THE EFFECT OF SHEARING EWES AT MID-GESTATION ON REPRODUCTION AND PERFORMANCE

A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Science in Zoology
at Massey University

Julie Elizabeth Hanna

2000

ABSTRACT

This study tested the hypothesis that shearing ewes in mid-gestation causes an increase in lamb birth weight. Growth rates of lambs were calculated to test for any additional trade-off between investment at gestation limiting investment at lactation. Liveweights and growth rates of lambs were analysed for a difference between the sexes with the expectation that sheep may put extra investment into male lambs, compared to female lambs. Experiments were conducted with mixed-sex twin pairs to determine if the male lamb was able to receive more milk than the female lamb.

Sixty ewes were selected after synchronised mating and pregnancy diagnosis: 30 were twin-bearing and 30 were single-bearing. Half of each group (twin- and single-bearing) were shorn at mid-gestation (approximately 77 days before lambing) and observations of their behaviour and estimations of their food intake were made.

Shorn ewes adjusted rapidly to shearing, exhibiting no apparent difference in behaviour one week after shearing. Shearing led to an increase in ewe weight and lamb birth weight. Rearing twins was costly for the twin-bearing ewes: they were lighter, had lower condition scores and less wool growth than ewes with singletons during late-gestation and lactation.

Twin lambs were born lighter and grew slower than single lambs. There was no evidence of sex-biased investment in this study. A slight trade-off between gestation and lactation was apparent for shorn, single-bearing ewes. There was no difference between twin lambs born to shorn or full fleece dams. Shearing ewes at mid-gestation appears to be a useful tool for increasing the birth weight of lambs which could lead to an increase in survival of newborn lambs.

ACKNOWLEDGEMENTS

I would like to thank Dr Robin Fordham and Dr Dean Revell for their supervision, assistance and endless encouragement during this study. I appreciate the extra mile both have gone, Robin taking on a student part way through a thesis and Dean for continuing to offer support from Australia.

I am indebted to Yvette Cottam for her assistance in all aspects of the study. She helped with all the field work and patiently showed me how to use SAS to analyse my samples. Her patience and good humour were much appreciated.

Mr Barry Parlane provided valuable assistance with the ewes and lambs indoors and his help in conducting the milk intake experiments were greatly appreciated.

Statistical advice was welcome from Mr Duncan Hedderley and Mr Ray Webster.

Last, but not least, I would like to thank all my friends who encouraged and assisted when it was most needed. You guys all know who you are!

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Chapter 1

Introduction and Methods

INTRODUCTION

Maternal investment has been defined as "anything done by the parent for the offspring that increases the offspring's chance of surviving while decreasing the parent's ability to invest in other offspring" (Trivers, 1972). In terms of the theory, investment by the mother could affect young in the same litter, as well as her future offspring. There are several ways this could happen. The mother could face a higher risk of predation because of her willingness to defend her offspring against predators, or have a shortened lifespan because of the effort she has expended in the offspring (Boyd *et al*, 1995; Clutton-Brock *et al.,* 1996). Alternatively, future offspring may be less likely to survive because of the effort she has invested in the current offspring.

In mammals, it has been argued that the greatest costs are incurred during lactation (Gittleman and Thompson, 1988), but Clutton-Brock *et al.* (1996) found no evidence in Soay sheep that lactation reduced fecundity in subsequent breeding seasons. Within mammals, ungulates have some of the highest post-natal growth rates known (Byers and Moodie, 1990), indicating ungulate mothers are investing heavily in their offspring at that stage.

Maternal investment is typically measured in two ways - behaviourally or physiologically (Gittleman and Thompson, 1988). Behavioural measurements can include the duration and frequency of suckling, the animal initiating and terminating suckling bouts, and estimates of the distance between mother and young. Measurements relating to physiology can include litter mass at birth or weaning, the calorific intake of young, net production, metabolic rate and/or daily energy expenditure. Many of these parameters are difficult to measure in the wild. For example, records of litter mass rely on correctly identifying the mother, and catching the mother and offspring for weighing and assessment of body condition (Verme, 1989). Other physiological measures usually require the animal to be in full or partial captivity which makes comparisons with wild populations difficult.

It is also difficult to account for the characteristics of individual mothers when analysing maternal investment. For instance, age and condition affect maternal investment (Festa-

Bianchet *et al.*, 1995; Clutton-Brock *et al.*, 1996) but age is not always known in wild populations and has to be estimated from physiological factors (Miura *et al.*, 1987). Birth date can also affect the survival of offspring (Clutton-Brock *et al.*, 1992). Hogg *et al.* (1992) found that late-born lambs of bighorn sheep (*Ovis canadensis*) were less likely to survive to weaning, and late-birth was a predictor of poor maternal condition. These factors further complicate comparative analyses of maternal investment within a population. Other factors, such as the mother's parasite load, can also cloud calculations of maternal investment (Festa-Bianchet, 1988).

Use of domestic sheep (*Ovis aries*) for the study of maternal investment has certain advantages: 1) body condition is controlled (they are usually maintained within a tight range of body condition) and are usually treated for parasites; 2) the age of the sheep can be selected with accuracy; 3) gestation length can be accurately determined, and oestrus can be managed, so that all the ewes ovulate and lamb very close together, thus reducing birth date variability; 4) litter sizes in sheep vary, therefore providing a range of maternal investment situations; 5) it is easy to weigh sheep and lambs in a farm situation, so accurate growth rates can be calculated; 6) finally, sheep with known investment histories can be selected for experimental use and placed together in the same paddock where it is relatively easy to manipulate conditions. The extent to which some of the advantages outlined above are confounded by genetic traits selectively bred into the stock (such as those concerning fibre quality or carcass size) is unknown. On this point comparisons with ancestral or feral breeds is significant.

General Aims:

The general aims of the study were to:

1. Determine ewes' reaction to a 'challenge' (placing the ewe under added stress) after litter size had been set. In this case the challenge was shearing at mid-gestation, i.e. 70 days of gestation.
2. Determine if there is any evidence of differential investment by ewes in lambs of one sex compared to the other.
3. Determine the effect on the ewe of having single or twin lambs, and whether this is affected by the 'challenge' to the ewe. In this case the body weight of ewes was measured over time.

METHODS

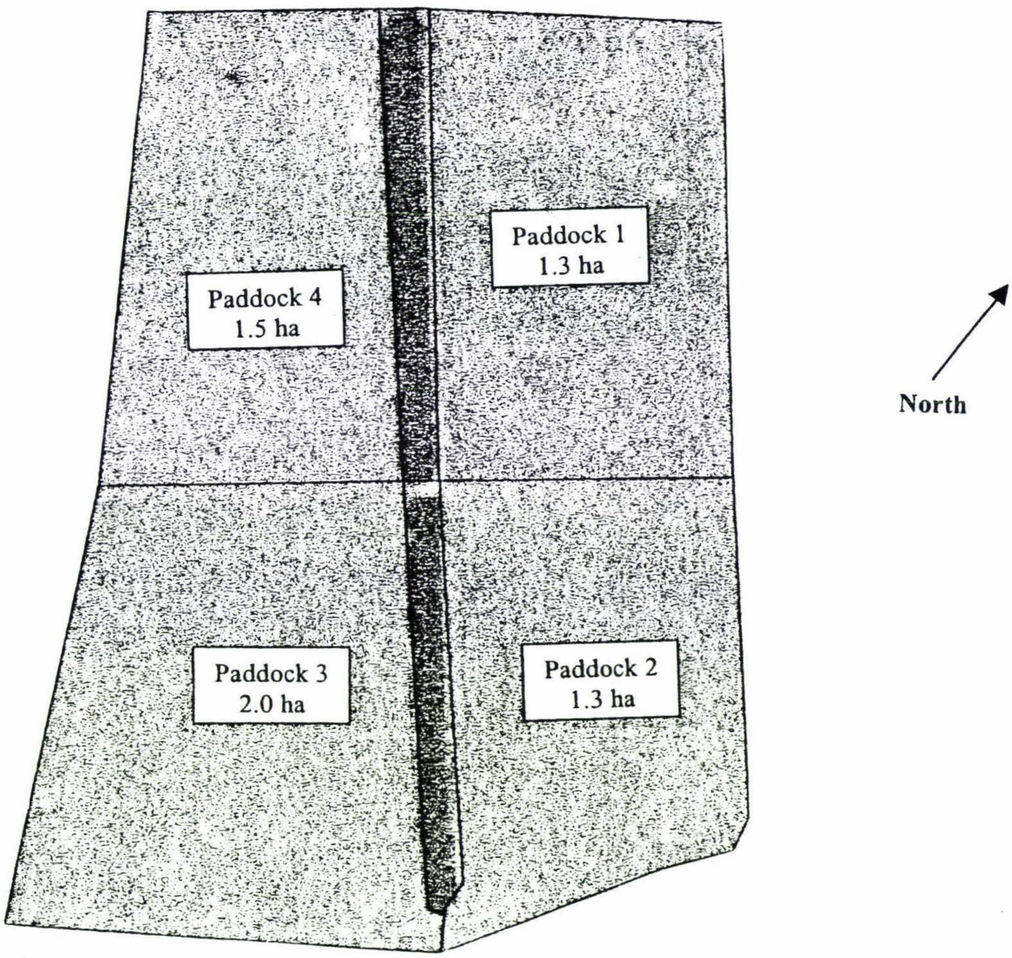
On 6 March 1997, 180 Coopworth ewes ranging from 2-3 years of age were weighed and fitted with intravaginal progesterone-release devices (controlled internal drug release devices, CIDR, InterAg Eazi-Breed). On 18 March 1997, the CIDRs were removed and the ewes placed in a paddock with 13 Coopworth rams fitted with mating harnesses. The harnesses were placed on the front of the rams with an attached crayon that left a mark on the ewe's rump when she was mounted by a ram. These 'tup marks' fixed the day of mating. Over the next three days all tup marks were recorded and were assumed to indicate successful mating. Nine days later, rams and crayon colour were changed so that any ewes having failed to become pregnant in the first oestrus cycle which had mated in the second cycle, could be identified and discarded from the trial.

At approximately 54 days of pregnancy 180 ewes were weighed and diagnosed by ultrasound for pregnancy and the number of foetuses being carried. Thirty single-bearing and 30 twin-bearing ewes were selected from this group because they were closest to the average weight of the group, and because they had not lost weight between mating and pregnancy diagnosis. The ewes were stratified by weight and half the twin-bearing ewes (n=15) and half the single-bearing ewes (n=15) were allocated to be shorn (S) on day 70 of pregnancy. The other half were left full fleeced (FF) to serve as controls.

The study took place on Massey University's Sheep and Beef Research Unit, Keeble Block. The four paddocks used during the trial, which were originally one large paddock, were similar in pasture composition, predominantly ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). Paddocks 1 and 2 (P1 and P2) were each 1.3 ha, Paddock 3 (P 3) was 2.0 ha and Paddock 4 (P 4) was 1.5 ha. Paddock 4 also had a gully running through part of it. A line of pine trees divided P1 and P2 from P3 and P4 (Figure 1.1).

The ewes challenged in the experiment were shorn on 28 May 1997, 77 days before lambing, and their wool weighed. All ewes were yarded and weighed the day before shearing. The FF group was crutched, but not fully shorn at this time. Weights and condition scores were taken monthly from 77 days before lambing to weaning (day 104 of lactation). All the ewes were shorn finally on 30 October 1997 and the wool was weighed. Annual greasy fleece production was calculated for the S group of ewes by adding the weights of the wool taken on both shearing dates.

Figure 1.1 – Map of paddocks 1-4 on Keeble Block, Sheep and Beef Research Unit, used during the study.



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Chapter 2

The effect of shearing at mid-gestation on ewe reproductive performance

INTRODUCTION

In New Zealand, ewes are mated in autumn, gestate through winter, and lamb between late winter and early spring. Lambs are weaned in early summer, leaving three months for ewes to recover from lactation and put on condition for mating the following season (Morris *et al.*, 1993). Liveweight of ewes at mating affects the ovulation rate (Morley *et al.*, 1978), so ability to recover from lactation in the previous season is important. Weight has also been shown to affect breeding performance of wild populations of sheep, for example Clutton-Brock *et al.* (1996) showed with Soay sheep (*Ovis aries*) that twins were more common from older ewes in higher weight classes. Younger ewes and lighter weight classes were more likely to have single lambs.

Since lactation appears to not affect fecundity or subsequent survival of offspring in sheep (Clutton-Brock *et al.*, 1996) the best reproductive strategy for ewes would apparently be to have twins every year. There are, however, disadvantages to having twins. Ewes pregnant with twins are more prone to casting and to being affected by pregnancy toxaemia (Spedding, 1970). Ewes mothering twin lambs take longer to recover from pregnancy, not gaining weight until the end of lactation, while ewes with single lambs are able to gain weight during lactation (Gibb and Treacher, 1982). Twin lambs are usually born lighter than single lambs and since birth weight is a significant factor in lamb survival (Hinch *et al.*, 1983) this makes twin lambs more likely to die shortly after birth.

Animals are often naturally stressed (challenged) after conception (Byers and Hogg, 1995). In most cases, this results from lack of food during gestation (Marrow *et al.*, 1996). In Soay sheep, the last two months of gestation (the most energetically costly period of gestation in ungulates) occurs at the time of greatest food shortage (Clutton-Brock *et al.*, 1996), and an unusually harsh year can make reproduction especially costly for sheep. Soay sheep have an unstable population that crashes due to food shortages caused by high population density every 3-4 years. In a crash year, ewes carrying twins are more likely to die than those carrying singletons (Clutton-Brock *et al.*, 1996).

Sheep that have been shorn become cold-stressed (Dabiri *et al.*, 1995*a*) and can be expected to show some sort of physiological or behavioural response in compensation. For example, stressed sheep will seek shelter (Clutton-Brock *et al.*, 1992) and higher food intakes have been reported after shearing (Austin and Young, 1977; Vipond *et al*, 1987; Merten, 1994; Dabiri *et al.*, 1996). Shearing ewes during pregnancy has led to heavier lambs at birth (Austin and Young, 1977; Vipond *et al*, 1987; Black and Chestnutt, 1990). Morris and McCutcheon (1997), however, recorded an increased birth weight of twin, but not single lambs, after shearing the ewe at mid-gestation (approximately day 70 of pregnancy). This response raises interesting questions about maternal investment in domestic sheep. One implication of an increase in twin birth weight is that sheep do not face an upper limit in their investment. Nevertheless, a comparison of gestation length between shorn and unshorn sheep would have to be carried out to ensure that twin weight did not increase simply because gestation took longer.

The lack of weight change in single lambs following mid-gestation shearing of the dam remains a puzzle. One possibility is that only sheep already under pressure conceive singles, so that if any further stress occurs they are unable to compensate. It is interesting to note that dry years result in small increases in lamb birth weights in bighorn sheep (Byers and Hogg, 1995). This could be interpreted as analogous to domestic sheep shorn at mid-gestation producing twins with higher birth weights.

The aim of this work was to determine if shearing ewes at mid-gestation produces an increase in lamb birth weight, and whether this increase is dependent on litter size. Food intake was estimated, and observations of behaviour were made to determine if there were differences between shorn and full fleece ewes, or between single- and twin-bearing ewes contributing to any birth weight effect.

The ewes used in the study were of similar ages, born in 1993 or 1994, and all had bred at least once. Using ewes of a similar ages reduced the chances of age-related differences in body condition and lamb growth, since there is evidence that the age of the ewe affects investment in offspring (Asofi, 1984; Clutton-Brock *et al.*, 1996).

METHODS

The sheep used and the mating procedures are described in Chapter 1 – Introduction and Methods.

Estimation of Intakes

Intake of food by the ewes was estimated with the use of chromium sesquioxide (Cr_2O_3, an indigestible marker) described by Morris *et al* (1994). Slow release chromium capsules were inserted in the rumen approximately 91 days before lambing (day 56 of pregnancy). Faecal samples were collected from the ewes according to the schedule in Table 2.1. The first set of sampling (four faecal samples from each sheep over a five day period) took place just prior to shearing. Two more sample periods followed in the two weeks after shearing. A second chromium capsule was inserted on 9 June 1997. A one week delay ensured the release rate of Cr_2O_3 from the capsule was consistent before sampling recommenced. Another three sample sets were taken over a three week period with a gap of one or two days between sample periods.

Faecal samples were oven-dried at approximately 60° C over a period of four-five days, then coarsely ground. Samples from each five day period were bulked by taking an equal amount from each day of the sample period. The bulked samples were then finely ground in preparation for later chemical analysis of chromium content, Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD) and Digestible Organic Matter in the Dry Matter (DOMD).

Pasture height was monitored using the HFRO sward stick (Barthram, 1986). One hundred height measurements were taken at the beginning and end of each sampling period in the paddocks that the sheep had grazed for that period. Grazing management aimed to ensure a sward height > 5cm and a similar height across all paddocks (Table 2.1).

Table 2.1 - Time scale, paddocks ewes occupied during faecal sampling periods May-July 1997, and average sward heights for the paddocks in each sample period.

Sample Period (Days Before Lambing)	Date (Days Before Lambing)	Paddock	Sward Height (cm)
1 (82-78)	23-27 May (82-78)	1 and 2	7.86
2 (75-71)	29 May-3-June (76-71)	3	8.83
3 (69-65)	4-9 June (70-65)	1 and 2	8.06
no sampling	10-15 June (65-59)	4	7.17
4 (58-54)	16-20 June (58-54)	3 and 4	7.02
5 (51-47)	21-27 June (53-47)	1 and 2	6.65
6 (45-41)	28 June-3 July (46-41)	3 and 4	5.53

Samples of pasture were taken using a 0.1 m^2 quadrat at the beginning of each sample period. At each sampling time, eight samples were taken, divided evenly between the number of paddocks used during that period (i.e. four in each paddock when two paddocks were used). Sampling sites were selected at random. Pasture herbage was cut as close to the ground as possible using a shearing handpiece, then bulked for each paddock. The samples were washed, oven-dried at 100^o C for more than 24 hours, then weighed to calculate the amount of dry matter (kg/ha) in the paddock.

Four wether sheep fitted with oesophageal fistulae were used to collect selected (consumed) herbage to determine *in vitro* DMD, DOMD and OMD. These results are used in the calculations to estimate herbage intake of the ewes. The wethers had grazed the sample paddock during the previous day so they had grazing experience in that paddock. Prior to taking a sample they were kept off the paddock for several hours to ensure they were hungry. They were then allowed to graze for 10 minutes with collection bags around their necks to collect the sample from their fistulae. The wethers were returned to the main flock at the end of sampling. The samples were placed in the freezer and later freeze-dried before being ground for later analysis. All samples were kept separate with resulting DMD, DOMD and OMD averaged for each day and paddock.

Observations

The sheep were identified with their treatment group by a coloured collar and stock marker on the nose and rump. Orange = single-bearing shorn, yellow = twin-bearing shorn, green = single-bearing full fleece, and blue = twin-bearing full fleece. There were 15 ewes in each group.

Observations of the ewes were carried out daily at 0800 hours from five days before shearing to 16 days after shearing, then weekly until 49 days after shearing (Table 2.2). The paddock in use, general weather, and wind direction and strength was noted. The paddocks were visually divided into rows running parallel to the treeline. Paddocks 1 and 2 had rows numbering from 1-3 and the slightly larger paddocks 3 and 4 were divided into rows numbering from 1-4. Rows were numbered relative to the tree line, 1 being closest and 4 the furthest from the treeline. Five sheep from each group were selected at random on each day and their row position and general behaviour were recorded. Behaviour was categorised as grazing, standing or lying. Position in the paddock gave an indication of any shelter-seeking behaviour related to the position of the sun and wind direction because rows were relative to the treeline.

Table 2.2 - Timetable of observation periods, May-July 1997.

Observation Period (Days From Lambing)	Date (Days After Shearing)	Paddock
1 (83-78)	24 May-27 May (-4--1)	1 and 2
2 (76-70)	29May, 30 May,1 June,2 June,4 June (1,2,4,5,7)	3 and 2
3 (69-64)	5 June-8 June, 10 June, 11 June (8-11, 13, 14)	1, 2 and 4
4 (63-56)	12 June, 13 June, 18 June (15, 16, 21)	4
5 (48)	26 June (28)	1
6 (42)	2 July (35)	4
7 (35)	9 July (42)	1
8 (28)	16 July (49)	1

All observations were made from outside the paddock to reduce any effect of the presence of an observer. The sheep always noticed the arrival of the observer, but returned to their previous activity within a few minutes. Binoculars were used to identify individuals. If the sheep were significantly disturbed sampling was abandoned.

Ewe Condition Measurements

Ewes were weighed (unfasted) and condition-scored monthly. Fleece weights were taken during shearing. A mid-side wool sample was taken from all ewes during shearing on 30 October 1997 and was used to calculate clean wool yield, staple strength, fibre diameter and colour. Clean wool yield was calculated by weighing the wool before and after washing. Fibre diameter was taken by an OFDA (Optical Fibre Diameter Analyser) and colour was measured by spectrophotometer. Yellowness index was calculated by reflectance.

Statistical Analysis

All analyses were performed using SAS version 6.12 (SAS, 1996). One ewe that had no lamb and two ewes that had possibly mis-mothered their lambs were removed from the analyses. The main effects tested in all the analyses were whether or not the ewes were shorn during pregnancy, and the litter size of the ewe.

Analysis of variance and repeated measures analysis were performed on the calculated dry matter intakes (DMI). Chromium concentration of the faecal sample was plotted for each sheep in each sample period. Any ewe found to have a faecal chromium concentration two standard deviations outside the mean was removed from the analysis on the assumption that the chromium capsule had malfunctioned. The ewes were removed only from the sample periods that would be affected by the same capsule (i.e. Periods 1-3 for the first capsule and Periods 4-6 for the second). The analysis was done with no covariate. Body weight of ewe at mating and estimated intakes from the first week of sampling were tried as covariates, but neither was significant.

Daily observations were combined into weekly totals. Behaviour and position were analysed using a log-linear model (Dobson, 1990). Observation days were combined by paddock and position, then analysed using a log-linear model because the variables were discrete rather than continuous.

Weights, condition scores, fleece weights, gestation length, total litter weight and wool samples were analysed with ANOVA and Repeated Measures testing for a shearing during pregnancy and litter size effect. Multiple comparisons were made using the Bonferroni procedure when interactions between the main effects were significant. The weights and condition scores of the ewes after lambing were analysed separately from the weights and condition scores before lambing. The first (pre-mating) weight and first condition score were used as covariates for the subsequent weights and condition scores, respectively. The shorn ewes had their fleece weight added to their live weight after shearing. The final weight taken seven days before lambing was adjusted by subtracting the total litter weight of the lambs. This removed some of the variation in body weight between the single- and twin-bearing ewes due to the size of their litters.

RESULTS

Herbage Intakes:

Single-bearing ewes ate 140 g/day more ($P<0.05$) than the twin-bearing ewes 51-47 days before lambing (Period 5), but for the other periods there was no significant difference in dry matter intake (Figure 2.1). Shearing treatment had no significant affect on the dry matter intake of ewes (Figure 2.2). No interactions between the main effects were significant.

Litter size became significant ($P<0.05$ – Table 2.3) with between-animal effects when the effect of time is removed. Shearing treatment and shearing treatment*litter size interaction both remain not significant. Figure 2.1 shows the consistently higher intakes that the single-bearing ewes had compared to the twin-bearing ewes.

Figure 2.1 – Dry matter intakes of single- and twin-bearing ewes.

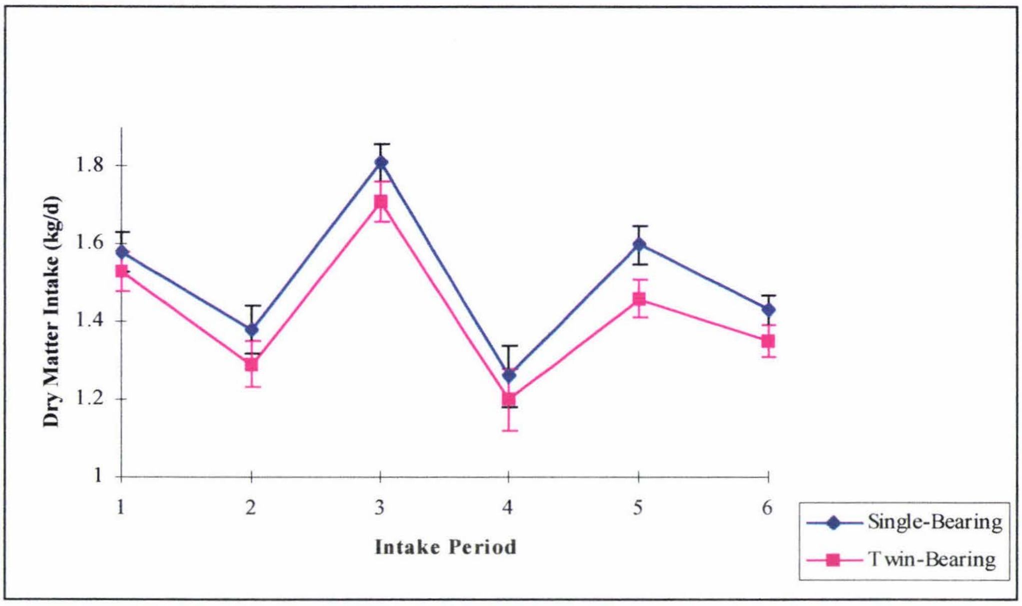


Figure 2.2 – Dry matter intakes of shorn and full fleece ewes.

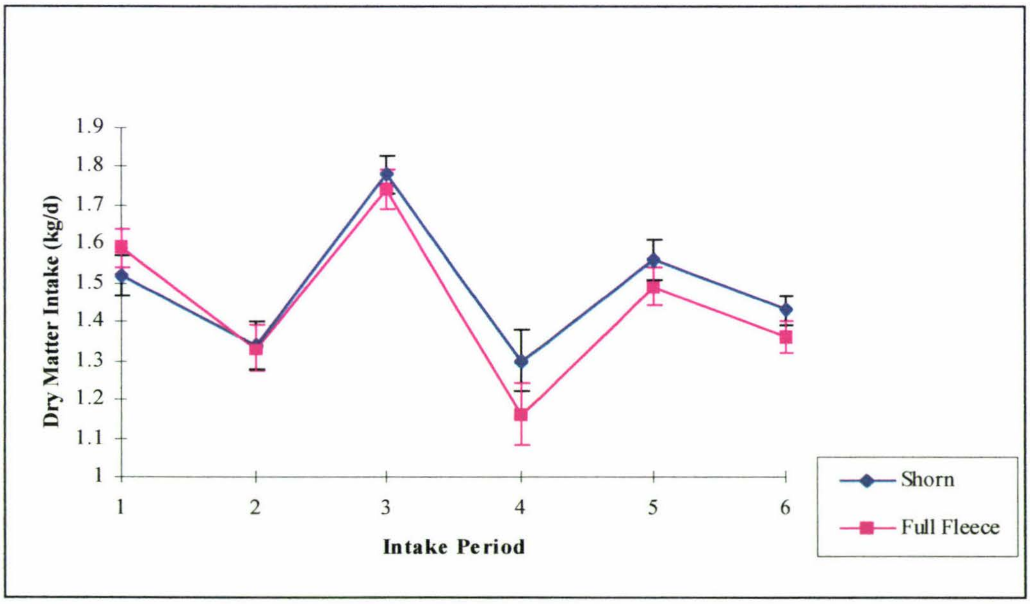


Table 2.3 - The significance of litter size and treatment between animals.

	Probability
Litter Size	0.05
Treatment	0.42
Litter Size*Treatment	0.72

The intakes of the ewes varied from week to week (Figures 1 and 2). The overall mean of each intake period is significantly different (P<0.001) to the intake periods immediately prior and subsequent (Table 2.4). The ewes' intakes in P1 and P2 were always significantly higher than their intakes in P3 and P4 (Tables 4-6, Figs 1 and 2).

Table 2.4 - contrast between intake period and the successive intake period (P-values), May-July 1997.

Intake Period (Days from Lambing)	Paddocks Grazed in Each Intake Period	Mean
1 (82-78) versus 2 (75-71)	P1 and P2 versus P3	0.001
2 (75-71) versus 3 (69-65)	P3 versus P1 and P2	0.0001
3 (69-65) versus 4 (58-54)	P1 and P2 versus P3 and P4	0.0001
4 (58-54) versus 5 (51-47)	P3 and P4 versus P1 and P2	0.0001
5 (51-47) versus 6 (45-41)	P1 and P2 versus P3 and P4	0.0001

Table 2.5 - Contrast between the first intake period (82-78 days before lambing), P1 and P2) and the other intake periods (P values).

Intake Period (Days from Lambing)	Paddock Grazed During Intake Period	Mean
2 (75-71)	P3	0.0001
3 (69-65)	P1 and P2	0.0001
4 (58-54)	P3 and P4	0.0001
5 (51-47)	P1 and P2	0.71
6 (45-41)	P3 and P4	0.0005

Table 2.6 - Contrast between the second intake period (75-71 days before lambing, P3) and the other intake periods (P values).

Intake Period (Days from Lambing)	Paddock Grazed During Intake Period	Mean
1 (82-78)	P1 and P2	0.0001
3 (69-65)	P1 and P2	0.0001
4 (58-54)	P3 and P4	0.08
5 (51-47)	P1 and P2	0.0001
6 (45-41)	P3 and P4	0.11

Observations:

There were no differences in grazing behaviour and position in the paddock between the single- and twin-bearing ewes from 83-28 days (Observation Periods 1-8) before lambing (Table 2.7). Shearing treatment affected grazing behaviour ($P<0.05$) and position in the paddock ($P<0.05$) during the first week after shearing (Grazing Period 2 - Table 2.7). During Period 2 (76-70 days from lambing) the same number of shorn ewes and full fleece ewes were grazing (n=32). Twice as many full fleece ewes were lying rather than standing (n=12 and n=6, respectively), the inverse of the behaviour of the shorn ewes (n=14 standing, n=4 lying - Appendix 1). During Period 2 shorn ewes also had a different distribution ($P<0.05$) within the paddock. Shorn ewes were evenly distributed across the rows (Appendix 2), while the full fleece ewes were concentrated in Rows 3 and 4 (n=39) with fewer full fleece ewes in Rows 1 and 2 (n=11 - Appendix 2).

When observation days were removed and analysis performed by paddock, the ewes had a non-random distribution within the paddocks (Table 2.8). This was very significant in Paddock 1 ($P<0.0005$), Paddock 3 ($P<0.01$) and Paddock 4 ($P<0.002$). The ewes were concentrated in Rows 1 and 2 in Paddocks 1 and 4, but were concentrated Rows 3 and 4 in Paddock 3. The ewes were concentrated in Rows 2 and 3 in Paddock 2 ($P<0.06$).

Table 2.7 - Grazing behaviour and position of the ewes in the paddock (P values).

Grazing	Behaviour		Position		
Period	Litter Size	Treatment	Litter Size	Treatment	All Ewes
1	0.08	0.32	0.73	0.97	0.01
2	0.87	0.02	0.84	0.05	0.03
3	0.40	0.11	0.30	0.28	0.0001
4	0.44	0.46	0.94	0.56	0.03
5	0.60	0.60	0.14	0.35	0.29
6	0.42	-	0.71	0.82	0.91
7	0.53	0.25	0.49	0.67	0.05
8	0.62	0.15	0.24	0.31	0.47

Table 2.8 - Position of ewes per paddock over the entire observation period.

Paddock	Row	Number of Ewes	*P* Values
1	1	63	0.0005
	2	50	
	3	27	
2	1	23	0.06
	2	42	
	3	35	
3	1	10	0.01
	2	13	
	3	25	
	4	32	
4	1	38	0.002
	2	57	
	3	25	
	4	0	

Ewe Condition Measurements

Litter size had no significant affect on the weight of the ewes prior to lambing (Table 2.9). Shorn ewes were 1.3 kg heavier ($P<0.05$) than the full fleece ewes 41 days before lambing, but for the other weighing dates there were no significant differences in weights (Table 2.9). No interactions between the main effects were significant and there were no significant time*main effect interactions.

Table 2.9 - Weight (kg) of shorn, full fleece, single- and twin-bearing ewes. Note that the first weight is pre-mating. (Values are LS means).

	Treatment		Litter Size		
Weight Date (Days from lambing)	Shorn	Full Fleece	Single-Bearing	Twin-Bearing	Pooled S.E.
3 March (163)	58.5	58.2	59.1	57.6	0.6
13 May (92)	58.4	58.0	58.1	58.3	0.3
27 May (78)	62.8	62.5	62.4	63.0	0.3
18 June (56)	65.2	64.6	64.7	65.2	0.4
3 July (41)	69.4[a]	68.1[b]	68.4	69.1	0.4
6 August (7)*	69.7	68.5	68.8	69.3	0.7

[a,b] Means within the same row and main effect with different superscripts are significantly different (P<0.05).

* Unadjusted liveweight.

Shearing treatment had no significant affect on the condition score of the ewes before lambing (Table 2.10). Twin-bearing ewes were 0.2 of a condition score less (P<0.05) than the single-bearing ewes 13 days before lambing, but at any other time there were no significant differences (Table 2.10), and no interactions between the main effects were significant.

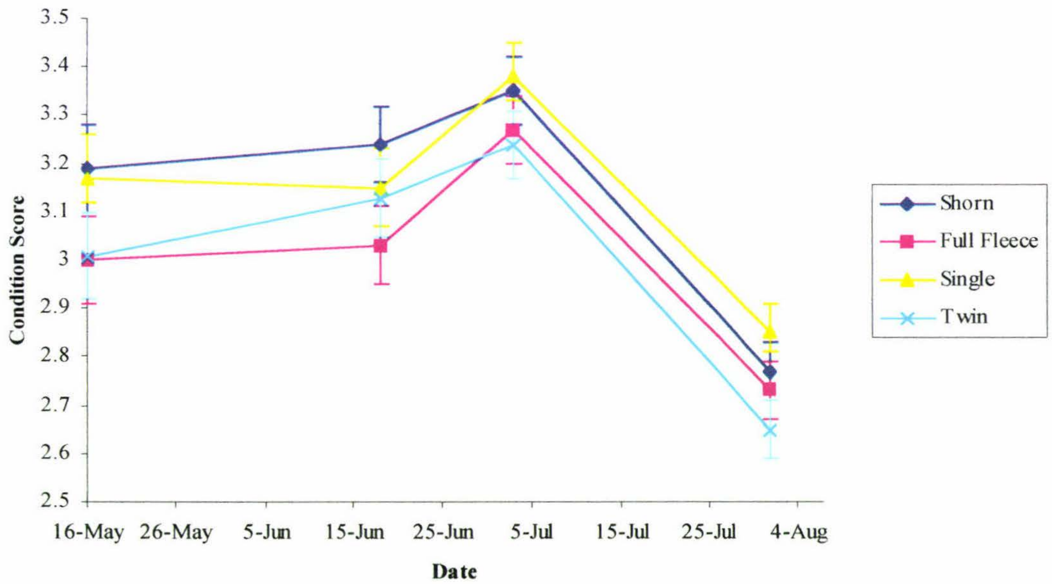
Stage of pregnancy had a significant effect on the mean condition scores (across all groups). There was a decline of 0.56 in average condition score from 3 July to 1 August (Figure 2.3). The mean condition score at 13 days before lambing was significantly (P<0.05) less than the mean condition score from 56 days before lambing.

Table 2.10 - Condition scores of shorn, full fleece, single- and twin-bearing ewes (Values are LS means).

	Treatment		Litter Size		
Condition Score Date (Days From Lambing)	Shorn	Full Fleece	Single-Bearing	Twin-Bearing	Pooled S.E.
16 May (89)	3.19	3.00	3.17	3.01	0.09
18 June (56)	3.24	3.03	3.15	3.13	0.08
3 July (41)	3.35	3.27	3.38	3.24	0.07
1 August (13)	2.77	2.73	2.85[a]	2.65[b]	0.06

[a,b] Means within the same row and main effect with different superscripts are significantly different (P<0.05).

Figure 2.3 – Condition scores of ewes by treatment group and litter size.



The adjusted (litter weight of the lambs removed from the ewe liveweight) August mean weight for the single-bearing ewes was 2.6 kg heavier than the twin-bearing ewes (P<0.05). All weights of single-bearing ewes during lactation were heavier (P<0.05) than those of twin-bearing ewes by 5-10 kg (Table 2.11). Fleece weight was also affected by litter size with twin-bearing ewes having a mean fleece weight 0.7 kg lighter than single-bearing ewes (Table 2.11). Shearing treatment had no significant effect on the liveweights or fleece weight and there were no main effect interactions.

Table 2.11 - Weight (kg) of ewes at the end of gestation and during lactation (Values are LS means).

	Treatment		Litter Size		
Weight Date (Days from lambing)	Shorn	Full Fleece	Single-Bearing	Twin-Bearing	Pooled S.E.
6 August (-7)	62.4	61.7	63.3[a]	60.7[b]	0.8
24 September (42)	62.4	64.5	68.5[a]	58.5[b]	1.1
5 November (84)	66.4	67.6	70.8[a]	63.2[b]	1.3
25 November (104)	66.5	67.7	69.9[a]	64.3[b]	1.3
Fleece Weight (kg)	5.3	5.1	5.5[a]	4.8[b]	0.2

[a,b] Means within the same row and main effect with different superscripts are significantly different ($P<0.05$).

When the combined fleece weights of the shorn ewes were separated according to shearing date (Table 2.12), only the fleece weight from the second shearing (30 October) showed a significant difference ($P<0.002$), with single-bearing ewes producing a mean fleece weight 0.6 kg higher than the twin-bearing ewes.

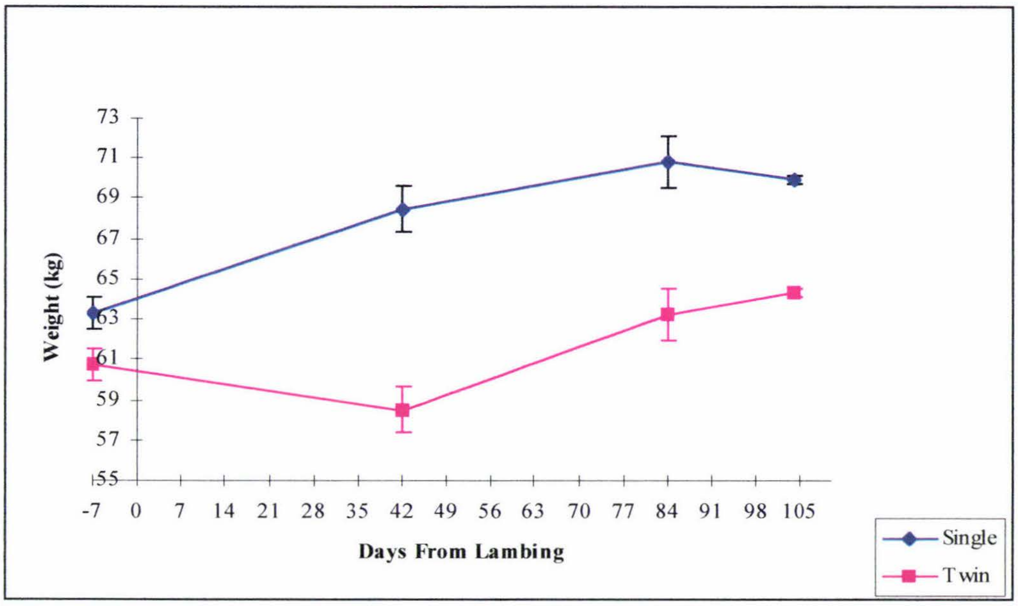
Table 2.12 - Fleece weights of the shorn ewes at both shearing dates.

Shearing Date	Single-Bearing	Twin-Bearing	Pooled SE
28 May 1997	3.8	3.7	0.1
30 October 1997	1.9[a]	1.3[b]	0.1

[a,b] Means within the same row with different superscripts are significantly different ($P<0.002$).

During lactation, single and twin- bearing ewes had a significantly different ($P=0.002$) pattern of weight gain (Figure 2.4). Single-bearing ewes steadily increased weight after lambing, while the twin-bearing ewes decreased in weight to 42 days after lambing before starting to increase weight. There were no other time or time*main effect interactions.

Figure 2.4 – Weight gain of single- and twin-bearing ewes during lactation.



Condition scores of the single-bearing ewes were 0.2 units higher (P<0.05) than the twin-bearing ewes at late gestation (Table 2.13) and 0.4 units higher (P<0.05) during lactation. Shearing had no significant effect on condition scores and there were no main treatment interactions. There were no time*main effect interactions.

Table 2.13 - Condition scores for the ewes in late pregnancy and lactation (Values are LS means).

Condition Score Date (Days from lambing)	Treatment		Litter Size		Pooled S.E.
	Shorn	Full-Fleece	Single-Bearing	Twin-Bearing	
1 August (-13)	2.77	2.73	2.85[a]	2.65[b]	0.06
24 September (42)	2.32	2.26	2.52[a]	2.07[b]	0.07
25 November (104)	2.49	2.46	2.69[a]	2.25[b]	0.10

[a,b] Means within the same row and main effect with different superscripts are significantly different (P<0.05).

Shorn single-bearing ewes had a mean gestation length of 148.4 days which was two days longer than for shorn twin-bearing ewes (P<0.10) and the full fleece twin-bearing ewes (P<0.06), (Table 2.14). Total litter weight was not significantly different between treatment groups but was highly significant (P<0.0001) between litter size with twin-bearing ewes having a mean total litter weight 3 kg heavier than the single-bearing ewes (Table 2.14).

Table 2.14 - Gestation length and litter weight of the ewes (Values are LS means).

Shearing Treatment	Litter Size	Gestation (Days)	Litter Weight (kg)
Shorn	Single	148.4^{a}	5.58^{a}
	Twin	146.3^{b}	8.38^{b}
Full Fleece	Single	$146.5^{a,b}$	4.73^{a}
	Twin	146.0^{b}	8.10^{b}
Pooled SE		0.4	0.23
P Values			
Shearing Treatment		0.07	0.10
Litter Size		0.03	0.0001
Interaction		0.16	0.40

[a,b] Means within the same column with different superscripts are significantly different ($P<0.05$).

Shorn single-bearing ewes had a 7% higher clean wool yield ($P<0.005$) and24 N/ktex stronger staple strength ($P<0.05$) when compared to the other groups (Table 2.15). Shorn ewes also had brighter wool than full fleece ewes (0.9 versus 3 - $P<0.0001$), but fibre diameter was not affected by litter size or treatment.

Table 2.15 - Wool sample results from shearing on 30 October, 1997.

Treatment	Litter Size	Clean Wool Yield (%)	Staple Strength (N/ktex)	Colour (y-z)	Fibre Diameter (µm)
Shorn	Single	85.7[a]	51.2[a]	0.90[a]	41.3
	Twin	78.4[b]	30.6[b]	0.89[a]	37.8
Full fleece	Single	79.3[b]	27.5[b]	2.96[b]	40.8
	Twin	77.5[b]	23.4[b]	3.09[b]	42.0
Pooled SE		0.9	3.5	0.31	0.9
P Values					
Treatment		0.005	0.003	0.0001	0.13
Litter Size		0.0008	0.02	0.89	0.34
Interaction		0.03	0.10	0.87	0.07

[a,b] Means within the same column with different superscripts are significantly different ($P<0.05$).

DISCUSSION

Shorn ewes were significantly heavier than full fleeced ewes at the end of the intake measurement period (41 days before lambing) but there was no significant difference in intake between the two groups to help account for this, although Figure 2.2 shows that after Intake Period 2, the shorn ewes had a slightly higher intake than the full fleece ewes. A larger group size may be necessary to show a difference since the variations are high. Husain *et al.* (1997) found no affect of shearing ewes in late gestation on food intake, even with different food availability, but the shorn ewes did not gain as much weight as full fleeced ewes. Morris and McCutcheon (1997) found no significant differences in ewe weights of those shorn at mid-gestation compared to full fleeced ewes. Dabiri *et al.* (1995*b*) also found live weights of pregnant ewes were unaffected by shearing treatment during pregnancy. Black and Chestnutt's (1990) study of shearing pregnant, housed ewes found that intake was more likely to increase with the earliness of the shearing. Intake response to shearing clearly depends on many factors e.g. at what stage of gestation shearing occurs, climatic factors, and food availability.

The intake fluctuations between intake periods (presumably caused by the paddocks the sheep were grazing) makes it difficult to draw any conclusions about intake patterns as the ewes approached lambing. This may be due to the ewes' utilisation of the paddock. Lynch *et al.* (1992) reported that sheep can use habitat patchily, even in relatively small (1 hectare) paddocks. The observation results suggest that the ewes utilised two-thirds of paddocks 1 and 2, but only half of paddocks 3 and 4. If the paddocks had been grazed during intake periods in pairs of 1 and 3, then 2 and 4, rather than 1 and 2, then 3 and 4, some of the intake variability may have been smoothed out. Also, observations were restricted to the morning, and grazing pattern could have changed as the day progressed. There was no evidence that shorn ewes actively sought shelter in the paddock. To the contrary, shorn ewes were more evenly distributed compared to full fleeced ewes in the week following shearing, and this was the only time there was a difference in paddock position between the two groups.

Shorn ewes behaved differently only in the week following shearing, indicating that they quickly acclimatised to the extra relative cold. In the week following shearing, shorn ewes spent as much time grazing as full fleeced ewes, but were less likely to be found lying down. Dabiri *et al.* (1995*b*) found that shorn ewes had a significantly lower rectal temperature than full fleece ewes, suggesting that the shorn ewes in the present study were better able to maintain body heat when standing and shivering, and not in direct bodily contact with the ground.

Suprisingly, single-bearing ewes ate more than twin-bearing ewes when averaged over all time periods. An explanation for this may be that the volume of the foetuses and uterine contents at mid-gestation limit the space in the gut of twin-bearing ewes. Space limitation due to the uterine contents explains the lower intake of twin-bearing ewes in late gestation, but it may also be a factor earlier in gestation. The twin-bearing ewes gained an average 0.7 kg between pre-mating (163 days prior to lambing) and pregnancy diagnosis (92 days before lambing), whereas single-bearing ewes lost an average of 1.0 kg in the same time period. The two condition scores at pregnancy diagnosis are not significantly different, so the greater weight-gain by twin-bearing ewes may result from the mass of the uterine contents.

However, twin-bearing ewes were significantly lighter than single-bearing ewes 7 days before lambing when their liveweight was adjusted by subtracting the combined litter weight. This allowed for the difference in uterine mass shown between single- and twin-bearing ewes. When weights remain unadjusted there is no significant difference in live weights between the two groups prior to lambing, and only at 13 days before lambing was the condition score of twin-bearing ewes significantly lower than that of single-bearing ewes.

Twin-bearing ewes were always significantly lighter and had lower condition scores than single-bearing ewes after lambing, indicating the extra investment the dams of twins had to put into milk production. Barnicoat *et al.* (1956) reported ewes with twin lambs secreting about one-third more milk than dams of singletons, and Gibb and Treacher (1979) supported this with their finding that dams of singletons secreted 138 kg over 12 weeks versus dams of twins secreting 186 kg on average over the same time period. Gibb and Treacher (1979) also found that the dams of singletons gained more weight than the dams of twins. Single lambs at birth weighed on average two-thirds less than average combined twin weights (a ratio of 100:150, single:twin) which compares favourably to the ratios reported by Hinch *et al.* (1983) of 100:147 and 100:158 for two flocks of Merino sheep. This, of course, means that individual twin lambs are lighter than single lambs at birth. Lamb birth weight may be influenced by gestation length, though only shorn, single-bearing ewes had a gestation length significantly longer than both twin-bearing groups. Full fleece, single-bearing ewes did not have a significantly different gestation length to any other group. Vipond *et al.* (1987) had a lamb birth weight increase of 0.93 kg and a 2.5 day increased gestation length when shearing ewes 12 weeks into gestation. The shorn, single-bearing ewes in the present study had lambs that were 0.85 kg heavier (though this was not significant) and an increased gestation length of 1.9 days over full fleece, single-bearing ewes.

Greasy wool weight of single-bearing ewes was higher than that of twin-bearing ewes, with the difference in fleece weight occurring in the second half of gestation and during lactation. This was not reflected in the clean wool percentage in the wool sample results. Only shorn single-bearing ewes had a significantly higher yield than the twin-bearing ewes from either treatment group. Staple strength for the shorn, single-bearing ewes was also higher than the other groups and these two results may indicate that the shorn, single-bearing ewes were under less stress than the other groups. There was, however, no difference in greasy wool production between the treatment groups indicating that there was no compensatory change in wool growth caused by relative cold exposure in the shorn group of ewes. This is in contrast to Dabiri *et al.* (1995*b*) who recorded greater mid-side wool growth in ewes that had been shorn, compared to ewes that had not. These authors proposed that this was a reflection of greater feed intake, even though the difference between groups was not significant.

In conclusion, shearing ewes at mid-gestation had no affect on feed intake and only a transient affect on behaviour. There were slight increases in litter birth weight and gestation length for shorn ewes compared to full fleece ewes, the most pronounced differences being between the single-bearing ewes. Twin-bearing ewes eat less during gestation and lose condition, taking longer to recover weight during lactation. Fleece growth of twin-bearing ewes also suffers during the later stages of pregnancy and lactation, indicating that twin lambs are more costly and require greater investment than singletons.

Chapter 3

The effect of shearing ewes at mid-gestation on the subsequent birth weights and growth rates of their lambs

INTRODUCTION

Many polygynous ungulates show sexual dimorphism at birth, for example *Ovis aries* (Everitt, 1964 and Morris *et al.*, 1993), *Ovis canadensis* (Hogg *et al.*, 1992), *Capra hircus* (Alley *et al.*, 1995) and *Rangifer tarandus* (Kojola, 1997). In all these species the adult male is larger than the female, and male offspring are usually heavier at birth than female offspring. The sex effect on birth weight can, however, be variable. For example, Robertson *et al.* (1992) found with Soay sheep that male lambs were heavier at birth than females only in good conditions, and male lambs born after a harsh winter tended to weigh less at birth than female lambs. Asofi (1984) found in domestic sheep that age could also affect birth weight. Male lambs were heavier than female lambs when they were born to two-year-old ewes, but there was no sex-related birth weight difference of lambs born to one-year-old ewes.

There are many environmental factors imposed on ewes that could potentially affect the birth weight of their lambs. Shearing ewes during pregnancy has led to heavier lambs at birth (Austin and Young, 1977; Vipond *et al.*, 1987; Black and Chestnutt, 1990). Morris and McCutcheon (1997), however, recorded an increased birth weight of twin, but not single lambs, after shearing the ewe at mid-gestation (day 70 of pregnancy).

There may be a trade-off between increased lamb birth weight caused by shearing at mid-gestation, and milk production, which would affect lamb growth rate. Shorn ewes may experience some stress from relatively more exposure to cold than full fleeced ewes, and this could affect their mothering ability. Festa-Bianchet (1988) showed that bighorn ewes under stress (high lungworm parasitism) spent less time suckling and were less likely to nuzzle their lambs. However, he was unable to determine a causal effect because the parasite load may have affected milk production or simply indicated ewes in poor condition.

Litter size also affects lamb birth weight. Twins tend to have a lower individual weight at birth than single lambs, and this can have significant negative consequences for survival (Hinch *et al.*, 1983; Asofi, 1984). Clutton-Brock *et al.* (1992) also found that lighter-than-average lambs of Soay sheep were less likely to survive. In the wild, Soay sheep twins were more common from ewes in heavier weight classes and older sheep were more likely to have twins (Clutton-Brock *et al.*, 1996). This agrees with maternal investment theory which predicts that animals should invest more in offspring at the end of their lifespan (Clutton-Brock, 1991). Domestic ewes carrying multiple lambs require a higher plane of nutrition than ewes carrying singletons (Sadlier, 1969). These studies indicate that ewes need to be in good condition to successfully rear twins and that in sheep twin lambs are significantly more energy-expensive than singletons.

The growth rates of twin lambs are also lower than those of single lambs (Barnicoat *et al.*, 1956; Doney, 1979; Gibb and Treacher, 1979; Robertson *et al.*, 1992), but ewes with twins produce more milk than ewes with single lambs (Barnicoat *et al.*, 1956; Gibb and Treacher, 1979). Rattray (1992) reports that the milk production of ewes with twin lambs is 20-50% more than that of ewes with singletons. However, this extra milk production is insufficient to allow each twin to ingest as much milk as a single lamb. As Doney (1979) stated, twins have a restricted milk intake.

Polygynous, sexually dimorphic species are more likely to show sex-biased investment in their offspring and there is evidence of preferential investment in males compared to females (Hogg *et al.*, 1992; Byers and Hogg, 1995; Bérubé *et al.*, 1996). Extra investment in males can be shown by sex differences in birth weights or postnatal growth rates (Byers and Moodie, 1990). Many ungulates are polygynous, but not all show sex-biased care (Byers and Moodie, 1990; Pélabon *et al.*, 1995). Byers and Moodie (1990) proposed that species that do not exhibit sex-biased care might already be investing at the highest possible level so that it is impossible for them to put extra investment into male offspring.

Since ewes with twin lambs are at a high level of investment, they may therefore be unable to preferentially invest in male lambs over female lambs. Ewes with single lambs may be more likely to show preferential investment, by males with higher birth weights or higher growth rates. In the following study, single- and twin-born lambs were weighed at birth and at regular intervals before weaning to determine growth rates. The following study tests the hypothesis of no difference in birth weight or growth rates between lambs born to full fleece ewes or ewes shorn mid-gestation, and also determines whether or not any difference is dependent on litter size or sex of the lamb.

METHODS

The sheep used and the mating procedures are described in Chapter 1 - Introduction and Methods.

Ewes were shepherded twice daily during lambing and lambs were weighed, sexed, tagged, identified to their dam, and the date of birth and litter size recorded. Lambs were then weighed at weekly intervals up until 6 weeks of age, and from that time until weaning (approximately 15 weeks) they were weighed at fortnightly intervals. At each weigh date percentage growth rate (%/day) and growth rate (kg/day) were calculated from the previous weight. Docking occurred at 3 weeks of age, and male lambs were castrated by rubber ring at this time. The mid-point of lambing was 14 August 1997 and the lambs were weaned on 25 November 1997.

On 25 November 1997 all lambs were shorn and fleece weights were recorded. The yield was determined by taking a mid-side sample of the fleece, which was weighed, washed, and reweighed. A clean wool percentage was then calculated, and fibre diameter was measured using an OFDA (Optical Fibre Diameter Analyser).

Statistical Analysis

All analyses were performed using SAS version 6.12 (SAS, 1996) after removal of all lambs that possibly had been mis-mothered. Twin lambs whose siblings died before weaning were also excluded from the analyses for 6 week weight, weaning weight, growth rates and wool weight. The number of lambs in each category is presented in Table 3.1.

Table 3.1 - Number of lambs in each category (by ewe treatment and litter size).

Ewe Treatment group	Litter Size	Number of Lambs in Category	Number of lambs in each Ewe Treatment group
Full fleeced	Single	10	
	Twin	8	18
Shorn	Single	8	
	Twin	8	16
All Ewes	Single	18	
	Twin	16	

Gestation length, birth weight, weight at 6 weeks of age and weaning weight were analysed by ANOVA, with birth weight as a covariate.

Analysis of variance and repeated measures analysis were performed on the lamb growth rates expressed on a 'absolute' and 'percent of body weight' basis. The sex of the lamb and age of the dam were assessed for significance in the model using the F-Test. These factors were not significant and were removed from the analyses. Litter size and shearing status of the dam were the main effects tested. Multiple comparisons were made using the Bonferroni procedure when interactions between the main effects were significant. Birth weight and gestation length were not significant covariates so were excluded from the statistical models.

RESULTS

Gestation Length

Litter size had no significant effect ($P>0.05$) on gestation length. Twins had a gestation length of 146.6 days while for singles it was 147.4 days with a pooled standard error of 0.49 days. Lambs from shorn ewes had a gestation period lasting one day longer ($P<0.05$) than lambs from full fleece ewes (147.5 versus 146.4 - standard error of 0.49). There were no significant interactions between the main effects.

Live Weights

Birth weight was affected by both shearing treatment and litter size (Figure 3.1), but there was no interaction between these effects. Twin lambs were born 1.0 kg lighter (4.09 versus 5.18 kg - standard error of 0.152 kg; P<0.0001) than single lambs. Lambs from shorn ewes were 0.6 kg heavier (4.99 versus 4.28 kg - standard error of 0.152 kg; P<0.01) than lambs born to full fleece ewes.

Figure 3.1 – Birth weight of lambs by shearing treatment of the dams (shorn at day 70 of gestation or full fleece) or by litter size (single or twin).

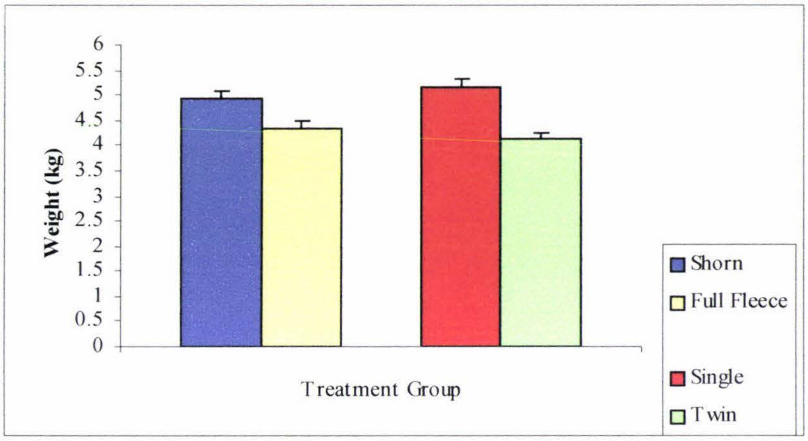
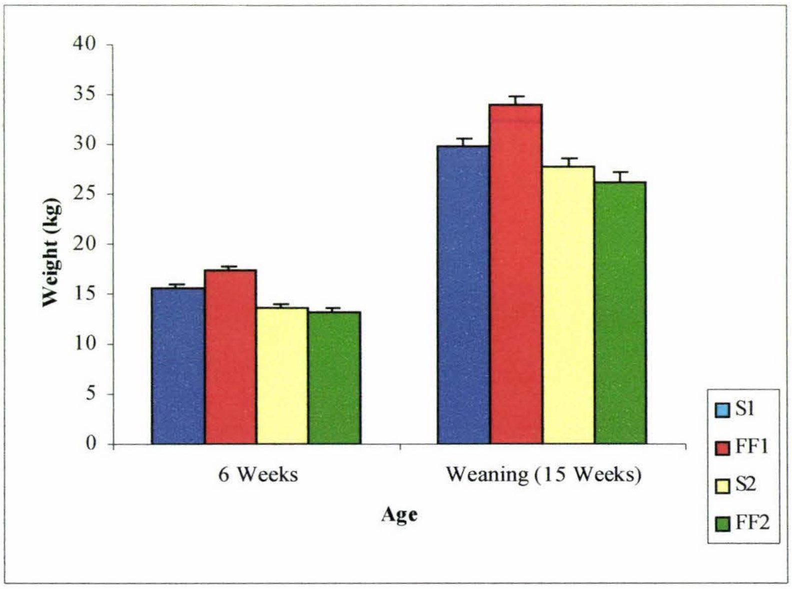


Figure 3.2 – Weights at six-weeks of age and at weaning, of single lambs with shorn dams (S1), single lambs with full fleece dams (FF1), twin lambs with shorn dams (S2) and twin lambs with full fleece dams (FF2).



Single lambs from full fleece dams were 2 kg heavier (17.4 versus 15.6 kg - standard error 0.37 kg; P<0.10) than single lambs from shorn dams, and 4 kg heavier (17.4 versus 13.2 and 13.7 kg - standard error 0.37 kg; P<0.0001) than either twin group (Figure 3.2). Single lambs from full fleece dams were 7 kg heavier (34.0 versus 26.3 and 27.8 kg - standard error 0.88 kg; P<0.002) than either twin groups at weaning (Figure 3.2).

Growth Rates

Growth rates of twin lambs were 0.10-0.13 kg per day (P<0.05) lower than the growth rates of single lambs from birth to three weeks of age. During the fourth week, growth rates were not significantly different, but from the fifth to the tenth week, the growth rates were 0.07-0.09 kg per day (P<0.05) lower for twin lambs compared to single lambs (Figure 3.3). Shearing treatment of the ewe did not affect the growth rate of lambs, and the only significant interaction between the main effects was found from week 10 to week 12 (Table 3.2). Single lambs from shorn dams grew 0.10 kg less per day than the single lambs from full fleece dams.

Figure 3.3 – Growth rates (kg/day) of single and twin lambs from birth until weaning (15 weeks of age).

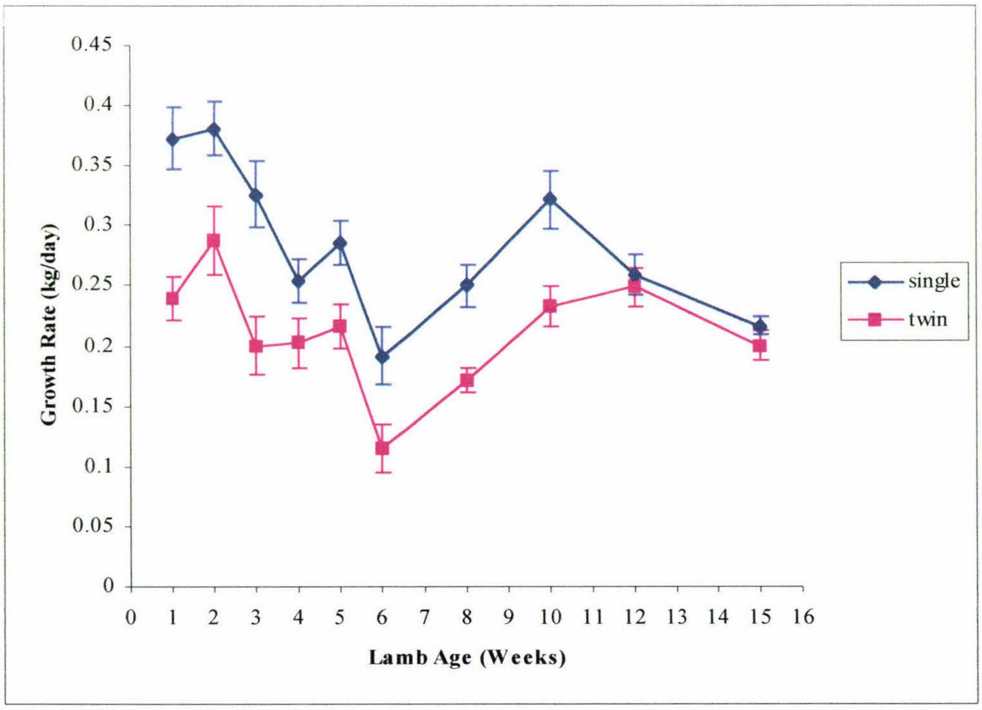


Table 3.2 - Growth rates of single and twin lambs from shorn and full fleece dams at 10 to 12 weeks of age (Values are LS means).

Shearing Treatment	Litter Size	Growth Rate (kg/d)
Shorn	Single	0.204^{a}
	Twin	$0.261^{a,b}$
Full Fleece	Single	0.303^{b}
	Twin	$0.236^{a,b}$
Pooled SE		0.014
P Values		
Shearing Treatment		0.08
Litter Size		0.80
Interaction		0.004

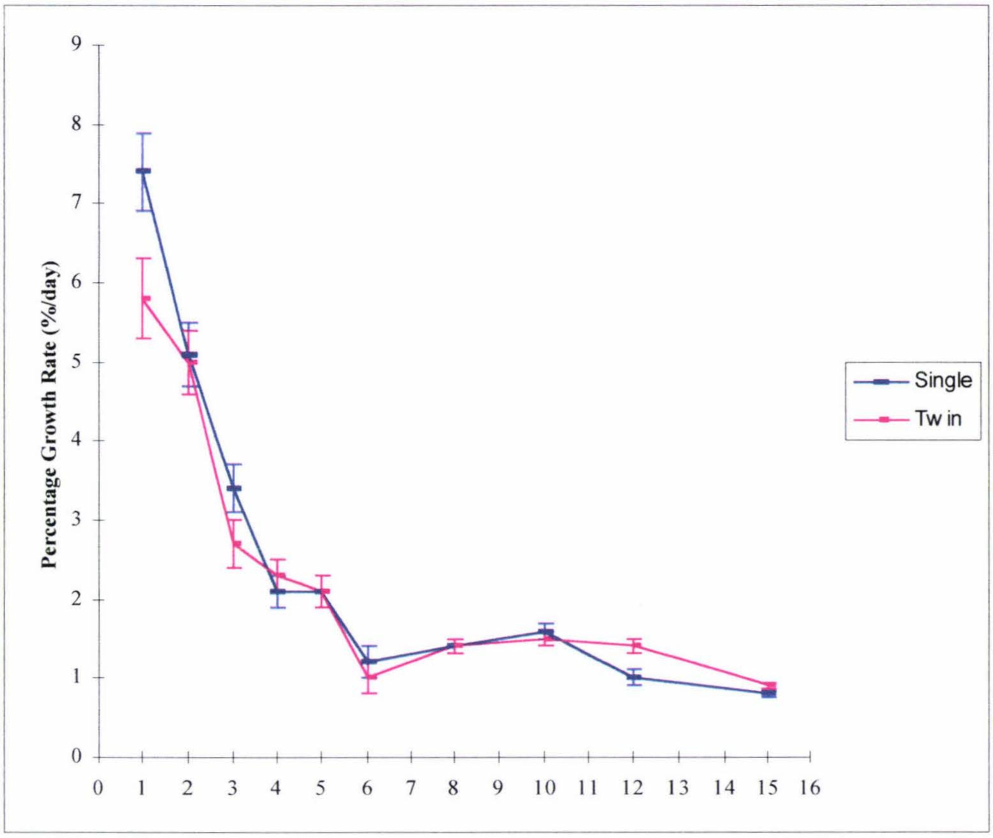
^{a,b} Values with different superscripts are significantly different (P<0.05).

Growth rate declined (P<0.0001) from birth to 6 weeks, then increased from 6-10 weeks (Figure 3.3). The interaction between age and litter size was significant (P<0.007) with the single lambs showing a different pattern of change in growth rates over time compared to the twin lambs (Figure 3.3). The age*shearing treatment interaction and the age*litter size*shearing treatment interaction were not significant.

Percentage Growth Rates

Percentage growth rates (i.e. growth rate expressed as a percentage of body weight gained per day) of twin lambs were 1.6%/day lower (5.80 versus 7.42 %/day, standard error 0.495 %/day; P<0.05) than single lambs during the first week (Figure 3.5). From week 2 to week 10 there was no significant difference in percentage growth rates of singleton and twin lambs. From week 10 until week 12 twin lambs grew 0.34%/day (1.37 versus 1.03 %/day, standard error 0.069 %/day; P<0.001) more than single lambs, and from week 12 to weaning at week 15 twin lambs grew 0.16%/day (0.91 versus 0.75 %/day, standard error 0.038 %/day; P<0.01) more than singleton lambs (Figure 3.4). Shearing treatment of the ewe did not affect the percentage growth rates of the lambs, and there were no significant interactions between the main effects.

Figure 3.4 – Percentage growth rates (%/day) of single and twin lambs from birth until weaning (15 weeks of age).



Lamb age had a highly significant (P<0.0001) effect on percentage growth rates across all groups (Figure 3.5). Percentage growth rates declined from week 1 to week 6 remaining steady from week 6 until weaning. The age*litter size, age*shearing treatment and the age*litter size*shearing treatment interactions were not significant.

Wool

Single lambs from full fleece dams had on average a fleece 0.4 kg heavier than twins from either shearing group (P<0.02; Table 3.3). Single lambs from shorn dams were not significantly different from any of the other groups (Table 3.3). There were no significant differences in clean wool percentage of fibre diameter between shearing treatment groups, or litter size.

Table 3.3 - The fleece weight of single and twin lambs from shorn and full fleece dams (Values and LS means).

Shearing Treatment	Litter Size	Fleece Weight (kg)
Shorn	Single	1.24[a,b]
	Twin	1.12[a]
Full Fleece	Single	1.49[b]
	Twin	0.99[a]
Pooled SE		0.05
P Values		
Shearing Treatment		0.41
Litter Size		0.0002
Interaction		0.02

[a,b] Values with different superscripts are significantly different ($P<0.01$).

DISCUSSION

The increased gestation length of shorn ewes , compared to the full fleece ewes probably accounts for some, if not all, of the difference in birth weight. Vipond *et al.* (1987) found that shearing pregnant ewes increased gestation length and lamb birth weight, and Thompson *et al.* (1982) showed that exposing ewes to constant cold for the last 5-6 weeks of gestation led to longer gestation periods and increased birth weight. In their study of pronghorns (*Antilocapra americana*) Byers and Hogg (1995) found that gestation length increased in a dry year, but birth weights remained the same when compared to a wet year. A low plane of nutrition during pregnancy can also lead to an increase in the gestation period (Sadlier, 1969).

Single lambs from full fleeced ewes were the heaviest of the four groups at 6 weeks of age and heavier than the two twin groups at weaning. This may indicate some trade-off between the increased birth weight and milk production for ewes which were not in good condition at mating. Shearing treatment had no affect on the twin groups, but ewes were presumably in better condition at mating to conceive twins (Allison and Kelly, 1978; Morley *et al.*, 1978). Shearing single-bearing ewes at mid-gestation may have created a trade-off in milk production because single lambs from shorn ewes failed to achieve the same increase in weight compared to twins as the single lambs from full fleeced ewes. Penning and Gibb (1979) showed that milk intake (and presumably production) was positively correlated with lamb growth rate, and Barnicoat *et al.* (1956) reported that the correlation between milk yield and live weight gains of the lambs were highest during the first 6 weeks.

The difference in live weights between the lamb groups is reflected in the difference in growth rates. Twin lambs had lower growth rates than single lambs but the difference lessened between 5 and 10 weeks of age. The drop in growth rate until 6 weeks of age may have been caused by the stress of docking at three weeks. Peak growth appears to have occurred at two weeks of age, which agrees with Spedding, (1970), and Gibb and Treacher, (1982), but Asofi (1984) found highest milk yields occurred in the first three weeks. According to Hinch (1989), frequency and duration of suckling declines with age of the lamb. The increase in growth rates from 6-12 weeks may therefore indicate more grazing and better efficiency at digesting grass.

Percentage growth rates indicate that the difference in growth between the twin and single lambs is not entirely due to differences in weights. This implies that twin lambs are not growing at their full potential, which agrees with Hinch (1989), who calculated a 0.45 litre/day deficit in milk available compared to demand for twin lambs at three weeks of age. The higher percentage growth rates of twin lambs in late lactation suggests that the dams suckled the lambs more, with slower declining milk yield that may have delayed weaning, compared to dams of single lambs.

Lamb fleece weights showed the same pattern as the growth rates. Single lambs from full fleece ewes had heavier fleeces than twin lambs, and single lambs from shorn ewes were not significantly different from either twin lambs or singletons from full fleece ewes. Fleece weight appears to be directly related to nutrition as indicated by growth rates.

Surprisingly, sex had no effect on either weight or growth rate of lambs. The lack of difference in birth weight between the sexes may be the result of ewes being fed less in late pregnancy. Their intake was reduced because of concerns about single foetuses becoming so large that there could be an increased incidence of dystocia. However, Rattray (1992) reports that a sudden restriction in intake in late pregnancy should be avoided, as it can result in a sharp drop or cessation of foetal growth rate. This compares to Byers and Hogg's (1995) findings that animals at maximum investment are unable to show sex-biased investment. Byers and Hogg were comparing pronghorn antelope and bighorn sheep but the theory may be applicable to different individuals within a species. It would explain why young ewes (one-year-old) show no sex differences in birth weights, while two-year-old ewes have male lambs that are born heavier than female lambs (Asofi, 1984). Any sex difference in growth rates may reflect the difference in birth weight. Barnicoat *et al.* (1956) found that differences in weight gain disappeared when the effect of initial weight was removed from the model.

In conclusion, shearing ewes in mid-gestation led to higher lamb birth weights, probably because gestation was prolonged. This did not result in any trade-off in growth rate for twin lambs but did cause a slight decrease in growth for single lambs from shorn dams. Overall, shearing in mid-gestation may be a useful tool for increasing survival of lambs at birth, since survival is positively correlated with birth weight (Hinch *et al.*, 1983; Asofi, 1984). No firm conclusions can be drawn from this study about the effect of sex on birth weights and growth rates, or about the interaction of sex of lamb and shearing treatment of the dam.

Chapter 4

Milk intake by mixed-sex twin lambs

INTRODUCTION

Polygynous, sexually dimorphic species show sex-biased investment in their offspring and there is evidence of preferential investment by pregnant and lactating females in male offspring compared to female offspring (Byers and Hogg, 1995, Hogg *et al.*, 1992 and Bérubé *et al.*, 1996). Because adult body size is thought to be related to birth weight and postnatal maternal investment (Clutton-Brock *et al.,* 1992), it could be expected that males from a sexually dimorphic, polygynous species would benefit more from higher maternal investment since reproductive success is often dependent on size (Clutton-Brock, 1991). In females, however, size is less important for reproductive success (Clutton-Brock, 1991). Although many ungulates are polygynous, but not all show sex-biased care (Byers and Moodie, 1990; Pélabon *et al.*, 1995). Byers and Moodie (1990) proposed that species in which differential investment was not evident may already be investing at the maximum level, so it is impossible for them to invest further in sons. Byers and Moodie (1990) suggest that extra investment in males can be shown by sex differences in birth weights, postnatal growth weights and milk intake; and by reduced fecundity of females which raise males versus females (i.e. females raising sons may not conceive the following season, or show reduced fecundity).

In pronghorns (*Antilocarpa americana*), known to have a very high level of reproductive effort among ungulates (Byers and Moodie, 1990), there was no differential investment between male and female offspring. When comparing other ungulates, Byers and Moodie (1990) found that the degree of sexual dimorphism was a poor predictor of differential investment, i.e., species in which the male was much larger than the female did not necessarily show differential investment in male offspring. Instead, the ratio of offspring birth weight:maternal weight, and the ratio of offspring growth rate:maternal weight, were better predictors. Byers and Moodie (1990) found that growth rate of the offspring was the best easily-available index of maternal investment and proposed that species apparently at their maximum reproductive limit are unable to further invest selectively in males.

Pélabon *et al.* (1995) suggested that there was no trade-off between maternal expenditure and sex-biased care. They used birth weight of the offspring as a measure of maternal expenditure during pregnancy, and weaning weight as an estimation of post-natal maternal care. In polygynous ungulates there was no evidence of a trade-off between post- and pre-natal expenditure. Sexual dimorphism in neonatal weight decreased when conditions became harsh, mainly because the male lambs dropped in weight. Pélabon *et al.* (1995) extra investment in male offspring by dams occurs only if it leads to an increase in the fitness of male offspring compared to female offspring receiving the same extra investment. Environmental conditions and relative effects of maternal care on male and female lifetime reproductive success therefore appear to be the best predictors of sex-biased care (Pélabon *et al.*, 1995).

In sheep, sexually-biased maternal investment can be compared between mixed-sex twins. Once twin lambs are over two weeks of age, ewes are unlikely to suckle only one member of a twin pair (Ewbank, 1964; Ewbank, 1967; Hinch, 1989). Alley *et al.* (1995) also observed that mixed-sex kid twins born to feral goats (*Capra hirca*) suckled at the same time and had similar time budgets. If male lambs show greater growth rates than their female siblings it may be due to a number of factors. For instance, the male may manage to obtain more suckles than the female; the male may be able to suck more milk in the same time as the female; the dam may let down more milk to the side suckled by the male; or the male may graze more, or sooner, or be more efficient at converting food to bodily tissues.

In the following study of mixed-sex twin lambs, weight gains and estimated milk intake were monitored to determine the extent of differential investment between the male and female offspring. Here it is assumed that in mixed-sex twin pairs weighed directly before and after suckling, relative changes in body weight would indicate whether males obtain more milk than their female sibling in the same suckling bout.

METHODS

The sheep used and their mating procedures are described in Chapter 1 - Introduction and Methods.

A sample of twin lambs and their dams (6 ewes in total) were brought indoors shortly after birth. The lambs were kept indoors with their dams until weaning and were raised on sheep pellets (12.5% crude protein, 5% fat, 9%fibre and 1.5% salt). Initially, the sheep were kept in pens holding two family groups, i.e. two ewes and four lambs, but at approximately 6 weeks of age the lambs and ewes were moved to much larger pens and kept together in larger groups. There was also a group of ewes with lambs that had been indoors for several weeks before lambing and had lambed indoors. These ewes had been mated with the original flock but were not used in the intake or observation part of the trial. They were penned in the same way as the lambs born outdoors. Lambs were weighed weekly up to 6 weeks of age, and from that time until weaning (approximately 9 weeks) they were weighed fortnightly. At three weeks of age, all lambs were docked and the males fitted with rubber castrator rings.

Measurements of four sets of mixed-sex twins were carried out at approximately four weeks of age. Two sets of twins were with ewes that had lambed outdoors. One ewe was from the shorn group and the other ewe from the full fleeced group. These two ewes and their lambs were penned together. The other sets of twins were with ewes that had lambed indoors. One ewe was from the shorn group and the other ewe was from the full fleeced group. They were also penned together.

On three occasions (9 September, 12 September and 15 September, 1997) lambs were weighed (±50g) before and after sucking to determine whether one twin imbibed more than the other during the same suckle event. These lambs were separated from their mothers for two hours prior to the 'measured suck' to stimulate a sucking response. Twins were weighed immediately prior to their return to the dam, and again after they had finished sucking. The lambs were observed carefully throughout to ensure they did not urinate or defecate between weighings, so that any weight change could be attributed to the milk taken in. Twin pairs were reunited with their dams at the same time. For each lamb the time spent sucking was measured, and the teat it used was noted. A barrier was employed during the measurements to prevent direct interference between the ewes.

Statistical Analysis

Growth rate (kg/day) and percentage growth rate (%/day) were calculated from the lambs' weights at 3 weeks and 5 weeks of age. This gave an average growth rate for the period during which milk intake measurements were recorded. Birth weight, growth rate, and percentage growth rate were log normally distributed. The data were converted to a log scale and analysed using ANOVA in SAS version 6.12 (SAS, 1996). Multiple comparisons were analysed using the Bonferroni procedure. The data were analysed with respect to the sex of the lamb and shearing treatment of the dam.

Milk intake data collected over three days of measurement were combined for analysis. The total time each individual spent sucking over the three samples and the total weight gained from the three samples, was calculated to give total time spent sucking and an estimation of total milk intake. Any negative weight gain was assumed to indicate zero milk intake and was changed to zero (one value). Both the time spent sucking and the weight gained during sucking were normally distributed. Results were analysed using MS Excel statistics paired students T-test.

RESULTS

Birth weight did not differ significantly between male and female lambs or between lambs with shorn dams compared to ewes with full fleece dams (Table 4.1). The growth rate and percentage growth rate of the lambs did not differ between the sexes or between the shearing treatment of the ewes (Table 4.1). There were no significant interactions between the sex of the lamb and shearing treatment of the dam.

Table 4.1 - Birth weight and growth rates of male and female mixed-sex twin lambs with shorn and full fleece dams.

	Sex of Lamb		Treatment of Dam		
	Male	Female	Shorn	Full Fleece	Pooled SE
Birth Weight	4.78	4.25	4.68	4.35	0.35
Growth Rate (kg/d)	0.212	0.204	0.173	0.242	0.042
Percentage Growth Rate (%/d)	2.54	2.69	2.26	2.97	0.38

The time spent suckling and the total milk intake (weight gain of the lambs) did not vary significantly between male and female lambs (Table 4.2).

Table 4.2 - Total time spent suckling and total milk intake of female and male mixed-sex twin lambs.

Sex	Time Spent Suckling (secs)	Total Milk Intake (kg)
Female	235±33.5	0.338±0.080
Male	239±46.5	0.413±0.043
P-Value	0.474	0.512

The correlation between suckling time and milk intake was significant for female lambs ($P<0.05$, Figure 4.1), but not for male lambs (Figure 4.2) or for the combined sexes (Figure 4.3).

Figure 4.1 - Time spent suckling versus milk intake by female lambs.

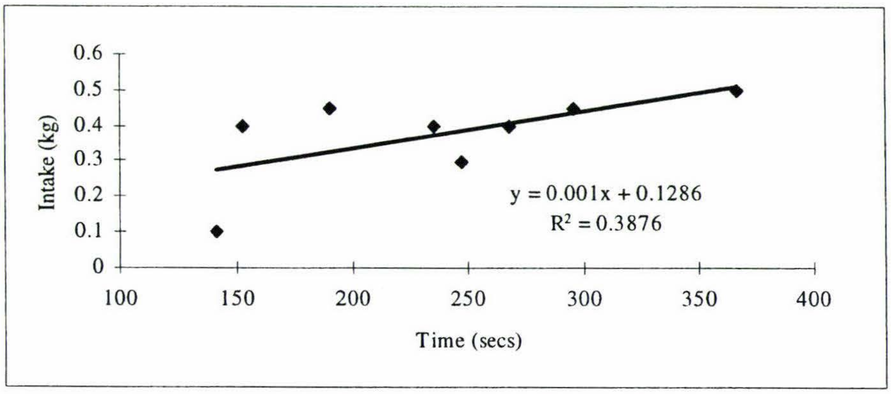


Figure 4.2 - Time spent suckling versus milk intake by male lambs.

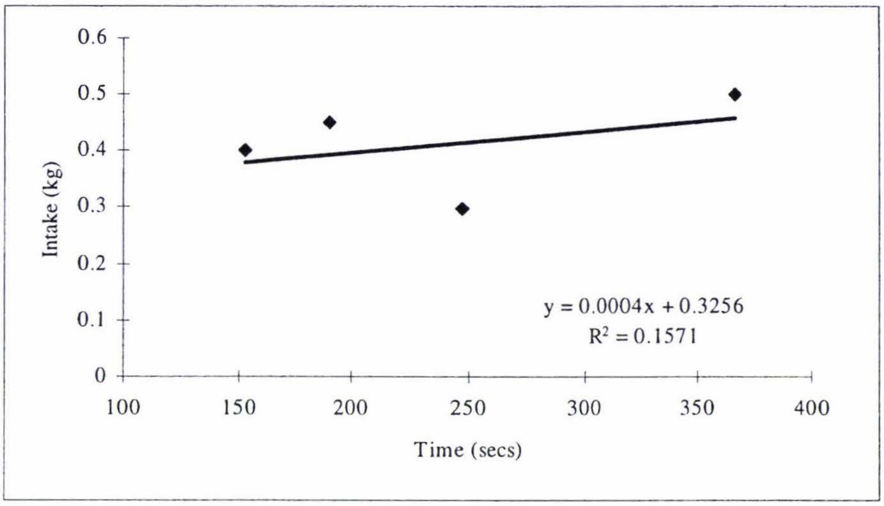
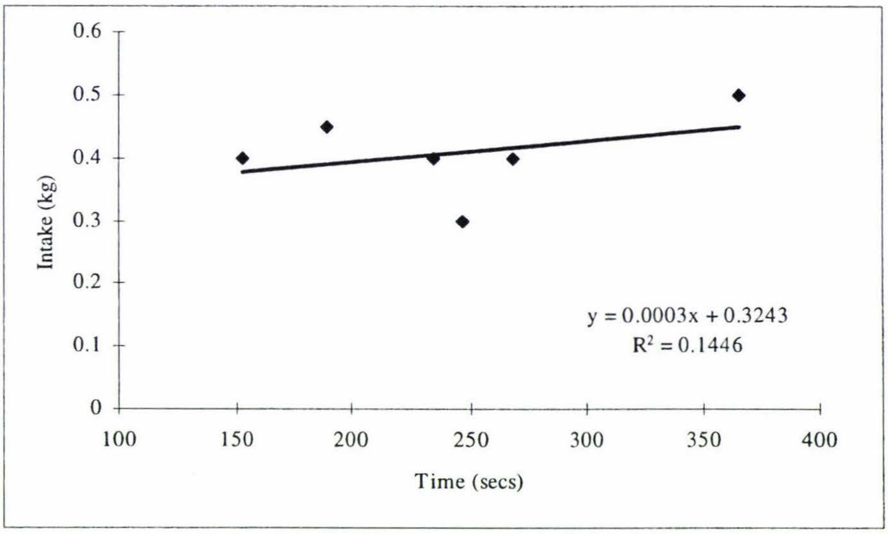


Figure 4.3 - Time spent suckling versus milk intake by all lambs.



DISCUSSION

The lack of a sex difference in birth weights or growth rates of the lambs (Table 4.1) was not anticipated. It suggests there is no sex-biased maternal investment in sheep. Male lambs did, however, tend to be heavier at birth than their female siblings and a larger data set may be required to detect significant differences in birth weight between the sexes. Sheep are recognised as being sexually dimorphic and Glücksmann (1981) reported an adult weight ratio of male/female as 1.16 and noted that the male lamb is usually the larger, with a higher growth rate than the female. Asofi (1984) found that male lambs born to two-year-old ewes were heavier at birth than females. Similarly, Burfening (1972) stated that males are born heavier than females and the greatest differences are between mixed-sex twins. However, Robertson *et al* (1992), found no differences in growth rates of male and female lambs of wild Soay sheep despite marked dimorphism in the adults.

The significant correlation between time spent sucking and milk intake for female lambs (Figure 4.1) may have been affected by the very low milk intake of one lamb. With the removal of that individual, the correlation is no longer significant. This lamb may have been an ineffectual sucker, but it and its sibling had a low percentage growth rate, indicating that neither lamb may have been receiving much milk. Time spent suckling may not be a very good indicator of milk intake. Cameron (1998) performed a meta-analysis on studies that have correlated measures of time spent suckling with milk intake estimates based on weight gain, and this revealed only a weak positive relationship. Hinch (1989) also reports no consistent relationship between weight gain and suckling frequency, lambs with low growth rates had either very high or very low sucking frequency.

Overall, the results are inconclusive for determining whether or not male lambs are able to receive more milk than female lambs. The method followed allowed both lambs to empty the udder, effectively blurring any difference in the intensity of sucking. A much larger number of lambs would need to be used, and a better method might be to leave the lambs suckling for a length of time that does not allow either lamb to fully deplete the udder, and then weigh them. This should indicate whether or not male lambs can drink more than female lambs in the same time period.

Chapter 5

General Discussion

This study examined the effect in reproduction and performance of subjecting pregnant ewes to a significant challenge mid-gestation. Shearing the ewes at mid-gestation presented that challeng, but did not affect their feed intake and had an only transient affect on behaviour. The shorn ewes acclimatised rapidly and no behavioural differences were detectable one week after shearing. Shearing led to an increase in ewe weight at the end of the intake period (41 days before lambing), and an increase in lamb birth weight, regardless of litter size.

An increase in gestation length probably accounts for the increase in lamb birth weight. Vipond *et al.* (1987) reported that shearing ewes during gestation led to longer gestation periods and similar challenges also led to an increase in gestation. Thompson *et al.* (1982) exposed ewes to constant cold for the last 5-6 weeks of gestation and reported both increased gestation and lamb birth weights.

Shearing ewes at mid-gestation may affect the development of the placenta. Placental development is normally completed by day 100 of gestation (Rattray, 1992), so relative cold exposure caused by shearing at day 70 of gestation may affect placental development. Jenkinson, *et al.* (1994) found that ewes that were mated in December (so that the placenta is developed through the warmest months) had significantly lighter foetuses, fewer placentomes and reduced carbuncle occupancy, than ewes mated in March. The ewes were fed similar quality pasture and maintained at similar weights so that the seasonal effect on the placenta and foetal weights could not be attributed to seasonal differences in pasture quality.

Thompson *et al.* (1982) exposed pregnant sheep to acute cold for two hours and found blood glucose levels increased both in the ewe and the foetus. Cold exposure also increased the concentration of non-esterfied fatty acids and glycerol in the maternal blood. Thompson *et al.* (1982) considered that additional glucose caused by cold exposure crossed the placenta. This would raise levels of glucose and insulin in the foetus and this, in turn, could change the partitioning of nutrients in favour of the foetus, leading to an increase in lamb birth weight.

In the present study, there was no evidence of sex-biased maternal investment. There was no significant difference in birth weight, growth rate, or percentage growth rate between female and male lambs. When milk intake experiments were conducted, there was no difference in milk consumed or time spent suckling between male and female twin pairs. However, this may partly reflect the small data set, since the male lambs were heavier than their female siblings and did imbibe more milk during the experiments, although the difference was not significant. The sheep in this study may have been at their maximum investment, therefore limiting their ability to differentially invest in males, because their intake was limited at late-gestation. Soay sheep in a harsh year show no sex-biased investment in males (Robertson *et al.*, 1992) and Asofi (1984) found a sex difference in lamb birth weights only in two-year-old ewes, not in young (one-year-old) ewes.

Litter size has a strong effect on the ewe, with twins clearly more costly to raise. Twin-bearing ewes were significantly lighter during late-gestation and lactation, had significantly lower condition scores for the same time period, and took longer to recover weight during lactation, when compared to single-bearing ewes. Wool growth also suffered for twin-bearing ewes, compared to single-bearing ewes.

Twin lambs were born lighter and grew slower than single lambs. This is probably due to limitations in milk production, restricting twin lamb growth rates. Penning and Gibb (1979) showed that milk intake by lambs was positively correlated with their growth rate, and Spedding (1970) states that twin-born lambs reared as singletons had a growth rate and growth pattern similar to single-born lambs.

There may have been a trade-off in milk production and foetal growth for shorn, single-bearing ewes. Single lambs from full fleeced ewes had significantly higher growth rates than single lambs from shorn ewes. This difference was not reflected in the twin-bearing groups; there were no significant differences in liveweights, growth rates or percentage growth rates between shorn and full fleeced twin-bearing ewes.

Domestic sheep are useful subjects for maternal investment studies. The sheep are maintained in good health, age is known, gestation length can be accurately determined, and oestrus can be managed, so that all the ewes ovulate and lamb very close together, thus reducing birth date variability. It is easy to weigh sheep and lambs in a farm situation, so accurate growth rates can be calculated.

In conclusion, the birth weight increase of lambs from shorn ewes, compared to full fleece ewes, is unlikely to be due to a behavioural response. It is likely that physiological responses underlie the increase in birth weight. Shearing ewes at mid-gestation may be useful for increasing lamb survival at birth, since survival is positively correlated with birth weight (Hinch *et al.*, 1983; Asofi, 1984). The results from this study are inconclusive for determining if there is sex-biased investment in male lambs, however, as indicated by birth weight, growth rates and milk intake.

Future studies would require more careful pasture management through the ewes' entire gestation to avoid undesirable, sudden reductions in food availability (and intake) which might adversely affect the growth of the foetuses. Ewes could either kept at a high level of food offered, or food availability could be lessened gradually. Paddocks would have to be carefully selected to avoid the erratic intake response in the present study, which made it impossible to draw any conclusions about intake change as gestation progressed. If larger numbers of ewes were used, it would be possible to analyse the effects of mid-gestation shearing of ewes on survival of lambs.

A birth weight difference between male and female lambs is more likely if the dams have not had a sudden restriction in food intake in late-gestation. Repeating the milk intake experiments with larger numbers of mixed-sex twin pairs may show a difference in investment between male and female lambs. It would be preferable to remove the lambs from the dam after a set time (one minute, for example) to calculate milk intake by weight. The lambs used would have to be weighed regularly leading up to the experimental phase to determine if one sex was growing faster (therefore receiving more milk) than the other. This method should show if one sex was receiving more milk than the other and the extent of the advantage to the lamb.

Appendices

Appendix 1 - Total numbers of ewes in the different treatments grazing, standing or lying for each grazing period.

Grazing Period	Behaviour	Shorn	Full Fleece	Single-Bearing	Twin-Bearing
1	grazing	18	12	13	17
	standing	12	13	10	15
	lying	10	15	17	8
2	grazing	32	32	31	33
	standing	14	6	11	9
	lying	4	12	8	8
3	grazing	42	33	41	34
	standing	16	13	14	15
	lying	2	14	5	11
4	grazing	20	17	18	19
	standing	2	5	5	2
	lying	8	8	7	9
5	grazing	8	7	7	8
	standing	0	0	0	0
	lying	2	3	3	2
6	grazing	8	6	8	6
	standing	0	4	1	3
	lying	2	0	1	1
7	grazing	5	6	3	8
	standing	0	0	0	0
	lying	5	4	7	2
8	grazing	4	5	3	4
	standing	0	0	0	0
	lying	8	5	7	6

Appendix 2 - Total number of ewes in each row during each grazing period.

Grazing Period	Row	Shorn	Full Fleece	Single-Bearing	Twin-Bearing	All Ewes
1	1	12	15	14	13	27
	2	19	18	18	19	37
	3	9	7	8	8	16
2	1	12	5	8	9	17
	2	12	6	9	9	18
	3	13	20	15	18	33
	4	13	19	18	14	32
3	1	8	13	10	11	21
	2	29	31	34	26	60
	3	23	16	16	23	39
	4	0	0	0	0	0
4	1	15	12	14	13	27
	2	9	13	11	11	22
	3	6	5	5	6	11
	4	0	0	0	0	0
5	1	7	5	4	8	12
	2	1	5	5	1	6
	3	2	0	1	1	2
6	1	4	2	2	4	6
	2	3	6	5	4	9
	3	3	2	3	2	5
	4	0	0	0	0	0
7	1	7	9	8	8	16
	2	3	1	2	2	4
	3	0	0	0	0	0
8	1	7	1	4	4	8
	2	1	5	2	4	6
	3	2	4	4	2	6

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