm 1.8 (17)	2.5 (1)
Lagoon of Islands	5.0 \pm 1.3 (6)	2.3 (1)	6.3 \pm 1.7 (8)	4.2 (1)
Western Lakes	6.9 \pm 2.2 (8)	1.8 \pm 0.1 (2)	5.7 \pm 2.4 (10)	3.7 (1)
Florentine Valley	5.9 \pm 0.9 (7)	3.3 (1)	-	-

Tasmanian Pademelon

	Winter 88		Winter 89	
	Successful	Unsuccessful	Successful	Unsuccessful
Maria Island	-	-	7.0 \pm 2.5 (14)	4.1 (1)
Rushy Lagoon	-	-	9.8 \pm 3.4 (26)	5.9 (1)
Lagoon of Islands	-	-	6.5 \pm 3.3 (23)	3.8 \pm 0.6 (3)
Florentine Valley	9.7 \pm 3.1 (7)	6.3 \pm 0.3 (2)	8.7 \pm 2.7 (25)	3.7 (1)
Styx	9.2 \pm 4.6 (8)	3.9 \pm 0.3 (2)	-	-
Granville Harbour	-	-	8.4 \pm 2.2 (18)	7.2 (1)

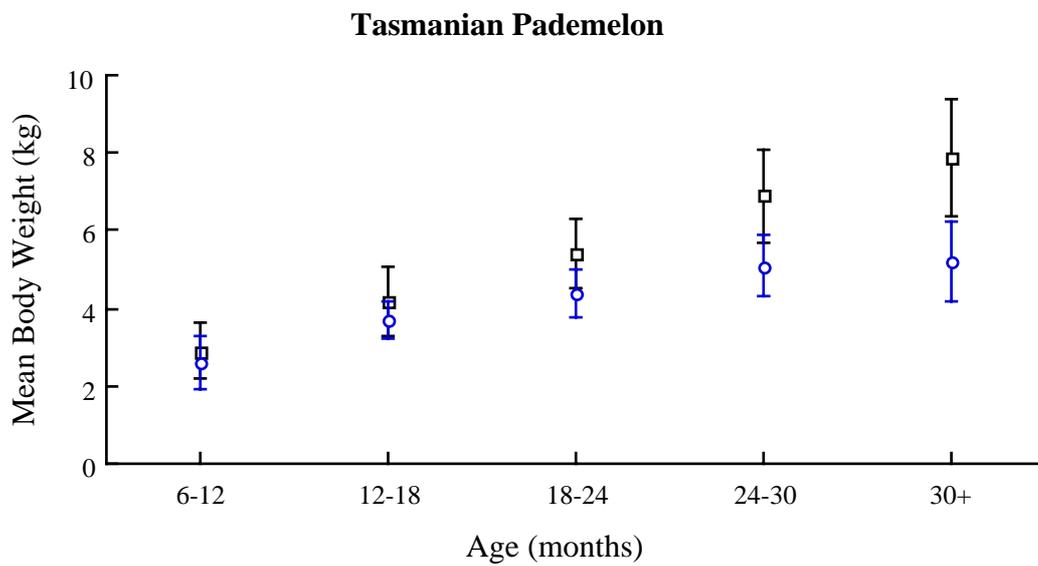
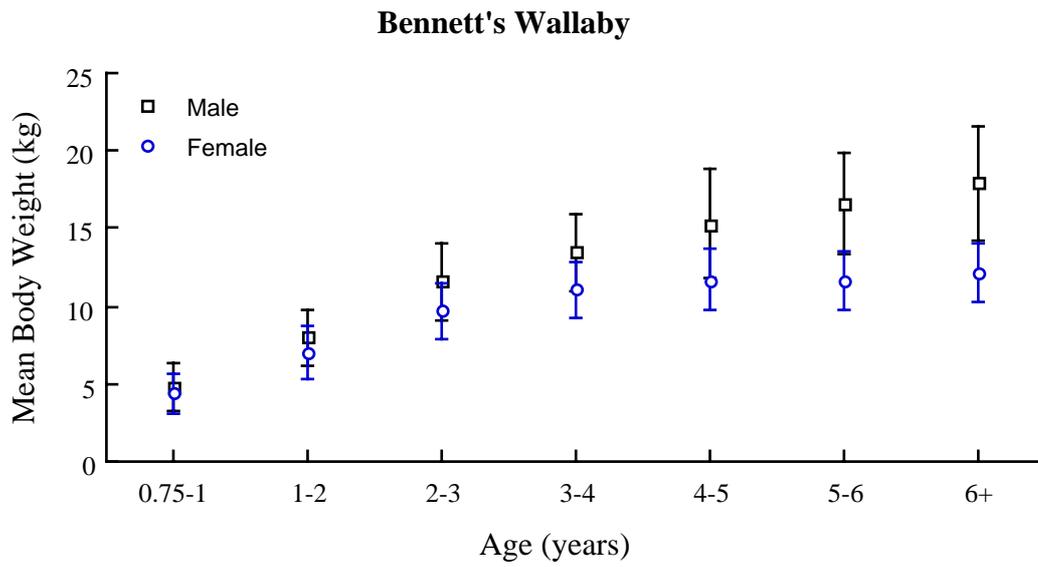


Figure 4.5 Comparison of mean growth rates (\pm s.d.) for male and female Bennett's wallabies and Tasmanian pademelons. All statistical information is given in Tables 4.10 and 4.11. Squares denote males and circles denote females.

Table 4.10 Comparison of mean body weights between male and female Bennett's wallabies. The data were pooled over all study areas. Values in rounded parentheses refer to sample sizes.

Age (yrs)	Male		Female		F-test	Significance
	Weight (kg)	% increase	Weight (kg)	% increase		
0.75-1	4.8 ± 1.6 (31)		4.4 ± 1.3 (17)		F _(1,46) = 0.66	ns
1-2	8.0 ± 1.8 (214)	66	7.0 ± 1.7 (159)	59	F _(1,371) = 26.83	P < 0.001
2-3	11.6 ± 2.5 (191)	45	9.7 ± 1.8 (128)	39	F _(1,317) = 50.62	P < 0.001
3-4	13.5 ± 2.5 (75)	16	11.1 ± 1.8 (58)	14	F _(1,131) = 36.66	P < 0.001
4-5	15.3 ± 3.5 (70)	13	11.7 ± 2.0 (63)	5	F _(1,131) = 51.34	p < 0.001
5-6	16.6 ± 3.2 (18)	8	11.7 ± 1.9 (16)	0	F _(1,32) = 29.44	P < 0.001
6+	17.9 ± 3.7 (45)	8	12.1 ± 1.9 (57)	3	F _(1,100) = 106.47	p < 0.001

Table 4.11 Comparison of mean body weights between male and female Tasmanian pademelons. The data were pooled over all study areas. Values in rounded parentheses refer to sample sizes.

Age (mths)	Male		Female		F-test	Significance
	Weight (kg)	% increase	Weight (kg)	% increase		
6-12	2.9 ± 0.7 (145)		2.6 ± 0.7 (119)		F (1,262) = 12.67	P < 0.001
12-18	4.2 ± 0.9 (171)	45	3.7 ± 0.5 (98)	43	F (1,267) = 25.54	P < 0.001
18-24	5.4 ± 0.9 (138)	29	4.4 ± 0.6 (78)	19	F (1,214) = 68.57	p < 0.001
24-30	6.9 ± 1.2 (121)	27	5.1 ± 0.8 (83)	16	F (1,202) = 145.70	p < 0.001
30+	7.9 ± 1.5 (95)	14	5.2 ± 1.0 (83)	1	F (1,176) = 198.19	p < 0.001

Table 4.12 Comparison of mean body weights (kg) between study areas for Bennett's wallabies.

Study Area	Age Class (years)						
	0-1	1-2	2-3	3-4	4-5	5-6	6+
MALE							
Maria Island		5.2 ± 0.4 (6)	8.0 ± 1.6 (4)	10.5 ± 1.4 (3)	11.4 ± 0.6 (9)		14.5 ± 0.8 (2)
View Point	2.9 ± 0.8 (3)	7.4 ± 1.8 (23)	9.8 ± 1.5 (18)	10.7 ± 0.8 (5)	11.5 ± 1.3 (3)		13.3 ± 2.7 (3)
Buckland	5.8 ± 1.8 (2)	6.6 ± 1.3 (19)	9.4 ± 1.1 (13)	11.0 ± 1.3 (6)	13.1 ± 1.4 (6)	14.0 ± 2.7 (3)	14.9 ± 1.3 (6)
Rushy Lagoon	4.7 ± 2.0 (5)	9.5 ± 1.5 (48)	14.5 ± 2.2 (30)	15.4 ± 1.4 (10)	19.0 ± 1.2 (5)		20.8 ± 2.5 (3)
Soldiers Marsh		7.3 ± 0.9 (26)	10.4 ± 1.2 (36)	12.5 ± 1.5 (18)	14.1 ± 2.0 (7)	18.4 ± 0.8 (2)	16.8 ± 1.6 (4)
Lagoon of Islands	3.8 ± 0.7 (5)	7.6 ± 1.5 (22)	11.3 ± 2.0 (25)	13.0 ± 1.4 (6)	14.2 ± 2.0 (8)	16.8 ± 0.9 (2)	16.3 ± 3.4 (8)
Western Lakes	5.7 ± 0.6 (2)	8.0 ± 1.4 (29)	12.1 ± 2.4 (30)	14.8 ± 2.0 (18)	16.0 ± 2.6 (12)	17.2 ± 3.0 (16)	19.4 ± 1.0 (7)
Florentine Valley	5.2 ± 1.8 (11)	8.6 ± 1.6 (33)	12.7 ± 2.0 (28)	16.5 ± 3.1 (7)	18.0 ± 3.6 (19)	16.9 ± 5.1 (4)	21.1 ± 3.6 (11)
F-test	F(5,22) = 1.7	F(7,198) = 15.9	F(7,176) = 21.2	F(7,65) = 11.1	F(7,61) = 10.4	F(4,12) = 0.6	F(7,37) = 5.6
Significance	ns	p < 0.001	p < 0.001	p < 0.001	p < 0.001	ns	p < 0.001
FEMALE							
Maria Island		4.9 ± 0.7 (10)	7.7 ± 1.0 (9)	8.7 ± 0.9 (5)	9.2 ± 0.9 (6)	10.0 ± 0.3 (3)	10.7 ± 2.5 (9)
View Point		5.9 ± 1.3 (17)	8.8 ± 1.8 (13)	9.8 ± 1.4 (5)	9.2 ± 1.2 (5)		10.6 ± 2.7 (5)
Buckland		5.9 ± 1.2 (14)	8.1 ± 1.2 (6)	9.3 ± 0.5 (5)	9.6 ± 1.4 (6)	10.4 ± 1.6 (2)	11.3 ± 0.9 (10)
Rushy Lagoon		8.8 ± 1.4 (33)	11.4 ± 1.6 (21)	12.8 ± 1.7 (10)	13.6 ± 1.0 (11)		13.6 ± 1.5 (12)
Soldiers Marsh		6.4 ± 0.8 (15)	9.4 ± 1.3 (18)	11.0 ± 1.2 (10)	12.2 ± 1.0 (9)		11.9 ± 1.0 (4)
Lagoon of Islands	3.8 ± 0.9 (4)	6.5 ± 1.4 (17)	8.9 ± 1.6 (13)	10.6 ± 0.7 (8)	11.5 ± 1.4 (7)	10.9 ± 0.3 (3)	12.1 ± 2.0 (4)
Western Lakes	4.4 ± 0.7 (2)	7.5 ± 1.8 (14)	10.2 ± 1.7 (19)	11.7 ± 0.7 (6)	11.8 ± 1.1 (8)	12.3 ± 0.8 (2)	13.2 ± 1.0 (8)
Florentine Valley	4.7 ± 1.7 (5)	7.6 ± 1.2 (31)	10.5 ± 1.4 (24)	12.5 ± 1.4 (9)	13.5 ± 1.3 (10)	14.2 ± 1.6 (4)	12.8 ± 0.7 (5)
F-test	F(2,8) = 0.5	F(7,143) = 17.4	F(7,114) = 10.0	F(7,50) = 10.2	F(7,54) = 17.5	F(4,9) = 7.8	F(7,50) = 2.99
Significance	ns	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.01	p < 0.025

Table 4.13 Comparison of mean body weights (kg) between study areas for Tasmanian pademelons.

Study Area	Age Class (months)				
	6-12	12-18	18-24	24-30	30+
MALE					
Maria Island	2.5 ± 0.3 (4)	2.4 ± 0.1 (2)		5.1 ± 0.6 (2)	6.3 ± 1.0 (3)
View Point	2.8 ± 0.5 (23)	4.0 ± 0.6 (43)	5.1 ± 0.8 (33)	6.0 ± 1.0 (23)	6.7 ± 1.2 (24)
Buckland	2.3 ± 1.1 (5)	3.9 ± 0.5 (11)	5.1 ± 0.7 (9)	6.5 ± 1.4 (8)	6.9 ± 0.9 (6)
Rushy Lagoon	3.3 ± 1.1 (18)	5.1 ± 0.9 (26)	6.3 ± 1.1 (12)	7.9 ± 0.8 (15)	9.4 ± 1.6 (4)
Soldiers Marsh	2.6 ± 0.7 (13)	3.7 ± 0.8 (15)	5.2 ± 0.9 (12)	6.5 ± 0.8 (8)	8.0 ± 1.2 (11)
Lagoon of Islands	3.1 ± 0.7 (22)	4.6 ± 0.8 (30)	5.6 ± 1.3 (19)	7.4 ± 1.3 (16)	8.1 ± 1.6 (7)
Western Lakes			5.8 ± 0.2 (2)	6.9 ± 0.6 (3)	
Florentine Valley	2.9 ± 0.9 (14)	4.3 ± 0.9 (13)	5.3 ± 0.7 (26)	7.1 ± 0.9 (28)	8.5 ± 1.4 (20)
Styx		3.5 ± 0.7 (6)	5.4 ± 0.4 (3)	7.3 ± 0.9 (9)	9.0 ± 0.6 (8)
Granville Harbour	3.0 ± 0.5 (43)	3.9 ± 0.6 (21)	5.3 ± 0.8 (20)	6.4 ± 0.4 (6)	8.4 ± 1.1 (10)
F-test	F (7,134) = 2.4	F (8,158) = 9.6	F (8, 127) = 2.8	F (9,108) = 5.47	F (8,84) = 6.2
Significance	p < 0.025	p < 0.001	p < 0.01	p < 0.001	p < 0.001
FEMALE					
Maria Island			3.4 ± 0.1 (3)	3.8 ± 0.2 (2)	4.4 ± 0.7 (10)
View Point	2.5 ± 0.5 (25)	3.6 ± 0.5 (28)	4.0 ± 0.4 (10)	4.3 ± 0.3 (14)	4.5 ± 0.5 (13)
Buckland	2.2 ± 0.6 (8)	3.9 ± 0.3 (3)	4.0 ± 0.2 (3)	4.4 ± 0.5 (4)	4.9 ± 0.6 (10)
Rushy Lagoon	3.0 ± 0.7 (19)	4.1 ± 0.4 (10)	4.9 ± 0.5 (7)	5.5.4 ± 0.8 (11)	5.7 ± 0.9 (5)
Soldiers Marsh	2.2 ± 0.5 (9)	3.3 ± 0.4 (5)	4.1 ± 0.5 (12)	4.9 ± 0.6 (5)	5.0 ± 0.4 (8)
Lagoon of Islands	2.7 ± 0.7 (15)	3.8 ± 0.5 (24)	4.3 ± 0.3 (14)	4.7 ± 0.5 (11)	4.8 ± 0.6 (8)
Western Lakes	3.2 ± 0.3 (4)		4.5 ± 0.1 (2)	5.4 ± 0.7 (4)	
Florentine Valley	2.5 ± 0.7 (14)	3.7 ± 0.5 (8)	4.9 ± 0.5 (15)	5.6 ± 0.7 (23)	6.0 ± 0.7 (13)
Styx	2.4 ± 0.5 (4)			5.8 ± 0.3 (4)	7.0 ± 0.3 (5)
Granville Harbour	2.8 ± 0.6 (19)	3.8 ± 0.5 (17)	4.5 ± 0.5 (9)	5.2 ± 0.3 (5)	5.7 ± 0.5 (9)
F-test	F (8,108) = 3.0	F (6,88) = 2.3	F (8,66) = 6.6	F (9,71) = 7.6	F (8,72) = 14.9
Significance	p < 0.01	p < 0.05	p < 0.001	p < 0.001	p < 0.001

Effect of hunting and rainfall on growth

The effects of hunting and rainfall on growth rate were investigated by correlation analysis. The oldest age class (6+ years for Bennett's wallabies and 30+ months for Tasmanian pademelons) was used for this analysis as these animals were considered most likely to give an 'average' indication of the condition of the habitat over an extended time period. Mean annual rainfall for 1977 to 1986 was used as an indication of rainfall conditions during the growth phase of these animals.

No correlations were found between hunting pressure and mean body weight of the oldest age class of either species (Table 4.14).

The relationships between mean annual rainfall and mean body weight of the oldest age class are given in Figures 4.6 and 4.7. With the exception of male pademelons, there was evidence of a correlation between these two variables (Table 4.15). In relation to rainfall the mean body weight of wallabies from Rushy Lagoon were higher than those of other study areas (Figures 4.6 and 4.7). Removal of this study area from the data set results in significant correlations between rainfall and mean body weight for all four comparisons (Table 4.16).

Table 4.14 Correlation between annual harvest pressure and mean body weight of oldest wallabies (6+ years for Bennett's wallabies and 30+ months for Tasmanian pademelons) using Kendall's Rank Correlation Coefficient (Tau).

Species	Sex	Tau	z	Probability
Bennett's wallaby	Male	0.161	0.558	0.2709
	Female	0.322	1.117	0.1314
Tasmanian pademelon	Male	0.327	1.227	0.3745
	Female	0.033	0.124	0.4880

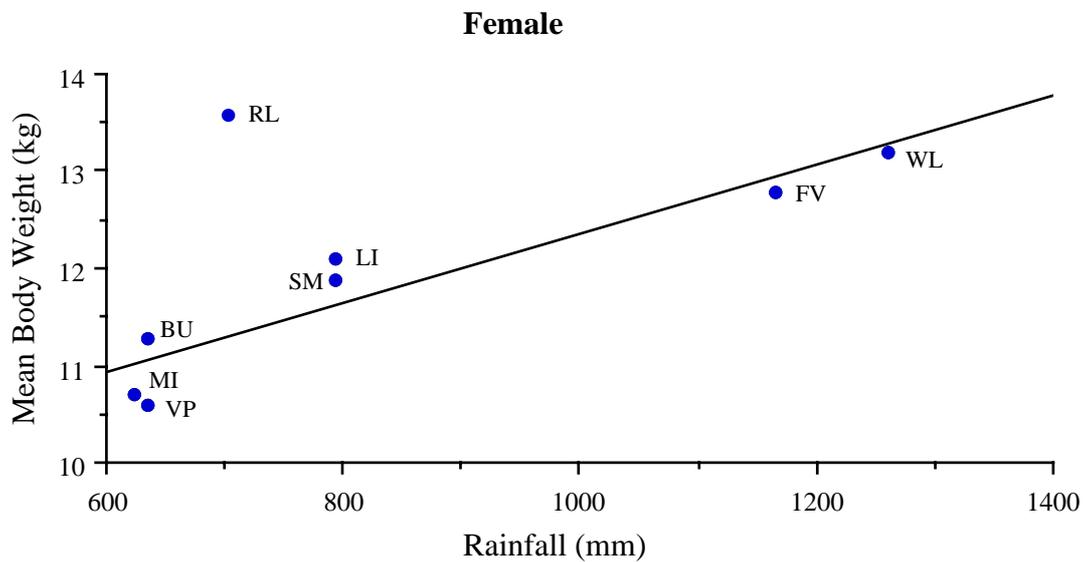
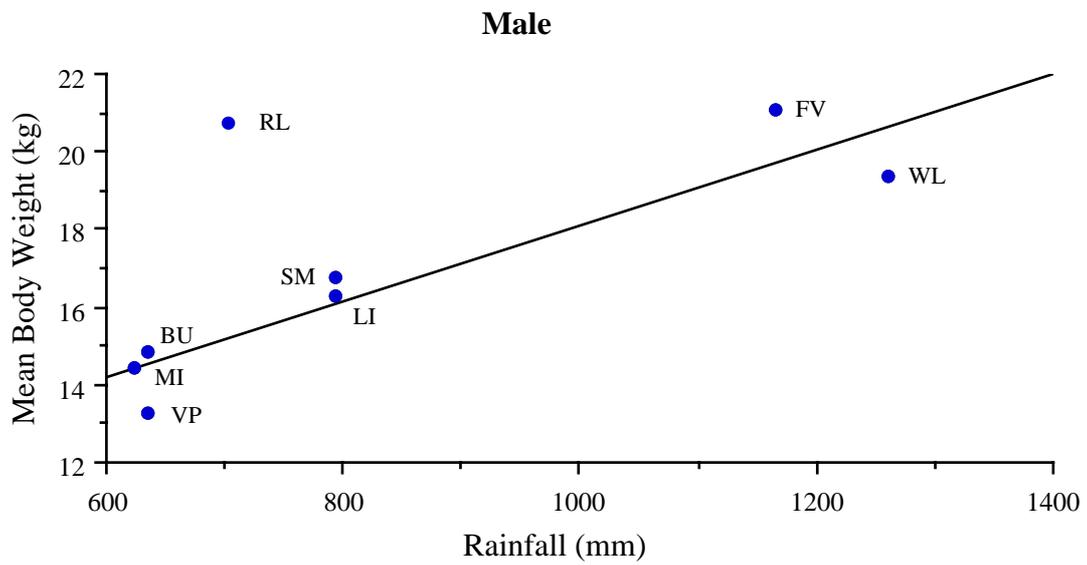


Figure 4.6 Correlation between mean body weight (standard deviations given in Table 4.12) of Bennett's wallabies in the oldest age class and mean annual rainfall (1977-86). For males $r=0.70$, $p=0.05$ and for females $r=0.65$, $p=0.08$. Note position of Rushy Lagoon.

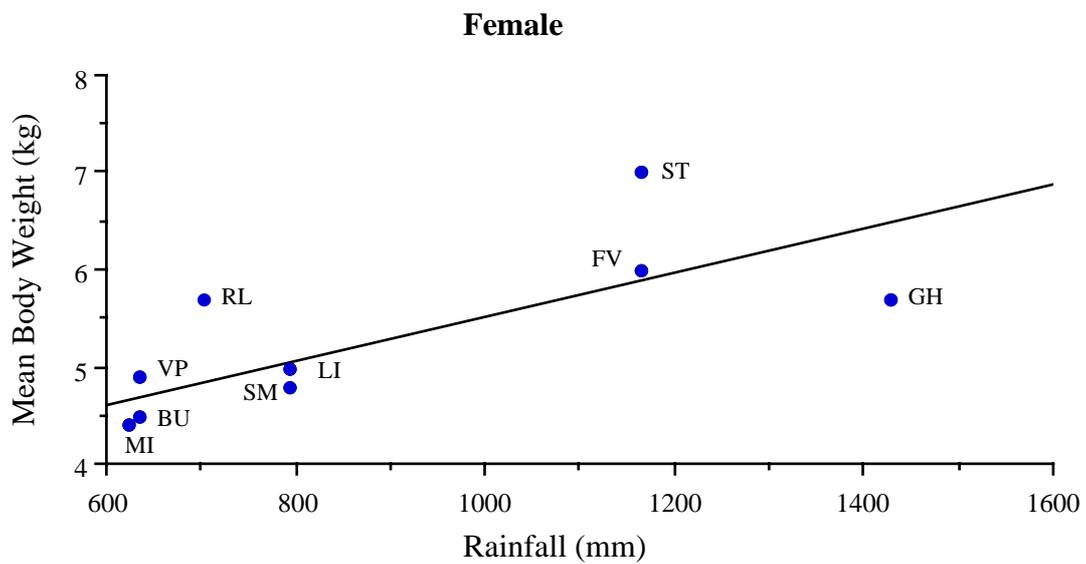
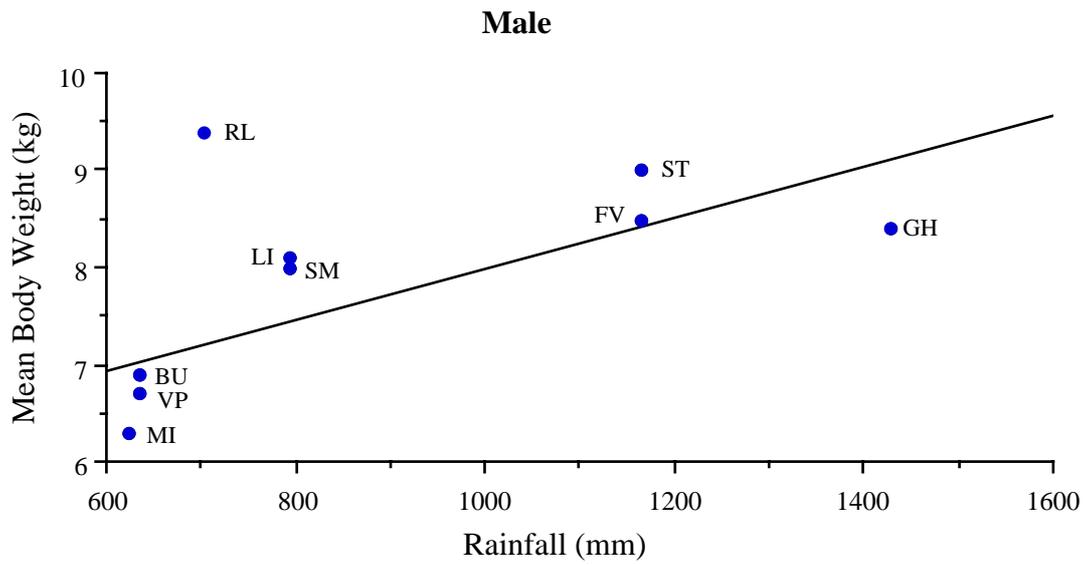


Figure 4.7 Correlation between mean body weight (standard deviations given in Table 4.13) of Tasmanian pademelons in the oldest age class and mean annual rainfall (1977-86). For males $r=0.56$, $p=0.10$ and for females $r=0.72$, $p=0.03$. Note position of Rushy Lagoon.

Table 4.15 Correlation between mean annual rainfall (1977-86) and mean body weight of oldest wallabies (6+ years for Bennett's wallabies and 30+ months for Tasmanian pademelons) for all study areas.

Species	Sex	r	F-test	Probability
Bennett's wallaby	Male	0.70	$F_{(1,6)} = 5.7$	0.05
	Female	0.65	$F_{(1,6)} = 4.2$	0.08
Tasmanian pademelon	Male	0.56	$F_{(1,7)} = 3.3$	0.10
	Female	0.72	$F_{(1,7)} = 7.6$	0.03

Table 4.16 Correlation between mean annual rainfall (1977-86) and mean body weight of oldest wallabies (6+ years for Bennett's wallabies and 30+ months for Tasmanian pademelons) for all study areas excluding Rushy Lagoon.

Species	Sex	r	F-test	Probability
Bennett's wallaby	Male	0.94	$F_{(1,5)} = 36.4$	0.002
	Female	0.94	$F_{(1,5)} = 37.8$	0.002
Tasmanian pademelon	Male	0.82	$F_{(1,6)} = 12.3$	0.010
	Female	0.79	$F_{(1,6)} = 10.0$	0.020

4.4 DISCUSSION

4.4.1 Variation in Kidney Weight to Body Weight Ratio

According to Van Vuren and Coblenz (1985), the underlying assumption of KFI, that kidney weight is proportional to body weight, has been assumed but not substantiated in past studies. Although Van Vuren and Coblenz (1985) found a significant correlation between kidney weight and body weight for feral sheep, *Ovis aries*, they also found that this relationship differed slightly between juveniles and adults. This was because juveniles had proportionally larger kidneys than adults. The results for both the Tasmanian pademelon and Bennett's wallaby showed this same pattern. Hence, KFIs for juvenile wallabies will be underestimated relative to adult wallabies. However, in most cases, the differences between mean KFIs for adults and juveniles (refer to Table 4.3 and 4.6) were greater than 26% which is more than can be attributed to the variation in kidney weight alone. Kidney weights did not vary between adults and juveniles by more than 10% and 13% for Bennett's wallabies and Tasmanian pademelons respectively. Only the comparison between mean KFIs for adult female and juvenile Bennett's wallabies during summer may be affected by variation in kidney weight as the difference in mean KFI was only 11%.

The present study found that, for both wallaby species, there were small decreases in mean KW/BW ratios during late autumn of 1989 and early winter of 1988. This decrease was due to a decrease in kidney weight rather than an increase in body weight (refer to Appendix I). A number of authors (Batcheler and Clarke 1970; Flux 1971; Dauphine 1975; Mitchell *et al.* 1976; Havera 1977; Finger *et al.* 1981; Spinage 1984; Van Vuren and Coblenz 1985; Pepin 1987; Coblenz and Van Vuren 1988) have shown that kidney weights may fluctuate seasonally and not necessarily as a function of body weight. However, there are differences of opinion about the effect of seasonal variation of kidney weight on estimates of body condition based on KFI. Some authors (Batcheler and Clarke 1970; Dauphine 1975; Van Vuren and Coblenz 1985) argue that variation in kidney weight will substantially influence inter-seasonal comparisons of KFI. Dauphine (1975) found that KFIs were distorted by a 70 to 80% increase in kidney weight during summer and early autumn for caribou, *Rangifer tarandus*. Other authors (Flux 1971; Finger *et al.* 1981; Mitchell *et al.* 1976; Spinage 1984; Pepin 1987) consider that the effect of seasonal variation in kidney weight in their studies was insignificant. Both Flux (1971) and Pepin (1987) reported variations in kidney weights of up to 10% in hares, *Lepus europaeus*, however, this was not considered to be large enough to cause any significant differences in seasonal patterns of KFI. Similarly, Havera (1977) found that KFI provided a satisfactory estimate of fox squirrel, *Sciurus niger*, body condition despite variations in kidney weights of up to 20% for males and 32% for females .

In the present study kidney weights did not vary by more than 12% for either wallaby species. This seasonal difference in kidney weight had little influence on seasonal trends in KFI because most seasonal differences between mean KFIs (Tables 4.3 and 4.7) were greater than 12%. In addition there was little sampling during that time when kidney weights were significantly low.

The cause of the decrease in kidney weight during late autumn is unclear but may be related to water stress at this time. In Tasmania effective rainfall is typically lowest during summer and early autumn (Section 2.2). In 1988 the low kidney weights continued into early winter, presumably due to the drought which ended in July of that year (Section 2.2). In the following year when rainfall had returned to more normal levels there were no significant decreases in kidney weight during early winter. Kidney weight has been shown to decrease during periods of water stress in shrews (Pucek 1970), feral sheep (Van Vuren and Coblenz 1985) and the Indian mongoose, *Herpestes auropunctatus*, (Coblenz and Van Vuren 1988).

For both wallaby species there were also small, but significant, differences in mean KW/BW ratios between study areas. This difference was also due to changes in kidney weight rather than body weight (refer to Appendix I). The maximum differences for kidney weights between study areas were 23% for Bennett's wallabies and 12% for Tasmanian pademelons. However, maximum differences between mean KFIs (Table 4.4 and 4.7) were typically greater than can be attributed to variation in kidney weight alone. Only the comparisons between juveniles during summer 1988 and winter 1989 may be influenced by the variation in kidney weight and this is taken into account when discussing mean KFIs below.

The cause of variation in kidney weight between study areas is unclear. It is possible that water stress and/or food deprivation are involved, as the two study areas with the lowest kidney weights were subject to low rainfall. However, the remaining study areas which had similar kidney weights do not support this explanation. It is possible that the proportionally higher kidney weights at Western Lakes for Bennett's wallaby was due to the cold temperatures (refer to Section 2.3) at this high altitude study area. Chaffee and Roberts (1971) and Balcer and Chaffee (1984) have reported for several mammal species that cold acclimation leads to an increase in kidney weight.

According to Coblenz and Van Vuren (1988) body water kinetics, metabolic activity, and temperature stress may all influence kidney mass simultaneously. Further explanation of variation in kidney weights for both wallaby species was beyond the scope of the present study. However, the variations in kidney weights between age groups, seasons and study areas were not considered to be large enough to influence the general trends observed in KFI. These trends are discussed below.

4.4.2 Kidney Fat Index

KFIs for Bennett's wallaby and the Tasmanian pademelon were used to assess the short term response in body condition to recent environmental conditions. Although small sample sizes hampered comparisons, some general trends were apparent.

KFIs for both wallaby species were higher in winter than in summer. This trend has been reported for a number of other species such as; grey kangaroos (Caughley 1962), thar, *Hemitragus jemlahicus*, (Caughley 1970), red deer (Caughley 1971a), hares (Flux 1971), chamois (Henderson and Clarke 1986), white-tailed deer (Waid and Warren 1984; DeLiberto *et al.* 1989) and wild European rabbits, *Oryctolagus cuniculus*, (Boyd and Myhill 1987). Yearly variation in body condition is often linked to the reproductive cycle which, in turn, is linked to the availability of food resources at critical stages of reproduction. For adult female wallabies, the yearly trend in KFI also appeared to be linked to the reproductive cycle. KFIs for adult females were lowest in summer presumably as a result of lactational demands from young during spring and summer. It is also likely that the decrease in KFI is associated with food shortages at the end of winter and before there is effective spring growth. Once the young have been weaned over summer, adult females showed evidence of increasing their fat reserves presumably in preparation for winter food shortages and the energy demands of the next young.

The loss of condition between winter and summer shown by males is also likely to be a result of food shortages at the end of winter. However, other factors must be involved otherwise they would show an increase in KFI over spring when food resources increase substantially. It is suspected that time and energy spent on activities associated with mating in spring and summer may be associated with this loss of body condition. Several studies have shown that KFIs for some species of ungulates decrease during the rutting season (Attwell 1982; Clutton-Brock *et al.* 1982; Dunham and Murray 1982). Whilst macropods do not have a rutting season, males of most species show increased levels of aggression around females which are in oestrous (Russell 1974). Physiological changes associated with mating, such as increases in prostate weight (Appendix II), may also contribute to a reduction in KFI. It is also possible that the lower KFIs recorded in summer for male wallabies is a result of maximizing growth during spring when food resources are relatively stable. Seasonal periodicity in growth has been shown for several species of ungulate in temperate zones (Wood *et al.* 1962; Houston *et al.* 1989) and peak growth occurs spring and summer. Whether this occurs in wallabies will require investigation.

Juveniles of both species also had lower KFIs in summer than in winter. The majority of young of both species vacate the pouch in spring and early summer and, as a result, have not had time to deposit fat reserves. This period when KFIs were low is associated with high mortality of young which have recently left the pouch (Johnson 1989c; section 5.4.4).

In winter adult females had higher KFIs than adult males. This sex-related difference in KFI has also been found in other animals such as white-tailed deer (Johns *et al.* 1984), nyala, *Tragelaphus angasi*, (Anderson 1985) and wild European rabbits (Boyd and Myhill 1987) and is attributed to the requirement by females for better body condition to cope with the demands of pregnancy and lactation. In addition, the lower KFIs recorded for males may be a result of maximising their potential for growth. Clutton-Brock *et al.* (1982) showed that, in winter, female red deer will reduce their growth rate to a greater degree than males in favour of depositing fat. For male red deer, large body size is important for reproductive success and hence there are obvious advantages in maximizing growth. Similarly, for both wallaby species, body size of males is important in establishing dominance relationships (Clancy 1982; Johnson 1989a) and Johnson (1989a) was able to show that for the mainland subspecies, the red-necked wallaby, large males accounted for most matings.

In summer female Bennett's wallabies had lower KFIs than males which can be attributed to the high energy demands placed on females at this time of the year by large pouch young or suckling young which have left the pouch. By contrast, female Tasmanian pademelons still had higher KFIs than male Tasmanian pademelons. Thus male Tasmanian pademelons showed a greater decrease in KFI between winter and summer than did male Bennett's wallabies (refer to Tables 4.3 and 4.6). Why this difference between the species should occur is not clear but may be related to the difference in onset of reproductive activity between the two species. Increases in prostate weight prior to breeding (Appendix II) indicate that male Tasmanian pademelons commence mating activity earlier in spring than Bennett's wallabies and presumably begin to lose condition earlier. In addition, fighting scars were frequently seen on Tasmanian pademelon pelts but rarely on Bennett's wallaby pelts (unpublished observations). This suggests that the degree of fighting between pademelons may be higher than that between Bennett's wallabies and this may also help to explain the differences in KFIs.

Juveniles of both species had lower KFIs than adults, although this difference was less apparent in summer than in winter. It should be noted that juveniles had proportionally larger kidneys than adults thereby decreasing their KFIs in comparison. However, for winter at least, this did not account for all of the observed difference in KFI. Such a difference is not unreasonable as younger animals have higher growth rates than adults (Tables 4.10 and 4.11) and have had less time to develop fat reserves. Similar results, using KFI, have been reported for other species such as red deer (Riney 1955), chamois (Henderson and Clarke 1986), red fox, *Vulpes vulpes*, (Lindstrom 1983), hares (Pepin 1987) and impala, *Aepyceros melampus*, (Dunham and Murray 1982).

Although sample sizes for unsuccessful breeders were small, there was evidence to suggest that a lack of breeding success was associated with low KFIs. Similar findings, using KFI, have

been reported for fox squirrels (Havera 1977) and caribou (Thomas 1982). In addition, Newsome (1977b) found that, during drought, weights of non-breeding red kangaroos were lower than their reproductive counterparts of the same age. This lower breeding success of animals in poor condition is presumably a strategy to conserve energy.

Mean KFIs were higher for Tasmanian pademelons than for Bennett's wallabies (compare Tables 4.3 and 4.6). Whether this difference represents a real difference in body condition between the two species is not known as it is possible that the different KFIs represent differences in patterns of fat deposition. However, it is possible that body condition of Tasmanian pademelons is higher than that of Bennett's wallabies as evidenced by differences in the quality of their diets. Bennett's wallabies are grazers feeding primarily on grasses (Calaby 1983; Statham 1983; Southwell 1987; Jarman and Phillips 1989) which are generally low in nutrients (Taylor 1981; Dawson 1989; Freudenberger *et al.* 1989; Norbury *et al.* 1989). By comparison, Tasmanian pademelons have a more varied diet (Statham 1983; Johnson and Rose 1983) feeding on soft green grasses, browse, forbs and shrubs which are generally high in nutrients (Dawson 1989). This difference in the quality of the diet consumed by each species was confirmed by analysing stomach samples for nitrogen content (Appendix III). Thus, it is possible that the differences in mean KFI between the two wallaby species may, in part, reflect differences in body condition.

Effect of hunting and rainfall on KFI

Both the 1987/88 drought and the variation in rainfall between study areas were found to influence KFIs for both species of wallaby.

Mean KFIs for Bennett's wallabies were significantly lower in 1988 than in 1989. As rainfall is a significant factor affecting vegetation quality and quantity (Sinclair 1977; Shepherd 1987), this result suggests that food resources for this species were poorer in 1988 as a result of the drought. The effect of the drought on Tasmanian pademelons was less apparent. Only mean KFIs for adult male pademelons were significantly lower in 1988 than in 1989. Although mean KFIs for adult females were 24% lower in 1988 than in 1989, this difference was not significant at the 0.05 level. Given the high variation in KFIs for adult female pademelons (Table 4.8) it's probable that greater sampling would have resulted in a significant difference in mean KFIs between years. This high coefficient of variation can be attributed to the fact that Tasmanian pademelon births occur over a period of 4 months (Section 5.4.1) and, hence, body condition will vary depending upon when a female gave birth. By comparison, Bennett's wallaby births occur over a much shorter period, hence, females are more likely to have similar body condition. These results suggest that the drought may have had a greater impact on the body condition of Bennett's wallabies than on Tasmanian pademelons. This difference between the two species is possibly due to differences in diet which has already been discussed. This difference in the quality of diet will be increased during periods of drought as it has been shown that, during

times of low rainfall, grasses characteristically lose crude protein more rapidly and to a greater degree than do shrubs (De Vos and Mosby 1969).

In 1988 variation in rainfall between study areas was positively correlated with mean KFI for both species. This indicates that the drought affected low rainfall study areas to a greater extent than high rainfall study areas. This is supported by the variation in rainfall deficit between study areas during the drought (Section 2.2). In 1989 there was no evidence of a correlation between rainfall and mean KFIs for either species of wallaby. Presumably the higher rainfall in the latter half of 1988 and all of 1989 resulted in improved food resources at all study areas. In addition, density may have been reduced as a result of lower survival of young after the drought (Section 5.4.4).

Similar relationships between KFI, rainfall and food resources have been shown for other species of kangaroos (Shepherd 1987) as well as other non-macropod mammals (Sinclair 1977; Anderson 1985).

There was little evidence that hunting pressure influenced KFI during the present study. The high mean KFIs for both species at Rushy Lagoon, the most heavily hunted study area, suggest that hunting may have some influence on body condition. It is reasonable to assume that if the level of wallaby hunting is high, then wallaby density will be low resulting in more resources for the surviving population (Caughley 1977). Such a response, using KFI, was reported by Kie *et al.* (1983) for white-tailed deer and Storch (1989) for chamois. It is possible that in 1988 the effect of the drought was such that it obscured any effect of hunting on KFI. In 1989 there was still little evidence of hunting pressure affecting body condition as a combined result of 1) greater quantity and quality of food due to good rainfall in late 1988 and 1989 and 2) reduced density due to low breeding success in 1988 (Section 5.4.4).

Other Effects on KFI

In addition to hunting and rainfall, there was evidence to suggest that low temperatures may also have an effect on KFI. Mean KFIs for Bennett's wallabies at Western Lakes showed a greater decrease between winter and summer than other study areas (note, no samples of Tasmanian pademelons were obtained from this study area). Western Lakes occurs at the highest altitude and is subjected to the coldest temperatures (Section 2.3). It is believed that this greater decrease in mean KFIs between winter and summer is due to the delay in spring growth caused by low temperatures (J. Yates, unpublished data). Hence the period of food shortage between the end of winter and the onset of spring growth is greater at this study area than at the other lower altitude study areas.

4.4.3 Growth

Growth in terms of mean body weight was used to assess variation in long-term body condition between study areas. When resources are abundant animals tend to grow larger and faster (Risenhoover and Bailey 1988).

The short-term response in KFIs to rainfall was also apparent in the growth of wallabies. Wallabies in high rainfall areas attained greater weights than wallabies in low rainfall areas. As high rainfall areas in Tasmania show less variability in rainfall than low rainfall areas (Langford 1965), growth rates are less likely to be reduced as a result of food and water shortages.

Although rainfall was found to influence the growth of wallabies, it is unlikely to be the only factor involved. This may be demonstrated by the fact that mean body weights at Rushy Lagoon were among the highest of all study areas despite the fact that this study area had a medium level of rainfall. The greater growth of wallabies at Rushy Lagoon may be due to the effect of high hunting pressure which maintained wallaby numbers at low densities. Hence, there will be greater resources for those wallabies which survive hunting. Challies (1973) reported such a response by red deer in New Zealand. In areas where harvesting pressure was high, the deer of similar age were larger than those in areas where harvesting pressure was low.

4.5 SUMMARY

The aim of this chapter was to assess the body condition of Bennett's wallabies and Tasmanian pademelons and to determine whether hunting and rainfall influences body condition. The Kidney Fat Index (KFI) was used to assess the short-term response of wallabies to the quality of their environment and growth in body weight was used to assess the longer term response.

The underlying assumption of KFI, that kidney weight is proportional to body weight, was tested. This relationship was found to vary among age groups, seasons and study areas and should be taken into consideration in future studies. In the present study, the variation in the kidney weight to body weight relationship was not large enough to influence general trends in KFI.

The trends in KFI and growth were generally similar for both species. Adults had higher KFIs than juveniles because juveniles put most of their energy into growth and because they have not had time to deposit fat reserves. Females had higher KFIs than males and this can be attributed to the requirement by females for better condition to cope with the demands of

pregnancy and lactation and because there are reproductive advantages for males to convert food resources into growth rather than into fat.

KFIs were higher in winter than in summer. This was, in part, due to food shortages at the end of winter and before the onset of spring growth. KFIs for adult females continued to decrease over spring and early summer due to the increasing demands of dependent young over this time. It was proposed that the continued decrease in KFI by males over spring and summer was due to time and energy spent on mating activities and, perhaps, seasonal periodicity in growth. Juveniles had lower KFIs in summer than in winter simply because they have not had time to deposit fat reserves.

Females which failed to breed had lower KFIs than those females which succeeded. This presumably reflects a strategy to conserve energy.

KFIs for Tasmanian pademelons were higher than those for Bennett's wallabies. This difference may be due to different strategies of fat deposition between the two species. However, the higher quality of diet consumed by Tasmanian pademelons suggests that the difference in KFI may reflect, in part, a difference in body condition.

Both the 1987/88 drought and variation in rainfall between study areas were found to influence KFIs. KFIs were lower in 1988 than in 1989 as a result of the drought. The drought appeared to have a greater affect on Bennett's wallaby KFIs than on Tasmanian pademelon KFIs possibly because of differences in diet. The drought had greater effect on KFIs in low rainfall areas than in high rainfall areas, as evidenced by a positive correlation between mean KFI and annual rainfall. In the year following the drought there was no such correlation due to improved conditions at all study areas. The effect of rainfall on KFI during the drought was also reflected in the different growth rates of wallabies between study areas. In general, wallabies in high rainfall areas attained greater body weights than those in low rainfall areas. This was attributed to less variability in rainfall in high rainfall areas than in low rainfall areas and, hence, less food shortages.

The effects of hunting on KFI were largely masked by the drought. However, high growth rates and high levels of body condition at the most heavily hunted study area suggested that an increase in hunting pressure can lead to an increase in body condition.