# The effect of mid-pregnancy shearing on lamb birthweight and survival to weaning

A thesis presented in partial fulfillment of the requirements of the degree of Doctor of Philosophy in Animal Science at Massey University, Palmerston North, New Zealand.

Paul Richard Kenyon

2002

# Abstract

Mid-pregnancy shearing has been promoted in New Zealand as a technique to improve both lamb birthweights and survival. In the literature mid-pregnancy shearing has resulted in an increase lamb birthweight. However, the results have been inconsistent in magnitude and birthrank specificity. Additionally the mechanism responsible for the birthweight response has not been identified. The objectives of this study were to: ascertain the causes of the variation in the birthweight response to mid-pregnancy shearing, identify a possible metabolic mechanism for the birthweight response and lastly, to examine the effect of mid-pregnancy shearing on the newborn lamb's thermoregulatory capability and survival rate to weaning.

The first study was designed to determine whether dam nutrition during the mid- to late- pregnancy period influenced the birthweight response to mid-pregnancy shearing. Mid-pregnancy shearing was found to significantly ($P<0.05$) increase lamb birthweight without differently affecting the birthweights single- or twin-born lambs. Dam feeding level post-shearing had no effect on the birthweight response. The newborn lamb's thermoregulatory capability was not affected by dam shearing treatment. When the results of this study were compiled with those of previous pregnancy shearing studies it was concluded that the birthweight response is greatest under conditions in which the unshorn ewe gives birth to a lamb(s) of low birthweight.

The second study was designed to examine the birthweight response to mid-pregnancy shearing under two differing maternal treatments (one designed to restrict foetal growth (low group), the other designed not to limit foetal growth (maintenance group)) allowing the conclusion made in Chapter 2 to be tested. Mid-pregnancy shearing was found to increase the birthweights of singletons ($P<0.05$) but not twins, and of lambs born to maintenance ($P<0.05$) but not low group ewes. Additionally, mid-pregnancy shearing had no effect on the thermoregulatory capacity of twin-born lambs. When the results of this study were considered with previous studies it became apparent that there are two criteria (not one) that must be met to achieve a birthweight response to mid-pregnancy shearing. First, the dam must have the potential to respond (i.e. give birth to an otherwise lightweight lamb(s)) and, second, she must have the means to respond (i.e. an adequate level of maternal reserves and/or level of nutrition to partition towards additional foetal growth).

The large-scale study was designed to investigate the effect of a mid-pregnancy shearing on lamb birthweights and survival rates to weaning under commercial conditions on two different farms. Mid-pregnancy shearing was found to significantly increase ($P<0.05$) the birthweights of twin-born lambs at each site and this tended to increase survival rates. However, at Tuapaka singletons born to shorn dams had significantly ($P<0.05$) lower survival rates than their counterparts born to unshorn dams. These findings indicate that under commercial conditions mid-pregnancy has the potential to increase the birthweight of at least twin born lambs. However, for this increase in birthweight to have any effect on survival rates to weaning, birthweights must otherwise be destined to be low and within a birthweight range in which survival rates to weaning are not optimal.

The final study examined a possible metabolic mechanism for the birthweight response to mid-pregnancy shearing. Twin bearing ewes were either; left unshorn or shorn during mid-pregnancy, and either had T3/T4 concentrations similar to that observed in the pregnant unshorn ewe or were subjected to elevated T3/T4 concentrations in the short to medium term post mid-pregnancy shearing (as previously reported in mid-pregnancy shorn ewes). Neither shearing nor T3/T4 treatment affected lamb birthweight or summit metabolism. Lamb birthweights in all groups were relatively high and as such a birthweight response to mid-pregnancy shearing was not expected. To successfully determine if elevated maternal thyroid hormones are the mechanism responsible for the birthweight effect, conditions must be present that would otherwise result in a birthweight response to mid-pregnancy shearing.

The present series of studies demonstrate that mid-pregnancy shearing is a technique that can be used commercially to increase lamb birthweights, but appears to have no effect on the newborn lamb's thermoregulatory capability. It is hypothesised that an elevation in maternal thyroid hormone concentration post-shearing is the mechanism responsible for the birthweight response but this requires further study. It has been shown that to achieve a birthweight response to mid-pregnancy shearing the ewe must meet two criteria, first; she must have the potential to respond (i.e. be destined to give birth to an otherwise lightweight lamb(s)) and second; she must have the means to respond (i.e. an adequate level of condition and/or nutrition). To increase lamb survival rates to weaning via an increase in birthweight alone, lambs must otherwise be destined to be born of a birthweight in which survival rates to weaning are below optimum.

Acknowledgements

This thesis was expertly supervised by Associate Professor Stephen Morris, Professor Stuart McCutcheon, Dr Dean Revell and Associate Professor Tim Parkinson. I would like to thank them all for their patients, guidance, continual support and prompt and constructive marking of manuscripts. I would especially like to thank Associate Professor Stephen Morris for successfully managing the role of supervisor, boss and colleague and Professor Stuart McCutcheon for never failing to have time to spend on this thesis in his very busy schedule.

I would also like to thank the technical support given by Dean Burnham, Geoff Purchas and Dr Phil Pearce. Many others also contributed on a part time basis during the many hours of trial work. My appreciation also goes to the managers and farm staff of the farms in which these trials were conducted.

My Gratitude is extended to my co-workers whose encouragement and advise for both the thesis and my lecturing obligations made life very much easier than it could have been.

I would like to acknowledge Woolpro, Meat New Zealand, the C. Alma Baker Trust and the Massey University Research Fund for their financial assistance.

Lastly, but most importantly I would like to thank Lynette for her patience and encouragement throughout the duration of this thesis both of which are gratefully acknowledged.

## Contents

**CHAPTER ONE - LITERATURE REVIEW** 16

**Preamble** 16
**Pregnancy shearing of the housed ewe** 19
*Body temperature and respiration rates* 19
*Ewe liveweight change and intake* 20
*Gestation length and birthweight* 21
*Brown Adipose Tissue (BAT) formation and heat production* 22
*Survival of lambs* 23
*Lamb growth rates* 23
*Factors affecting the birthweight response* 24
- *Stage of gestation when shorn* 24
- *Intake response to shearing* 25
- *Effect of ewe allowance following pregnancy shearing* 25

*Conclusion* 26
**Pregnancy shearing under pastoral conditions** 26
*Ewe body temperature* 26
*Ewe body condition and liveweight* 27
*Lamb birthweights* 28
*Heat production of lambs* 30
*Lamb survival and growth* 30
*Factors affecting the productive responses* 31
- *Stage of gestation when shorn under New Zealand conditions* 31
- *Intake response to shearing* 32
- *Effect of ewe herbage allowance following pregnancy shearing* 32

*Conclusion* 33
**The effect of pregnancy shearing on wool quality and quantity** 33
**Metabolic responses to pregnancy shearing** 35
*Blood metabolites* 35
- *Glucose* 35
- *Fatty acids* 36
- *Hydroxybutyrate* 37

*Maternal hormones* 38
- *Cortisol* 38
- *Insulin* 38
- *Thyroid hormones* 39
- *Growth hormone* 41

*Summary of shearing effect on maternal hormones* 41
**Purpose and scope of the investigation** 42

**CHAPTER TWO - THE EFFECT OF EWE NUTRITION DURING MID- AND LATE-PREGNANCY ON THE BIRTHWEIGHT RESPONSE FROM MID-PREGNANCY SHEARING** 43

**Abstract** 43
**Introduction** 44
**Methods** 45
*Experimental design and animals* 45

*Treatments* 46
*Pasture* 47
*Climatic data* 48
*Animal measurements* 48
*Ewes* 48
*Lambs* 50
*Data analysis* 52
**Results** 54
*Pasture conditions* 54
*Animal Measurements* 54
*Ewe liveweight* 54
*Ewe intake* 58
*Ewe condition score* 61
*Ewe fleece weight* 62
*Ewe rectal temperatures* 62
*Gestation length* 65
*Lamb liveweights* 65
*Lamb crown-rump length, girth and wool depth* 67
*Lamb rectal temperature* 68
*Calorimetry* 69
**Discussion** 71
**Conclusion** 75

**CHAPTER THREE - MATERNAL CONSTRAINT AND THE BIRTHWEIGHT RESPONSE TO MID-PREGNANCY SHEARING** 77

**Abstract** 77
**Introduction** 78
**Methods** 79
*Experimental design and animals* 79
*Pasture* 80
*Animal measurements* 81
*Ewes* 81
*Lambs* 82
*Climatic Data* 83
*Data analysis* 83
**Results** 84
*Ewe liveweight and condition score* 84
*Ewe intake* 85
*Ewe rectal temperatures* 86
*Gestation length and lamb liveweights* 88
*Girth, crown rump length, dry and wet wool depth* 91
*Summit metabolism* 91
**Discussion** 93
**Conclusion** 97

**CHAPTER FOUR - THE EFFECT OF MID-PREGNANCY SHEARING ON LAMB BIRTHWEIGHT AND SURVIVAL RATES TO WEANING UNDER COMMERCIAL CONDITIONS** 99

**Abstract** **99**
**Introduction** **101**
**Methods** **102**
*Riverside* *102*
*Experimental design and animals* *102*
*Treatments* *102*
*Pasture* *103*
*Animal measurements* *104*
*Ewes* *104*
*Lambs* *105*
*Tuapaka* *105*
*Experimental design and animals* *105*
*Treatments* *105*
*Animal measurements* *106*
*Ewes* *106*
*Lambs* *106*
*Data Analysis* *107*
**Results** **107**
*Ewe liveweight* *107*
*Riverside* *107*
*Tuapaka* *108*
*Ewe condition score* *111*
*Riverside* *111*
*Tuapaka* *111*
*Annual ewe fleece weight* *114*
*Riverside and Tuapaka* *114*
*Lamb birthweights and liveweights* *114*
*Riverside* *114*
*Tuapaka* *115*
*The relationship between ewe liveweight and condition score during mid-pregnancy and mid-pregnancy shearing treatment in twin-born lambs* *115*
*Lamb survival* *119*
*Cause of death at Tuapaka* *120*
**Discussion** **122**
**Conclusion** **127**

**CHAPTER FIVE - ARE ELEVATED MATERNAL THYROID HORMONE CONCENTRATIONS RESPONSIBLE FOR THE LAMB BIRTHWEIGHT EFFECT?** **129**

**Abstract** **129**
**Introduction** **130**
**Methods** **131**
*Experimental design and animals* *131*
*Treatments* *131*
*Surgery and thyroxine implants* *132*
*Thyroxine injections* *132*
*Ewe management* *133*
*Pasture conditions* *133*
*Animal measurements* *134*
*Ewes* *134*

*Lambs* 134
*Data analysis* 135
**Results** 135
*Ewe liveweight and Condition Score* 135
*Dam blood T3/T4 concentrations* 137
*Gestation length and lamb size* 138
*Summit metabolism* 141
**Discussion** 142
**Conclusion** 145

**CHAPTER SIX - GENERAL DISCUSSION** 147

**Introduction** 147
**Achievement of ewe liveweight targets** 148
**Evaluation of measurement techniques** 148
*Ewe intake* 148
*Ewe rectal temperatures* 149
*Condition scores* 151
*Measurement of newborn lamb thermoregulatory capability* 151
*Large scale commercial field studies* 152
*Maternal T3/ T4 manipulation* 153
*Statistical analysis* 154
**The effect of mid-pregnancy shearing on lamb birthweight** 154
**Does a birthweight response always mean an increase in lamb survival rates to weaning?** 156
**The possible impact of using the mid-pregnancy shearing on New Zealand sheep farms** 162
**What is the financial effect?** 163
**Should New Zealand farmers routinely use mid-pregnancy shearing?** 165
**How should the mid-pregnancy shearing technique be managed on New Zealand sheep farms?** 166
**Areas requiring further study** 167
**Conclusion** 168

**REFERENCES** 169

**APPENDIX** 179

**Appendix 1: Artificial control of thyroid levels** 179
*Introduction* 179
*Study 1 - Development of a technique to control maternal thyroid hormone concentrations at a level seen in the unshorn ewe* 180
*Aim* 180
*Method* 180
*Data analysis* 181
*Results* 181
*Discussion/Conclusion* 182

*Study 2 - Development of a technique to elevate thyroid hormone concentrations in the short to medium time period* 184
*Aim* 184
*Method* 184
*Data analysis* 184
*Results* 184
*Discussion/Conclusion* 185
**Appendix 2: Autopsies of dead lambs at Tuapaka** **187**
*Introduction* 187
*Diagnosing cause of death* 187
*Autopsy sheet used at Tuapaka* 188

## List of Tables

**Table** **Page**

***Table 1.1.*** *Summary of studies examining birthweight responses to pregnancy shearing under New Zealand conditions.* 29

***Table 2.1.*** *The effect of pregnancy rank, shearing treatment and feeding regimen on ewe liveweights (kg) at P101, P139, L38 and L76 (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).* 55

***Table 2.2.*** *The effect of pregnancy rank, shearing treatment and ewe feeding regimen on ewe Digestible Organic Matter Intakes (DOMI) (kg DOMI ewe$^{-1}$ day$^{-1}$) (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).* 60

***Table 2.3.*** *The effect of pregnancy rank, shearing treatment and feeding regimen on ewe condition scores at P101 and P139 (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).* 61

***Table 2.4.*** *The effect of pregnancy rank, shearing treatment and feeding regimen on annual fleece weights (kg) for all ewes and the effect of pregnancy rank and feeding regime on second shear fleece weights (July – November) of pregnancy-shorn ewes (P70 – L56) (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).* 62

***Table 2.5.*** *The effect of pregnancy rank, shearing treatment and feeding regimen on ewe rectal temperatures (°C)(Mean ±SE) at different times from mid-pregnancy until parturition. The maximum and minimum air temperature (°C) for each day of measurement is shown. Means within treatments having different superscripts are different (P<0.05).* 64

***Table 2.6.*** *The effect of pregnancy rank, dam shearing treatment and feeding regimen on gestation length (days) (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).* 65

***Table 2.7.*** *The effect of birth-rank, dam shearing treatment and feeding regimen on lamb liveweight (kg) at birth, L38 and L76 (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).* 66

***Table 2.8.*** *The effect of birth-rank, dam shearing treatment and feeding regimen on crown-rump length (CRL) (mm), girth (mm), and dry and wet wool depth (mm) measurements of new-born lambs (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).* 67

***Table 2.9.*** *The effect of birth-rank, dam shearing treatment and feeding regimen on average lamb rectal temperatures (°C) (Mean ±SE) at 1, 3, 6 and 9 hours after birth. Means within treatment having differing superscripts are different (P<0.05).* 68

***Table 2.10.*** *The effect of birth-rank, dam shearing treatment and feeding regimen on the proportion (%) of lambs (<36hrs of age) that failed to reach summit metabolism. Means with different superscripts are different (P<0.05).* 69

***Table 2.11.*** *The effect of birth-rank, dam shearing treatment and feeding regimen on the rate of increase in heat production (W/kg/min) and the effect of shearing treatment and dam feeding regimen on summit metabolic rate*

*(W/kg) of twin-born lambs (Means ±SE). Means within treatment having differing superscripts are different (P<0.05).* 70
***Table 3.1.*** *The effect of pregnancy rank, ewe group and shearing treatment on ewe liveweights (kg) at P69, P105, P140, L36 and L84 (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).* 84
***Table 3.2.*** *The effect of pregnancy rank, ewe group and shearing treatment on ewe condition score at P69, P105, P140, L36 and L84 (Mean ±SE). Means within treatments having different superscripts are significantly different (P<0.05).* 85
***Table 3.3.*** *The effect of ewe group and shearing treatment on ewe digestible organic matter intakes (DOMI) of twin-bearing ewes in late pregnancy (kg DOMI ewe$^{-1}$ day$^{-1}$) (Mean ±SE). Means within treatments having different superscripts are significantly different (P<0.05).* 86
***Table 3.4.*** *The effect of pregnancy rank, ewe group and shearing treatment on ewe rectal temperatures (°C) (Mean ±SE) at P124, P130, P135 and P137. Maximum and minimum air temperatures (°C) for the day of rectal temperature measurement are shown. Means within treatments having different superscripts are significantly different (P<0.05).* 87
***Table 3.5.*** *The effect of pregnancy rank, ewe group and shearing treatment on gestation length (days) (Means ±SE). Means within treatments having different superscripts are significantly different (P<0.05).* 88
***Table 3.6.*** *The effect of birth rank, ewe group and ewe shearing treatment and their interactions on lamb liveweight (kg) at birth, L36 and L86 (Means ±SE). Means within treatments having different superscripts are significantly different (P<0.05).* 90
***Table 3.7.*** *The effect of ewe group and shearing treatment on girth (cm), crown rump length (CRL) (cm), dry (Dry) and wet (Wet) wool depth measurements (mm) of new-born twin lambs (Mean ±SE). Means within treatments having different superscripts are significantly different (P<0.05).* 91
***Table 3.8.*** *The effect of sex of the lamb, ewe group and ewe shearing treatment on the proportion (%) of twin-born lambs (less than 36hrs of age) that did not reach summit metabolism (Mean ±SE).* 92
***Table 3.9.*** *The effect of ewe group and shearing treatment on summit metabolism (W/kg) of twin-born lambs less than 36 hrs of age (Mean ± SE). Means within treatments having different superscripts are significantly different (P<0.05).* 92
***Table 4.1.*** *Average herbage masses (kgDM/ha) during pregnancy (P-11 to P133), prior to set stocking (P133) and during lactation (P133 to L87) and average sward heights (cm) prior to set stocking (P133) and during lactation (P133 – L87) at Riverside.* 104
***Table 4.2*** *Average herbage masses (kg DM/ha) during pregnancy (P-13 to P130), at set stocking (P130) and during lactation (P130 to L91) and average sward heights (cm) at set stocking (P130) and during lactation (P130 – L91) at Tuapaka.* 106
***Table 4.3.*** *The effect of pregnancy rank and shearing treatment on ewe liveweights (kg) at P67, P101, P133, L34/35 and L86/87 at Riverside (Mean ±SE). Means within treatment having different superscripts are different (P<0.05).* 109

***Table 4.4.*** *The effect of pregnancy rank and shearing treatment on ewe liveweights (kg) at P69, P101, P130, L28/29 and L90/91 at Tuapaka (Mean ±SE). Means within treatment having different superscripts are different (P<0.05).* ___ *110*

***Table 4.5.*** *The effect of pregnancy rank and shearing treatment on ewe condition score at P67, P101, P133, L34/35 and L86/87 at Riverside (Mean ±SE). Means within treatment having different superscripts are different (P<0.05).* ___ *112*

***Table 4.6.*** *The effect of pregnancy rank and shearing treatment on ewe condition score at P69, P101, P130, L28/29 and L90/91 at Tuapaka (Mean ±SE). Means within treatment having different superscripts are different (P<0.05).* ___ *113*

***Table 4.7.*** *The effect of pregnancy rank and ewe shearing treatment on ewe annual fleece weight (kg) at Riverside and Tuapaka (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).* ___ *114*

***Table 4.8.*** *The effect of birth-rank and ewe shearing treatment on lamb liveweight (kg) at birth, docking (L34/35) and weaning (L86/87) at Riverside and at birth, docking (L28/29) and weaning (L90/91) at Tuapaka (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).* ___ *117*

***Table 4.9.*** *The effect of ewe liveweight (kg) group at mid-pregnancy (P67 and P69 at Riverside and Tuapaka respectively) and shearing treatment on twin lamb birthweight (kg) (Mean ±SE). Means within farms with different superscripts are different (P<0.05).* ___ *118*

***Table 4.10.*** *The effect of ewe condition score group (scale 1 – 5) at mid-pregnancy (P67 and P69 at Riverside and Tuapaka respectively) and shearing treatment on twin lamb birthweight (kg) (Mean ±SE). Means within farms with different superscripts are different (P<0.05).* ___ *118*

***Table 4.11.*** *The effect of birth-rank and ewe shearing treatment on proportion (%) of lambs surviving to weaning at both Riverside and Tuapaka (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).* ___ *120*

***Table 4.12.*** *The effect of birth-rank and ewe shearing treatment on cause of lamb mortality (%) in autopsied lambs at Tuapaka (Mean, ±SE). Means within treatments having differing superscripts are different (P<0.05).* ___ *121*

***Table 5.1.*** *The effect of dam treatment on the liveweight (kg) of twin-bearing ewes at P69, P106, P140, L47 and L122 (Mean ±SE).* ___ *136*

***Table 5.2.*** *The effect of dam treatment on the condition score of twin-bearing ewes at P69, P130 and L122 (Mean ±SE).* ___ *137*

***Table 5.3.*** *The effect of dam treatment on annual fleece weight (kg) (Mean ±SE).* *137*

***Table 5.4.*** *The effect of dam treatment on the gestation length (days) and liveweights (kg) at birth (L1), L47 and L122 of twin lambs (Mean ±SE). Means within columns having different superscripts are different (P<0.05).* ___ *140*

***Table 5.5.*** *The effect of dam treatment on the crown rump length (CRL) (cm) and Girth (cm) of twin lambs (Mean ±SE). Means within columns having different superscripts are different (P<0.05).* ___ *141*

*Table 5.6. The effect of dam treatment on the proportion of lambs (%) that reached summit metabolism and the summit metabolic rate (W/kg) of twin lambs (Mean ±SE).* ____ *141*
*Table 6.1. The effect of dam shearing treatment on predicted twin lamb survival rates (based on survival data presented by Dalton et al. (1980)) to weaning at Tuapaka.* ____ *157*
*Table 6.2. The effect of dam shearing treatment on predicted singleton lamb survival rates (based on survival data presented by Dalton et al. (1980)) to weaning at Tuapaka.* ____ *158*
*Table 6.3. The effect of dam shearing treatment on predicted twin born lamb survival rates (based on survival data presented by Dalton et al. (1980)) to weaning at Riverside.* ____ *159*
*Table 6.4. The effect of dam shearing treatment on predicted singleton lamb survival rates (based on survival data presented by Dalton et al. (1980)) to weaning at Riverside.* ____ *160*
*Table 6.5. Actual survival of multiple-born lambs by birthweight range and predicted survival rate if birthweights are increased by 0.5 kg due to pregnancy shearing (adapted from Morris et al. 1999).* ____ *161*
*Appendix Table 1. Ewe treatment groups.* ____ *181*
*Appendix Table 2. Ewe treatment groups.* ____ *184*

# List of Figures

**Figure** **Page**

*Figure 2.1. Ewe-group feeding regimens.* ____ *47*
*Figure 2.2. Stylised graph of an increase in heat production observed in lambs when subjected to the standard stimuli (an increase in heat production to the standardised stimuli is measured as the difference in heat production between point B and line A divided by the time elapsed between line B and point C). Vertical bars represent the standard deviation of the first four points, not of each point.* ____ *52*
*Figure 3.1. Birthweight responses to mid- to late-pregnancy shearing (singles- closed symbols, twins- open symbols) as a function of the birthweights of control lambs (each point represents a separate trial or treatment [shearing date] within a trial (Morris and McCutcheon 1997, Morris et al. 2000, Revell et al. 2000, Revell et al. 2002 and Chapter 2)). Shearing responses for each of the feeding regimes in this study are indicated by their subscripts (single maintenance (SM), single low (SL), twin maintenance (TM), twin low (TL).* ____ *98*
*Figure 4.1. Birthweight responses to mid- to late-pregnancy shearing (singles- closed symbols, twins- open symbols) as a function of the birthweights of control lambs (each point represents a separate trial or treatment [shearing date] within a trial ((Morris and McCutcheon 1997, Morris et al. 2000, Revell et al. 2000, Revell et al. 2002 and Chapter 2 and 3)). Shearing responses for each the two farms (within each birth rank) in the present study are indicated by Tuapaka (Ta) and Riverside (Rv).* ____ *128*

***Figure 5.1.*** *Effect of dam treatment on maternal T3 (ng/dL) (upper graph) and T4 (•g/dL) (lower graph) concentrations during mid- to late-pregnancy. In the T3 graph 'Morris' indicates T3 elevation reported by Morris et al. (2000). The vertical bars indicate standard errors of the means.* ______ *139*
***Figure 5.2.*** *Birthweight responses to mid- to late-pregnancy shearing (singles- closed symbols, twins- open symbols) as a function of the birthweights of control lambs born to unshorn dams (each point represents a separate trial or treatment [shearing date] within a trial (Morris and McCutcheon 1997, Morris et al. 2000, Revell et al. 2000, Revell et al. 2002 and Chapter 2 and 3)). The present study is indicated by '2000'. The results of Morris et al. (2000) within each birthrank for each of the shearing dates are indicated by 'Morris'.* ______ *146*
***Appendix Figure 1.*** *From Morris et al. (2000). Effects of time of shearing (P50, triangels; P70, diamonds; P100 squares; and unshorn, circles) and pregnancy rank (single-bearing ewes, closed symbols; twin-bearing ewes, open symbols) on plasma triiodothyronine (T3) concentration.* __ *179*
***Appendix Figure 3.*** *The effect of differing T4 injection regimens on maternal T4 (μg/dL) (upper graph) and T3 (ng/dL) (lower graph) concentrations. The results reported by Morris et al. (2000) are indicated by "Morris et al. 2000).* ______ *186*

# List of Abbreviations

| | |
|---|---|
| BAT | brown adipose tissue |
| CIDR | controlled internal drug release |
| $Cr_2O_3$ | chromic sesquioxide |
| CRL | crown-rump length |
| CS | condition score |
| CT | computer topography |
| d | day(s) |
| DM | dry matter |
| DMD | dry matter digestibility |
| DOMD | organic matter digestibility of dry matter |
| DOMI | digestible organic matter intake |
| g | gram(s) |
| ha | hectare(s) |
| h | hour(s) |
| IU | international unit(s) |
| kg | kilogram(s) |
| L | day of lactation (e.g. L34 = day 34 of lactation) |
| LCT | lower critical temperature |
| MJ | megajoules |
| ME | metabolisable energy |
| m | metre(s) |
| mm | millimetre |
| mg | milligrams |
| μg/dL | micrograms per deci-litre |
| min | minute(s) |
| NEFA | non-esterified fatty acids |
| ng/dL | nanograms per deci-litre |
| NPRQ | non-protein respiratory quotient |
| NST | non-shivering thermogenesis |
| OF | oesophageal fistulated |
| OM | organic matter |
| OMI | organic matter intake |
| OMD | organic matter digestibility |
| P | day of pregnancy (e.g. P70 = day 70 of pregnancy) |
| PMSG | pregnant mare serum gonadotropin |
| SMR | summit metabolic rate |
| s.u. | stock unit |
| T3 | tri-iodothyronine |
| T4 | thyroxine |
| vs | versus |
| W | watts |
| $^{o}C$ | degree(s) celsius |

# Chapter one - Literature review

**Preamble**

Peri-natal mortality of lambs on New Zealand farms was reported by Hight and Jury (1970) to be between 5 and 25%. Not only were these lambs lost to the purpose for which they were intended, but the ewes produced less wool and required more feed than if they had not been pregnant (Hight and Jury 1970). This occurred at a time when the average lambing percentage was 93% (MWES 2000a). In the late 1990's the average lambing percentage has been as high as 116% (MWES 2000a) with peri-natal moralities still in the 5 - 32% range (Geenty 1997; McCorkindale 1999; Sheath *et al.* 1999). Therefore, under the current farming conditions any treatment that can reduce peri-natal loss could substantially increase the numbers of lambs weaned and financial returns to New Zealand sheep farmers. In addition, Geenty (1997) stated that losses were greater in multiples (15-22%) than in singles (9-16%). With the current push to further increase lambing percentages a technique to reduce peri-natal losses will become even more important.

Most lamb mortality occurs within three days of birth (Hight and Jury 1970; Dalton *et al.* 1980; Scales *et al.* 1986). The main causes of lamb deaths under New Zealand conditions are dystocia, starvation-exposure, infections, abnormalities and misadventure (Hight and Jury 1970). Dystocia and starvation-exposure contribute to 60% of deaths (Hight and Jury 1970), with birthweight playing an important role in lamb survival (Hight and Jury 1970; Dalton *et al.* 1980; Knight *et al.* 1988). Dalton *et al.* (1980) reported that the lamb survival rate is highest in the 3.5 to 5.5 kg birth weight range, with birthweights below 3.0 and above 6.5 kg resulting in very low survival rates. Scales *et al.* (1986) concluded that any method that maintained birthweights within the 4.0 - 4.5 kg range would be advantageous to lamb survival. The current drive to increase lambing percentages (Geenty 1997) would be expected to increase the proportion of multiple-born lambs and hence the proportion of lambs at the lower end of the birthweight range.

Deaths due to dystocia are associated with the disproportionate size of the newborn in relation to the pelvic area of the ewe (Smith 1982), with heavier lambs at birth having a higher incidence of dystocia (Scales *et al.* 1986; Fogarty *et al.* 1992). Dystocia is a major cause of deaths in singles, especially males, but is of lesser importance in multiple-born lambs (Hight and Jury 1970; Dalton *et al.* 1980; Scales *et al.* 1986).

Starvation-exposure causes approximately 30% of new-born lamb losses (McCutcheon *et al.* 1981) under New Zealand conditions. Relatively light lambs, which are predominantly multiple-born, are particularly susceptible to starvation-exposure mortality (Dalton *et al.* 1980; Fogarty *et al.* 1992). Eales *et al.* (1982) suggested that multiple-born lambs are more likely to succumb to hypothermia, due to the fact that they take longer to stand and suckle and have a higher rate of heat production per unit body weight, resulting in body reserves being depleted earlier. Deaths due to starvation-exposure decrease as birthweight increases, for both single- and multiple-born lambs (Dalton *et al.* 1980). Scales *et al.* (1986) found no effect of sex of the lamb on susceptibility to starvation and exposure.

When a lamb's maximum sustainable rate of heat production is exceeded by the rate at which heat is lost to the environment, deep body temperature falls (McCutcheon *et al.* 1981). Lambs born in the field may suffer a considerable decline in rectal temperature during the first hours of life, and in extreme cases this can exceed $9^0$C in the first 10 minutes after birth (Alexander and McCance 1958). The failure of the lamb to maintain normal deep body temperature in a cold environment is implicated in many starvation-exposure mortalities (McCutcheon *et al.* 1981; McCutcheon *et al.* 1983). Eales *et al.* (1982) found that there are two periods of high risk; first, birth to 5 hours of age, in which hypothermia is caused by excessive heat loss; and second, from 12 to 36 hours of age in which hypothermia results largely from depressed heat production associated with a depletion of energy reserves. Cold exposure may not only deplete body reserves by increasing energy demand, but also prevent the replenishment of reserves by reducing mobility and inhibiting the sucking drive (Sykes *et al.* 1976).

Maximum sustainable rate of heat production (summit metabolic rate or SMR) is a function of both shivering thermogenesis (primarily in skeletal muscle) and non-shivering thermogenesis (mainly in brown adipose tissue) (Clarke *et al.* 1994). While SMR per unit of body weight is independent of size, small lambs have a larger surface area to weight ratio than large lambs, and thus a higher ratio of heat loss (a function of surface area) to heat production (a function of weight). As a result, in a given environment small lambs will show more pronounced cooling than large lambs (Hight and Jury 1970).

Pregnancy shearing is a possible mechanism for reducing multiple-born lamb losses due to starvation-exposure. Evidence from overseas suggests that lambs born to ewes shorn during pregnancy have heavier birth weights (Rutter *et al.* 1971; Symonds *et al.* 1986; Vipond *et al.* 1987) and improved cold resistance (Stott and Slee 1985; Symonds *et al.* 1992) than those born to unshorn dams. Each effect individually would be expected to improve lamb survival under New Zealand conditions, but a combined effect has the potential to substantially increase the survival rates of newborn lambs. However the effects of shearing on pregnant housed ewes (typical of overseas studies) may not be the same as their counterparts under pastoral conditions especially where they are exposed to winter conditions. Hence the two farming situations need to be considered separately.

**Pregnancy shearing of the housed ewe**

Under pastoral conditions in New Zealand, shearing ewes during the winter period in the cold, wind and/or rain can expose ewes to conditions below their lower critical temperature (Gregory 1995) and may result in cold stress. In the housed situation where the pregnant dam is not subjected to wind and/or rain it is difficult to suggest that these ewes are subjected to a severe type of cold stress. In the housed pregnancy shearing studies of Glanville and Phillips (1986), Symonds *et al.* (1986), Black and Chestnutt (1990) and Symonds *et al.* (1992) the average minimum and maximum temperatures reported were 4 and 14, 5.1 and 12.6, 2.8 and 8.0, 6.8 and 12.3$^0$C respectively. These temperatures are similar to those reported by Revell *et al.* (2000) (9.3 to 12.7$^0$C) who suggested shearing in the housed situation may alleviate negative effects of heat stress although, the classic effects of heat stress occur at temperatures above those recorded by Revell *et al.* (2000).

The effects of shearing on both the housed and under pastoral grazing ewes (as is the case in New Zealand) will be considered separately in this review as it is possible that there are two separate mechanisms working, depending on the environmental conditions that the pregnant dam is exposed too.

In the United Kingdom each year, pregnant ewes are typically housed during the winter period. Ewes are housed to: avoid adverse weather conditions prevalent at that time of year, ensure that the ewes have easy access to an adequate level of nutrition and permit more intensive monitoring during the lambing period. Housing usually occurs in mid- to late-pregnancy and continues though to the end of lambing when they are returned to pasture.

*Body temperature and respiration rates*

Heat stressed ewes exhibit higher rectal temperatures (Alexander and Williams 1971; Brown *et al.* 1977) and respiration rates (Alexander and Williams 1971; Hopkins *et al.* 1980) during late pregnancy than non-heat stressed ewes. Salman and Owen (1986) stated that the higher respiration rates of unshorn ewes in comparison to shorn ewes indicated their increasing rate of heat loss.

The rectal temperatures (Nedkvitine 1972; Russel *et al.* 1985; Salman and Owen 1986; Vipond *et al.* 1987; Black and Chestnutt 1990) and skin temperatures (Maund 1980; Vipond *et al.* 1987) of shorn housed ewes have been found to be lower than those of unshorn ewes in the period following shearing. Similarly, respiration rates of shorn housed ewes are lower (Austin and Young 1977; Morgan and Broadbent 1980; Kirk *et al.* 1984; Russel *et al.* 1985; Glanville and Phillips 1986; Salman and Owen 1986; Black and Chestnutt 1990;) and less variable (Glanville and Phillips 1986; Austin and Young 1977) than in unshorn housed ewes. Morgan and Broadbent (1980) stated that the difference in respiration rate between shorn and unshorn ewes seemed to increase with increasing external temperature.

It therefore appears that shearing of housed pregnant ewes relieves heat stress. Other authors have come to a similar conclusion (Nedkvitine 1972; Austin and Young 1977; Vipond *et al.* 1987; Black and Chestnutt 1990).

*Ewe liveweight change and intake*

In most studies pregnancy shearing of housed ewes has been observed to have no effect on ewe liveweight in the post-shearing period (Nedkvitine 1972; Murray and Crosby 1986). Kneale and Bastiman (1977) noted that there was no difference in pre-lamb ewe liveweight in the year that both shorn and unshorn ewes lost weight after shearing but, in the year in which ewes gained weight, shorn ewes gained significantly more. They therefore suggested that there could be an interaction between the effects of shearing and environmental temperature on liveweight change. Austin and Young (1977) reported that shorn ewes gained more weight than unshorn ewes, while Russel *et al.* (1985) found that weight loss occurred in shorn ewes following shearing. They suggested that immediately after shearing there is a small but real effect on energy stores such that the energy deficit is somewhat greater in shorn than unshorn ewes.

High ambient temperatures result in reduction in appetite of pregnant ewes (Shelton 1964; Shelton and Huston 1968; Cartwright and Thwaites 1976) and shearing might therefore be expected to increase appetite. In fact, however, studies on the effect of pregnancy shearing on feed intake by the ewe have been inconsistent.

In some studies pregnancy shearing has been found to increase the intake of ewes in comparison to unshorn ewes (Nedkvitine 1972; Maund 1980; Morgan and Broadbent 1980; Glanville and Phillips 1986; Salman and Owen 1986; Phillips *et al.* 1988). Kneale and Bastiman (1977) found that shorn ewes ate slightly more than unshorn ewes during pregnancy, but this was mostly due to a very much higher intake during the four weeks immediately following shearing. Vipond *et al.* (1987) observed in two of three studies that shearing increased dry matter (DM) intake. Diets in all three studies differed, so there may have been an interaction between type of diet and shearing treatment. They also reported that shearing increased intake by a greater amount overall in smaller ewes. Black and Chestnutt (1990) stated that there was a tendency for feed intake to increase the earlier in pregnancy that shearing was carried out.

In other studies, pregnancy shearing has failed to increase voluntary feed intake (Rutter *et al.* 1972; Symonds *et al.* 1986; Black and Chestnutt 1990). Revell *et al.* (2000) found that shearing increased the voluntary feed intake of twin-bearing ewes for a period after shearing, but not of single-bearing ewes. Is it possible that where increases in intake have been found, intake levels are only being returned to a 'normal' state, having been reduced by heat stress in unshorn ewes. Similarly, Revell *et al.* (2000) suggested that unshorn ewes, particularly those bearing twins, had depressed voluntary feed intake when housed indoors, in order to prevent heat stress.

*Gestation length and birthweight*

Heat-stressing of pregnant ewes results in a restriction of placental growth and weight (Alexander and Williams 1971; Bell *et al.* 1989), with chronic heat stress during both mid- and late-pregnancy retarding foetal growth and lamb birth weight, and shortening gestation (Yeates 1958; Shelton 1964; Shelton and Huston 1968; Alexander and Williams 1971; Cartwright and Thwaites 1976; Brown *et al.* 1977; Hopkins *et al.* 1980). Therefore, if pregnancy shearing of housed ewes relieves heat stress, it might be expected to lead to greater gestation lengths and lamb birthweights.

In most studies pregnancy shearing of ewes has indeed been shown to increase gestation length (Adalsteinsson 1972; Nedkvitine 1972; Murray and Crosby 1986; Vipond *et al.* 1987). However, Stott and Slee (1985) reported no effect.

Pregnancy shearing of housed ewes has also increased lamb birthweights in most studies (Rutter *et al.* 1971; Aldalsteinsson 1972; Rutter *et al.* 1972; Austin and Young 1977; Maund 1980; Morgan and Broadbent 1980; Kirk *et al.* 1984; Glanville and Phillips 1986; Murray and Crosby 1986; Salman and Owen 1986; Symonds *et al.* 1986; Vipond *et al.* 1987; Black and Chestnutt 1990; Symonds *et al.* 1992). Phillips *et al.*

(1988) observed a shearing effect on birthweight in one of two studies and, in the other, found it to be twin-lamb specific. Black and Chestnutt (1990) showed that repeated shearing (four times) during mid- to late-pregnancy resulted in an increased birth weight response, over and above that found in lambs born to ewes shorn once during the same period.

However, this increase in birthweight has not always been found, with Revell *et al.* (2000) reporting the response to be twin-lamb specific in ewes housed for only a short period of time, and others finding no effect at all (Nedkvitine 1972; Kneale and Bastiman 1977; Russel *et al.* 1985; Stott and Slee 1985).

*Brown Adipose Tissue (BAT) formation and heat production*

Pregnancy shearing of housed ewes has enhanced the thermoregulatory capability of the new-born lamb (Stott and Slee 1985; Symonds *et al.* 1992; Egan *et al.* 1997). In these studies ewes were housed post-shearing in average environmental conditions of 5 to 12.3$^0$C. It is difficult to suggest that under these protected housed conditions that these ewes were under true cold stress. Therefore conclusions drawn regarding the effects of maternal cold stress should be read with caution. Stott and Slee (1985) found that lambs born to shorn dams housed at 6$^0$C tended to have higher summit metabolic rates than their counterparts born to unshorn dams. They also found an enhanced metabolic response to an injection of noradrenaline (indicating a greater non-shivering thermogenesis (or NST) capability). They concluded that cold exposure during late pregnancy favoured fetal BAT deposition. Symonds *et al.* (1992) found that twin lambs born to shorn housed ewes (held at 6.8 to 12.3$^O$C post-shearing) exhibited greater metabolic responses to cold exposure. They concluded that maternal cold exposure during late pregnancy stimulates thermogenic activity of BAT in the neonatal lamb. Symonds *et al.* (1995) showed that in late pregnancy foetuses from shorn ewes had greater perirenal BAT than their counterparts born to unshorn ewes. Egan *et al.* (1997) reported that rectal temperatures of lambs born to shorn ewes (housed at 5$^O$C post-shearing) declined less during the first 12 hours after birth than those of their counterparts born to unshorn ewes. All these studies indicate that in the housed situation lambs born to shorn dams have enhanced thermoregulatory capability.

*Survival of lambs*

Thermal stress in ewes during pregnancy has been found to result in weaker lambs at birth (Brown *et al.* 1977) and reduced overall lamb survival rates (Shelton 1964; Shelton and Huston 1968). In most studies pregnancy shearing has been associated with reduced lamb mortality rates (Rutter *et al.* 1971; Nedkvitine 1972; Austin and Young 1977; Maund 1980; Salman and Owen 1986; Vipond *et al.* 1987). Morgan and Broadbent (1980) found, in a series of experiments, that mortality rates were lower in lambs born to shorn ewes in all groups except one, in which high birth weights resulted in a higher mortality rate. Conversely, Kneale and Bastiman (1977) found that mortality up to 24 hours of age, including still-borns, was higher in lambs born to shorn than unshorn ewes, while Adalsteinsson (1972), Rutter *et al.* (1972) and Murray and Crosby (1986) showed no effect of pregnancy shearing on lamb survival. Pre-lamb shearing of housed ewes has been found to result in the ewe being more aware of the proximity of the lamb and a reduction in difficulty for the lamb in finding the teat, though this is dependent on the timing of shearing during pregnancy (Rutter *et al.* 1971; Black and Chestnutt 1990). Under housed conditions, where animal management is relatively intensive and where newborn lambs are not exposed to extreme weather conditions, enhanced heat production and birthweight are likely to be of minimal importance. It is therefore possible that increased new-born lamb survival rates found in lambs born to shorn housed ewes are due to an improved mothering ability *per se*, rather than the effects of increased birthweight and heat production in the new-born lamb.

*Lamb growth rates*

Pregnancy shearing of housed ewes has increased lamb growth rates to: 3 weeks of age (Kneale and Bastiman 1977); 6 weeks of age (Russel *et al.* 1985); 8 weeks of age (Morgan and Broadbent 1980; Kirk *et al.* 1984); 11 weeks of age (Glanville and Phillips 1986); and 12 weeks of age (Austin and Young 1977). Nedkvitine (1972) found that, in two of three flocks, liveweights at weaning were greater for twin lambs born to shorn dams than for those born to unshorn dams. Austin and Young (1977) suggested that the improved lamb growth might be due to ewes lambing in better body condition and having improved lactation, or to a direct advantage conferred upon the lambs themselves. Phillips *et al.* (1988) stated that the increased liveweight gain of lambs reared by shorn ewes was confined to situations where adequate herbage was available when ewes had been returned to pastoral grazing. Nedkvitine (1972) stated that there was evidence for lambs born to shorn ewes having a higher dressing out percentage, implying a difference in body composition.

However, increased lamb growth rates have not been observed in all cases. Black and Chestnutt (1990) and Symonds *et al.* (1992) found no difference to 5 weeks and 4 weeks of age respectively. Similarly, Russel *et al.* (1985) and Murray and Cosby (1986) observed no effect of pregnancy shearing on lamb liveweight at weaning. There appears to be no published studies in which pregnancy shearing reduced subsequent lamb growth to weaning. Therefore, it can be concluded that pregnancy shearing of housed ewes will not adversely affect lamb growth rates to weaning but can, under certain circumstances, increase them.

*Factors affecting the birthweight response*

The majority of studies involving pregnancy shearing of housed ewes have centred around the birthweight response, with relatively little work being undertaken in the area of thermoregulatory responses in the newborn lamb. Therefore, this section will concentrate on factors likely to be affecting the birthweight response.

*Stage of gestation when shorn*

The exact timing of shearing to maximise the birthweight response from pregnancy shearing of housed ewes has not been identified. Shearing in: early pregnancy (day 30 – 60 of pregnancy (P30-60)) (Rutter *et al.* 1971; Rutter *et al.* 1972); mid-pregnancy (P60 – 100) (Austin and Young 1977; Maund 1980; Kirk *et al.* 1984; Symonds *et al* 1986; Murry and Crosby 1986; Salman and Owen 1986; Vipond *et al.* 1987; Black and Chestnutt 1990; Revell *et al.* 2000) (only in twins)); and late pregnancy (P100 - 135) (Granville and Phillips 1986; Vipond *et al.* 1987; Phillips *et al.* 1988; Black and Chestnutt 1990) have all resulted in increased lamb birthweights.

However, shearing of housed ewes in: early pregnancy (Lodge and Heaney 1975; Kneale and Bastiman 1977); mid-pregnancy (Russel *et al.* 1985; Revell *et al.* 2000) (in singles only)) and late pregnancy (Nedkvitine 1972; Stott and Slee 1985) has also failed to increase birthweights. Kneale and Bastiman (1977) suggested that ewes shorn in early pregnancy might have reduced benefit than in later stages of pregnancy when the birth weight response would be more sensitive to stress. Black and Chestnutt (1990), however, concluded that there is a relatively long period in which the shearing effect may influence fetal growth. When all of these studies are examined it becomes apparent that there is no clear relationship between the time of shearing and either the consistency of achieving a birthweight response or the magnitude of the response.

*Intake response to shearing*

Austin and Young (1977) suggested that an increase in maternal feed intake following shearing might result in better nutrition for the foetus. Similarly, Russel *et al.* (1985) suggested that the birthweight response to shearing is most likely attributable to increased intake by the ewe. The data of Revell *et al.* (2000) suggests that, rather than pregnancy shearing resulting in an increase in ewe intake (and thus lamb birthweight), the non-shearing of twin-bearing ewes actually reduces intake, though avoidance of heat stress and thereby reduces lamb birthweight. However, Symonds *et al.* (1986) suggested that their results, in combination with those of Rutter *et al.* (1972), showed that the birthweight response to shearing occurs independently of any effects of shearing on voluntary food intake. Similarly, Austin and Young (1977) concluded that increased intake may only be a contributing factor for the increase in birthweight, as the increase in birthweight still occurs without an increase in intake.

*Effect of ewe allowance following pregnancy shearing*

An increase in birthweight from shearing has occurred in ewes offered a maintenance level of feed (Rutter *et al.* 1971; Kirk *et al.* 1984; Symonds *et al.* 1986) and in ewes offered *ad libitum* levels (Rutter *et al.* 1972; Austin and Young 1977; Maund 1980; Glanville and Phillips 1986; Vipond *et al.* 1987; Black and Chestnutt 1990). Revell *et al.* (2000) found a birthweight response in twin lambs only born to ewes offered *ad libitum* levels during mid-pregnancy followed by a maintenance level of feed during late pregnancy. However, pregnancy shearing did not increase birthweights from housed ewes that were offered a low level of feed (Lodge and Heaney 1975), a maintenance level of feed (Nedkvitine 1972) and *ad libitum* levels (Kneale and Bastiman 1977).

When all studies are examined it is evident that there is no clear relationship between the magnitude of the birthweight response and the level of feed allowance when ewes are offered either a maintenance or above-maintenance level of feed. This conclusion is further supported by Vipond *et al.* (1987) who stated that shearing equally affected birthweight at all levels of dietary energy intake, in ewes offered different diets at *ad* *libitum* levels. The study of Lodge and Heaney (1975) is the only study to this author's knowledge where the shearing effect was examined under conditions in which ewes were offered a below-maintenance level of feed. Based on this one study, it would appear that a below-maintenance level of feed allowance does not allow a birth weight response to shearing.

*Conclusion*

Heat stressed ewes exhibit high body and skin temperatures, higher respiration rates, have reduced gestation lengths and give birth to lambs of low birthweight. Shearing of the housed dam has been shown to reduce body and skin temperatures and respiration rates. Shorn-housed dams have longer gestations than their unshorn counterparts and generally give birth to heavier lambs. These results indicate that shearing of the housed dam may relieve heat stress. However, it is unlikely, under the pastoral conditions found in New Zealand, that the unshorn pregnant (spring-lambing) dam is under heat stress in the winter-spring period.

**Pregnancy shearing under pastoral conditions**

*Ewe body temperature*

Shearing, even in warm environmental climates, results in a marked change in a sheep's individual climate (Wodzicka-Tomaszewska 1963a), with shearing under pastoral conditions being found to reduce ewe rectal temperature (Elvidge and Coop 1974; Dabiri *et al.* 1995b). Removal of the fleece (from 10 cm to 1cm depth) increases thermal conductance and increases the lower critical temperature (LCT) of maintenance-fed ewes from –35°C to 17°C in still conditions (Gregory 1995). Even at a twice maintenance level of feeding, a recently shorn sheep can be exposed to its LCT (4°C) in calm, dry conditions (Gregory 1995). These conditions are often observed at the time of pregnancy shearing. An increase in wind or rain, or a decrease in nutrient intake can further raise the LCT (Gregory 1995). These conditions are often present at the time of pre-lamb shearing in New Zealand. Thus shearing pregnant ewes can result in management and animal health risks, including possible ewe losses, especially in poor weather conditions (Wodzicka-Tomaszewska 1963a; Elvidge and Coop 1974; Parker

1992; Parker *et al.* 1994; Dabiri *et al.* 1995b; Gregory 1995). In such conditions large ewe losses have occurred for up to two weeks following shearing (Geytenbeek 1962).

Dabiri *et al.* (1995a) showed that in the first few days following shearing, ewes shorn by the standard comb (leaving 2-4 mm wool stubble) produced substantially more heat than cover comb-shorn ewes (leaving 5-7 mm wool stubble). Dabiri *et al.* (1995a) stated that ewes shorn by the cover comb could withstand ambient temperatures 4 to 5°C cooler than those shorn with the standard comb before having to evoke thermoregulatory heat production. They are therefore likely to have lower mortality rates in the period immediately following shearing (Dabiri *et al.* 1995b).

These reports indicate that any pregnancy-shearing responses found under New Zealand conditions could in fact be due to cold stress, rather than relief of heat stress as possibly found in the indoor situation. This would especially be the case for ewes shorn by the standard comb in poor weather conditions and with low pasture availability.

*Ewe body condition and liveweight*

Pregnancy shearing has generally been reported to have no effect on ewe liveweight in the immediate post-shearing period (Dabiri *et al.* 1994, 1996; Morris *et al.* 2000; Revell *et al.* 2002). However, Morris and McCutcheon (1997) found, when comparing different shearing dates in mid- to late pregnancy, that ewe liveweight during late pregnancy was adversely affected by shearing in only one of three groups. Similarly, Dabiri *et al.* (1995b) observed that shorn ewes were lighter post-shearing during the late pregnancy period. In contrast, Jopson and Davis (2000) reported that shorn ewes gained more total weight than their unshorn counterparts during the last 70 days of pregnancy. Using computer topography (CT) they also observed that shorn ewes gained more carcass lean than their unshorn counterparts.

Inconsistent effects of shearing treatment on ewe liveweight during both lactation and in the post-weaning period have been recorded. Some studies have shown no effect (Dabiri *et al.* 1995b, 1996; Revell *et al.* 2002). However, Morris *et al.* (2000) found shorn ewes were lighter than their unshorn counterparts during mid-lactation, but this effect was gone by weaning. Morris and McCutcheon (1997) reported that only one of three groups of shorn ewes were lighter during mid-lactation than their unshorn counterparts, but observed no difference post-weaning. In contrast Dabiri *et al.* (1994) reported one of three groups of shorn ewes to be heavier post-weaning than their unshorn counterparts.

The findings of Husain *et al.* (1997) may explain why there are inconsistent effects of shearing on ewe liveweight. They noted that ewe liveweight gain in the post-shearing period was dependent on the sward surface height to which the ewes were exposed. At low sward surface heights, liveweight gain of shorn ewes was less than their unshorn counterparts, while at higher sward surface heights there was no difference. However, sward surface height tended to have no effect on ewe intake in the post-shearing period similarly, there was no interaction between shearing treatment and sward surface height.

Ewe condition score during pregnancy and lactation is not affected by shearing treatment (Dabiri *et al.* 1996; Revell *et al.* 2002). However, Dabiri *et al.* (1996) and Jopson and Davis (2000) both reported that back fat depths were lower in shorn ewes during late pregnancy than in their unshorn counterparts.

*Lamb birthweights*

Cold exposure of the dam tends to increase gestation length (Thompson and Goode 1981; Thompson *et al.* 1982) and lamb birthweight (Thompson *et al.* 1982). Thompson *et al.* (1982) stated that exposing pregnant ewes to a cold environment could change the partitioning of nutrients between mother and foetus, in favour of the foetus. Therefore, if pregnancy shearing exposes ewes to cold stress under outdoor pastoral conditions, one would expect to find longer gestations and increased birthweights.

Greater gestation lengths have been observed in shorn ewes compared to their unshorn counterparts (Revell *et al.* 2002). However, pregnancy shearing has not consistently increased lamb birthweights (Table 1.1). Husain *et al.* (1997) reported an increase in lamb birthweights in one of two groups. Morris *et al.* (2000) and Revell *et al.* (2002) reported the response to be single-specific, while Morris and McCutcheon (1997) and Smeaton *et al.* (2000) observed it to be twin-specific. In a large-scale study involving twin-bearing ewes only Morris *et al.* (1999) observed an increase in birthweights from pregnancy shearing. Similarly, in an intensive study involving twin-bearing ewes only

**Table 1.1.** Summary of studies examining birthweight responses to pregnancy shearing under New Zealand conditions.

| Stage of gestation when dam shorn and shearing method | Lamb rank | Response to shearing (kg)[1] | Reference |
|---|---|---|---|
| P50(sc,cc) | Singles | +0.7 * | Morris *et al.* (2000) |
| | Twins | -0.1 | |
| P70(sc,cc) | Singles | -0.4 | Morris and McCutcheon (1997) |
| | Twins | +0.7 * | |
| P67 | Twins | +0.3 * | Morris *et al.* (1999) |
| P70(sc,cc) | Singles | +0.8 * | Morris *et al.* (2000) |
| | Twins | -0.3 | |
| P70(sc) | Singles | +0.8 * | Revell *et al.* (2002) |
| | Twins | +0.2 | |
| P70(sc) | Singles | 0.0 | Smeaton *et al.* (2000) |
| | Singles | +0.2 | |
| | Twins | +0.2 * | |
| | Twins | +0.2 * | |
| P74 | Twins | +0.3 * | Jopson and Davis (2000) |
| P91(sc) | All | -0.1 | Parker *et al.* (1991) |
| P100(sc,cc) | Singles | -0.2 | Morris and McCutcheon (1997) |
| | Twins | +0.4 * | |
| P100(sc,cc) | Singles | +0.8 * | Morris *et al.* (2000) |
| | Twins | +0.3 | |
| P114(sc) | All | +0.1 | Dabiri *et al.* (1995b) |
| (cc) | All | +0.1 | |
| P115(sc) | All | +0.6 * | Husain *et al.* (1997) |
| (cc) | All | +0.2 | |
| P118 | All | -0.1 | Dabiri *et al.* (1996) |
| P119(sc) | All | +0.05 | Orleans-Pobee and Beatson (1989) |
| P123(sc) | All | -0.3 to +0.1 | Dabiri *et al.* (1994) |
| P130(sc,cc) | Singles | -0.6 | Morris and McCutcheon (1997) |
| | Twins | +0.3 * | |
| P130 | Twins | +0.2 * | Morris *et al.* (1999) |

[1] Birthweight response in comparison to lambs born to unshorn dams.

* Response significant at $P<0.05$

sc = standard comb, cc = cover comb.

Jopson and Davis (2000) reported a birthweight response. Lambs born to shorn ewes in that study were longer in body length (crown rump length) but shorter in stature (hip to foot length) than their counterparts born to unshorn dams. In other studies, pregnancy shearing has failed have any effect on birthweights (Orleans-Pobee and Beatson 1989; Parker *et al.* 1991; Dabiri *et al.* 1994, 1995b, 1996). Cloete *et al.* (1994) in South Africa observed a birthweight response in only one year of a two-year study.

Morris and McCutcheon (1997) and Morris *et al.* (2000) observed the birthweight response in lambs born to ewes shorn with either the standard- or the cover-comb. However, Husain *et al.* (1997) found the shearing response occurred only in lambs born to ewes shorn with the standard-comb.

Pregnancy shearing has not been observed to reduce lamb birthweights in any study. However, on some occasions it has resulted in a birthrank specific response only. There is no clear indication as to why this occurs. Factors affecting the consistency of the birthweight response will be examined in a later section of this review.

*Heat production of lambs*

Revell *et al.* (2002) found that the summit metabolic rates (SMR) of singleton lambs born to shorn dams were lower than that of their counterparts born to unshorn dams. In contrast they found twin-lambs born to shorn dams had increased SMR. They failed to conclude why the response was birthrank specific. However, they stated, that the whole body SMR (W/kg x live weight) did not differ between singletons born to either unshorn or shorn dams, as the lambs born to unshorn dams were significantly lighter. Therefore further studies are required to determine if the thermoregulatory response seen in newborn lambs born to winter shorn pasture grazed dams is the same as that seen observed housed conditions.

*Lamb survival and growth*

Traditionally pre-lamb shearing under pastoral conditions has been associated with increased newborn lamb survival. It has resulted in: the ewe being more likely to seek shelter; easier lambing; suckling being facilitated with reduced difficulty in teat finding; and fewer ewes being lost to casting with consequent loss of their lambs (Wodzicka-

Tomaszewska 1963a; Frengley 1964; Alexander and Lynch 1976; Lynch and Alexander 1976). Alexander *et al.* (1980) noted that survival rates of multiple-lambs born to shorn dams tended to he higher in poor weather conditions. However, the relationship was reversed for singles. Morris *et al.* (1999) reported that pregnancy shearing tended to increase survival rates of twin-lambs. In contrast Everitt (1961), Cloete *et al.* (1994), Dabiri *et al.* (1995b) and Smeaton *et al.* (2000) all reported no effect of pregnancy shearing on lamb survivability.

Gregory (1995) concluded that, in cold weather, pre-lamb shearing favours the lamb but not the ewe, while leaving the ewe unshorn disadvantages the lamb. Light-weight lambs (predominantly multiple-born) are susceptible to starvation-exposure due to their smaller body size and greater surface area to body weight ratio. Morris and McCutcheon (1997) suggested that the increase in birthweight of twin-born lambs (which are lighter than their single-born counterparts) from pregnancy shearing should increase their survivability. However, an increase in the bodyweight of singles may negate the positive effects of increased birthweight in lighter twins by increasing losses due to dystocia.

Pregnancy shearing under New Zealand pastoral conditions has generally not affected lamb growth rates (Dabiri *et al.* 1994, 1995b, 1996; Morris and McCutcheon 1997; Husain *et al.* 1997; Morris *et al.* 2000; Revell *et al.* 2002). However, Morris *et al.* (1999) found that weaning weights of twin lambs born to shorn dams were heavier than their counterparts born to unshorn dams. Similarly, Cloete *et al.* (1994) in South Africa reported higher growth rates to 8 weeks of age in lambs born to shorn dams. Smeaton *et al.* (2000) found singletons born to shorn ewes were heavier at weaning than their counterparts born to unshorn ewes in one of two studies. However, in the same studies there was no effect of ewe shearing treatment on weaning weights of twin born lambs.

*Factors affecting the productive responses*

*Stage of gestation when shorn under New Zealand conditions*

Birthweight responses have occurred from both mid- and late-pregnancy shearing of ewes (Table 1.1). However, across studies, both mid- and late-pregnancy shearing have also failed to achieve a birthweight response. As observed in shorn housed ewes, there is no exact time of shearing that maximises the birthweight response. However, the data suggest that a more consistent birthweight response occurs if ewes are shorn before the last third of gestation. Morris and McCutcheon (1997) suggested that shearing ewes during mid-pregnancy (P70) has a greater chance of affecting placental development and thus birth weight than shearing in late pregnancy, as placental weight peaks at around day 100 of gestation.

*Intake response to shearing*

It is known that shearing can result in an increased intake of castrated males and non-pregnant ewes (Wodzicka-Tomaszewska 1963a,b). An often-cited disadvantage of pre-lamb shearing is an increase in the feed requirement of the ewe, but this varies with air temperature, wind velocity, herbage length and availability and other environmental factors (Frengley 1964). Elvidge and Coop (1974) showed that in exposed conditions, pregnant and non-pregnant ewes could increase their intake by up to 80% in the month following shearing in comparison to intakes of unshorn ewes in either exposed or calm conditions.

However, pregnancy shearing has generally failed to increase voluntary intake prior to lambing (Parker *et al.* 1991; Dabiri *et al.* 1995b; Husain *et al.* 1997; Revell *et al.* 2002) with only Dabiri *et al.* (1996) noting an increase in intake 20 days after shearing. Parker *et al.* (1991) found that pre-lamb shorn ewes had consistently higher intakes during lactation (though not always significant) than ewes that were unshorn. Since both Husain *et al.* (1997) and Revell *et al.* (2002) observed a birthweight response from pregnancy shearing it would appear that the response is not dependent on an increase in intake.

Husain *et al.* (1997) suggested that the lack of an effect on intake from pregnancy shearing could be due to the physiological state of the ewes. Forbes (1968) stated that uterine compression of the rumen volume in later pregnancy limits the ability of the ewe to increase intakes. Morris and McCutcheon (1997) suggested that ewes shorn relatively early in pregnancy would have a greater opportunity to increase intakes than those shorn in late pregnancy.

*Effect of ewe herbage allowance following pregnancy shearing*

Herbage allowance describes the amount of pasture that is offered to an animal on a per day basis, and is measured to ground level however, due to the physical impossibilities of consuming all of this pasture, intake is always smaller than allowance.

A birthweight response to pregnancy shearing has occurred in single- (Morris *et al.* (2000) and twin-bearing (Morris and McCutcheon 1997) ewes offered a maintenance level of herbage allowance during the mid- to late-pregnancy period. However a birthweight response has not occurred in single bearing (Morris and McCutcheon 1997) and twin bearing (Morris *et al.* 2000) ewes offered a maintenance level of allowance. The contradicting results for maintenance herbage allowance, and the lack of data for either high or low allowances (which often occurs on New Zealand farms in the winter period) mean a conclusion regarding the relationship between dam allowance and the birthweight response cannot be made. Additionally, definitions of what constitutes a low, maintenance or high level of allowance post-shearing often differ between studies, making it difficult for a true comparison to be made. Therefore the relationship between the birthweight response to mid-pregnancy shearing and dam allowance requires further examination

*Conclusion*

Cold stress of the dam results in longer gestations and greater birthweights. Pregnancy shearing under pastoral conditions has been observed to increase both gestation length and birthweight in many studies, indicating that cold stress may be the signalling mechanism. There appears to be no clear relationship between the birthweight response and either ewe intake or herbage allowance post-shearing. No exact time of shearing to maximise the birthweight response has been identified, but the data suggest that a more consistent result occurs when ewes are shorn in mid-pregnancy rather than late pregnancy.

**The effect of pregnancy shearing on wool quality and quantity**

Although the main reason for considering pregnancy shearing in this study are to examine the lamb birthweight and heat production/survival responses, shearing of the dam can also affect wool quality and quantity. The wool collected from ewes shorn during pregnancy is commonly referred to as pre-lamb shorn wool. Wool growth is minimal during winter/early spring (Sumner *et al.* 1994; Champion and Robards 1995; Dick and Sumner 1997), which often coincides with late pregnancy and early lactation. Thus treatments that occur during this period may have little effect on yearly wool production.

Wodzicka-Tomaszewska (1963a) stated that wool of pre-lamb shorn ewes is of better quality than post-lamb shorn wool, having fewer faults (cotting, tenderness, yellowness and discolouration) and a higher clean scoured yield. Similarly, Parker (1992) stated that pre-lamb wool is of better colour and strength than main shear wool. Hawker and Littlejohn (1989) suggested that an advantage of pre-lamb shearing, is that it occurs when the weakest part of the fibre is at the butt end. In comparison, summer-shorn full length wools are weakest near the middle of the fibre, which can adversely affect average fibre length post-processing. Others however, have failed to find any effect of pre-lamb shearing on wool quality and grade (Rutter *et al.* 1971, 1972; Maund 1980). Morris *et al.* (2000) observed that neither shearing treatment (shorn vs unshorn) nor shearing method (standard vs cover comb) had any effect on staple strength. Dabiri *et al.* (1996) reported there was no effect of shearing treatment on mean fibre diameter.

Pre-lamb shearing has generally been found to have no effect on wool growth (Nedkvitine 1972; Salman and Owen 1986; Dabiri *et al.* 1996; Husain *et al.* 1997; Morris and McCutcheon 1997; Morris *et al.* 2000; and Revell *et al.* 2002). However, Kneale and Bastiman (1977) observed, in one of two studies, that pre-lamb shearing reduced wool growth. In contrast, Smeaton *et al.* (2000) found mid-pregnancy shearing increased ewe annual fleece weight by 0.2 to 0.6 kg.

Morris and McCutcheon (1997) and Morris *et al.* (2000) noted that method of pregnancy shearing (standard vs cover comb) had no effect on wool growth.

Pregnancy shearing obviates one full muster of ewes with lambs at foot (Frengley 1964). Once yearly pre-lamb shearing has a number of advantages including a reduction in overdraft charges for seasonal finance, higher wool returns, less shearing costs, reduction in wool lost from ewes that die over lambing, increase in spread of labour requirements, and an increase in flexibility around the weaning period, (Frengley 1964; Parker and Gray 1989; Parker 1992; Parker *et al.* 1995). However, under most New Zealand conditions, pre-lamb shearing would most likely require the implementation of a twice-yearly shearing policy, which may increase costs. Shearing twice yearly results in one of two management options, firstly, shearing pre-wean/pre-tup or post-wean/post tup (Livingston and Parker 1984). Shearing post-weaning and post-tupping best matches the mid-pregnancy shearing policy. The wool producer is paid on the basis of quantity and quality. These studies generally indicate that total wool production and quality are not adversely affected (although staple length will be reduced by a twice-yearly shearing policy) by pregnancy shearing. Therefore, the total value of the wool clip should not be negatively affected by the pregnancy shearing in a twice-yearly shearing policy however, costs may be increased.

**Metabolic responses to pregnancy shearing**

Due to the limited information on the effects of pregnancy shearing on maternal metabolic responses, the indoor and pastoral situations will be discussed together. However, the effects of pregnancy shearing on maternal metabolites and hormones in the housed situation are probably different from those reported under pastoral conditions due to differences in the dam's environment (as discussed earlier) and therefore need to be considered separately when conclusions are being drawn.

*Blood metabolites*

*Glucose*

Glucose is the central fuel in the energy metabolism of most animals (Herdt 1997). Acute maternal cold exposure is known to result in increased concentrations of glucose and glycerol in maternal plasma and increased concentrations of glucose in foetal plasma (Thompson *et al.* 1982). Therefore, if pregnancy shearing under outdoor conditions exposes ewes to cold stress, one would expect to find elevated concentrations of glucose and glycerol in maternal plasma post-shearing. An increase in maternal blood glucose levels should in turn increase foetal supply of glucose (as indicated by the results of Thompson *et al.* 1982), since foetal uptake of glucose across the placenta is largely dependent on the maternal-foetal concentration gradient. An increase in foetal glucose supply is a possible mechanism for the birthweight response to pregnancy shearing.

Post shearing, Morris *et al.* (2000) observed higher maternal glucose concentrations under pastoral conditions in shorn ewes in comparison to their unshorn counterparts. Similarly, Pierzchala *et al.* (1983) found that shearing increased the plasma glucose concentrations in non-pregnant housed animals. However, cooling following shearing had no effect. This suggests a glucocorticoid (effects on cortisol will be discussed in a later section) response post-shearing independent of cold exposure. An increase in maternal glucose concentrations has also been reported in some housed pregnancy shorn ewes (Kirk *et al.* 1984; Black and Chestnutt 1990) but not in others (Symonds *et al.* 1986; Symonds *et al.* 1992). Revell *et al.* (2000) observed no effect of shearing on maternal basal glucose concentrations.

*Fatty acids*

As pregnancy advances and as foetal requirements for glucose increase the dam is often unable to maintain normal blood concentrations of glucose (Russel *et al.* 1967). In such a situation the ewe will begin to mobilise body fat reserves (Russel *et al.* 1967). Aulie *et al.* (1971) suggested that non esterified fatty acids (NEFA) and free glycerol concentrations are good indicators of fat mobilisation. Increased circulating concentrations of NEFA indicate increased rates of body fat mobilisation to support heat production (Dabiri *et al.* 1995a). Therefore, if pregnancy shearing induces cold stress in the outdoor situation, one would expect to find elevated levels of NEFA post-shearing. Elvidge and Coop (1974) reported that shorn ewes had elevated plasma NEFA concentrations in comparison to their unshorn counterparts. They stated that the levels found were similar to those observed in under-nourished sheep.

Under housed conditions, shearing of pregnant ewes has been found in some studies to increase maternal concentrations of NEFA for at least the one week following shearing (Nedkvitine *et al.* (1971) cited by Nedkvitine 1972; Aulie *et al.* 1971); but in others to have no effect (Symonds *et al.* 1986, 1992). Symonds *et al.* (1986) however, did find an increase in the oxidation of fatty acids (as measured by Non-Protein Respiratory Quotient (NPRQ)). Similarly, Symonds *et al.* (1989) reported that both the whole body NEFA entry and oxidation rates were significantly higher in shorn than unshorn ewes, although there was no difference in circulating NEFA concentrations. They suggested that the NEFA concentration is not increased in shorn ewes because the high lipolytic rate is associated with a significant rise in the rate of NEFA oxidation. Higher free glycerol concentrations post shearing have also been reported (Aulie *et al.* 1971).
Symonds *et al.* (1986) concluded that shorn ewes derive more energy from mobilised maternal tissue than their unshorn counterparts. Similarly, Symonds *et al.* (1989) concluded that shearing imposes a chronic increase in energy demand, which is met by oxidising maternal adipose tissues. Symonds *et al.* (1986) further concluded that winter shearing of pregnant ewes results in long-term metabolic adaptation to a cold environment which is beneficial to both the ewe and the foetus. They suggested, ewes appeared to be able to utilise NEFA without exhibiting the high plasma NEFA and

ketone body concentrations (as found in animals at risk from pregnancy toxaemia) to meet the increased expenditure associated with cold exposure. Furthermore, foetal growth was enhanced perhaps as a result of these metabolic adaptations (Symonds *et al.* 1986).

Revell *et al.* (2000) found that housed unshorn twin-bearing ewes had higher plasma NEFA concentrations and reduced intake compared to their shorn counterparts. It is possible that this reduced intake was a mechanism to avoid heat stress. Therefore the twin-bearing unshorn ewe needed to mobilize body reserves to provide sufficient energy for itself.

*Hydroxybutyrate*

β-hydroxybutyrate is a ketone body and is often used as an indicator of excessive rates of fat breakdown. Therefore if shearing places the ewe under cold stress which is met by increased fat breakdown to support heat production, elevated concentrations of β-hydroxybutyrates may be expected (especially in situations were carbohydrate supply is low i.e. low feed intake). However, Symonds *et al.* (1986), Black and Chestnutt (1990) and Symonds *et al.* (1992) found no effect of shearing on maternal plasma concentrations of 3-hydroxybutyrate plasma concentrations in housed ewes. On the other hand, Vipond *et al.* (1987) found that mean concentrations of β-hydroxybutyrate were significantly higher in late gestation in unshorn than in shorn ewes. They suggested that this could be interpreted as indicating nutritional stress, as in contrast to unshorn ewes shearing resulted in an increased intake (therefore reducing any possible negative effects of a nutritional stress).

The lower intakes of unshorn pregnant ewes in housed conditions may be an avoidance mechanism to heat stress (and may therefore help explain the elevated β-hydroxybutyrate concentrations). However, Bell *et al.* (1989) reported that maternal 3-hydroxybutyrate levels were not affected by heat stressing pregnant ewes, even though intake tended to be reduced in late pregnancy. Since there are no trials where hydroxybutyrate concentration has been measured in pregnancy-shorn ewes under pastoral outdoor conditions or in very cold housed conditions it is difficult to determine whether maternal concentrations are affected in cold conditions.

*Maternal hormones*

*Cortisol*

Cortisol is a glucocorticoid hormone produced by the adrenal cortex. Glucocorticoids stimulate hepatic gluconeogenesis, which results in an increase in hepatic glycogen and a tendency to increase blood glucose concentrations and increase the rate of lipolysis in adipose tissue (Greco and Stabenfeldt 1997). Excess levels of cortisol increase plasma glucose levels, by inhibiting insulin-stimulated glucose uptake in muscle (Genuth 1993; Greco and Stabenfeldt 1997). Therefore if cortisol concentrations were increased by pregnancy shearing, it is possible that extra glucose may become available to the foetus via diffusion across the placenta.

When an animal is stressed, the cortisol concentration increases, with the magnitude of this increase being proportional to the level of stress (Greco and Stabenfeldt 1997). Pregnancy shearing may result in an increase in cortisol due to both stress associated with shearing and a sudden change in body temperature. Symonds *et al.* (1986) found no effect of pregnancy shearing on maternal cortisol concentrations in housed ewes. In contrast, Pierzchala *et al.* (1983) reported that in non-pregnant animals shearing increased blood plasma cortisol concentrations but cooling following shearing had no effect. There are no data available on the effect on cortisol concentrations of pregnancy shearing ewes under pastoral conditions

*Insulin*

Insulin promotes glucose entry into cells of the body and in this way controls the rate of metabolism of most carbohydrates (Guyton 1991). Symonds *et al.* (1986) found that concentrations of insulin tended to be lower in shorn than unshorn ewes. They concluded that cold stress induced by shearing may inhibit insulin secretion resulting in increased plasma glucose concentrations. In contrast Revell *et al.* (2000) noted that shearing had no effect on insulin concentrations in the dam during mid-pregnancy. However, in late pregnancy basal concentrations tended to be lower in twin-bearing shorn ewes (were a birthweight response was observed) in comparison to their unshorn counterparts. They also observed that shearing twin-bearing ewes caused a greater reduction in the insulin response to a glucose challenge in late pregnancy than it did for single-bearing ewes. This would be consistent with an increased sensitivity of maternal tissue to insulin. However, insulin challenges caused the same reductions in plasma glucose concentrations in all ewes. Revell *et al.* (2000) suggested that a reduced insulin release in response to glucose challenge might reflect an enhanced non-insulin dependent glucose clearance. A possible candidate for this uptake is diffusion across the placenta. Under pastoral conditions Morris *et al.* (2000) found no effect of pregnancy shearing on maternal insulin concentrations and stated that the productive responses found (increased singleton lamb birthweight) were unlikely to be mediated though a change in insulin sensitivity. Interestingly, Thompson *et al.* (1982) showed that acute cold stress of the dam resulted in higher concentrations of insulin in foetal plasma. This may indicate that endocrine changes in the foetus rather than the dam stimulate the birthweight response from cold exposure (and possibly pregnancy shearing). However, if this is correct, there must be a maternal trigger to effect changes in foetal hormone concentrations.

*Thyroid hormones*

Thyroid hormones increase oxygen consumption of tissues and, as a result, increase heat production (known as the calorigenic effect), affect carbohydrate metabolism, and facilitate the movement of glucose into both fat and muscle, facilitate insulin-mediated glucose uptake by cells, and affect lipid metabolism (Greco and Stabenfeldt 1997). Of the total thyroid hormone released, about 90% is thyroxine (T4) and 10% is tri-iodothyronine (T3) (Kaneko 1997). T4 is converted to T3 by deiodinase enzymes in tissues such as the liver and possibly the kidney (Genuth 1993). T3 is the active form of the thyroid hormone within the target cell (Kaneko 1997).

Over the final stages of foetal development thyroid hormones are necessary for promoting maturation of many tissues and organs, including BAT, liver and lungs (Symonds 1995). Therefore, alterations in thyroid hormone regulation can have a major effect on foetal growth and development. However, the importance of thyroid hormones in manipulating foetal growth reduces with advancing gestational age in sheep (Symonds 1995).

Athyroid foetuses are known to have low birthweights (Hopkins and Thorburn 1972). Similarly, Cabello and Levieux (1981) reported a positive correlation between new-born lamb T3 and T4 concentrations soon after birth and birth weight.

Bell *et al.* (1989) found T3 concentrations to be significantly reduced in heat stressed ewes, though T4 concentrations were not affected. They suggested that heat-induced foetal growth retardation is secondary to a primary reduction in placental growth and that this could be mediated partly by reduced peripheral activity of thyroid hormones. Similarly, Symonds (1995) stated that chronic maternal heat stress during mid- to late pregnancy lowers plasma T3 concentrations and leads to a reduction in food intake, the combination of which inhibits placental growth. However, Shelton (1965) reported that additional thyroxine implants during pregnancy of non-thyroidectomised heat-stressed ewes actually lowered lamb birthweights (the thyroid gland is likely to display a negative feedback effect and thus total T4 concentrations may not have been increased). It is unlikely under pastoral conditions that the birthweight effect from pregnancy shearing is due to relief of heat stress, although it may be the case in some indoor situations.

Symonds *et al.* (1986) suggested that a possible endocrine mechanism for the cold adaptation found in shorn ewes, may be due to elevated concentrations of thyroid hormones. In non-pregnant housed animals Pierzchala *et al.* (1983) found a rise in T4 concentrations following shearing which appeared to be dependent on the degree of cooling, returning to initial levels after 5 to 10 days. T3 concentrations were also elevated for the period following shearing. Symonds *et al.* (1989) found maternal T3 and T4 concentrations to be higher in pregnancy-shorn housed ewes than unshorn ewes.

Under outdoor conditions Morris *et al.* (2000) found an increase in maternal T3 concentrations for at least 20 days after shearing. They suggested that this provided a possible signalling mechanism that affected foetal growth. However, they only found the birthweight effect in singleton lambs (in contrast the elevated T3 concentrations were found in both single- and twin-bearing ewes). They suggested the response from an increase in maternal T3 concentrations will only occur if there is a potential for increased foetal growth.

The results of Symonds *et al.* (1989) and Morris *et al.* (2000) suggest that the birthweight response to pregnancy shearing could be due to changes in maternal thyroid hormone concentrations. Elevated maternal thyroid hormones could be working in one of two ways: first by elevating foetal thyroid hormones concentrations; or second, by affecting maternal metabolism and thus foetal nutrition. It is known that, at least over the final third of gestation, the ovine placenta is impermeable to maternal T4 (Hopkins and Thorburn 1972; Nathanielsz *et al.* 1973). This suggests, that the foetal lamb is wholly dependent on its own thyroid gland in late pregnancy (Hopkins and Thorburn 1972). Therefore increased maternal thyroid hormone concentrations found in pregnancy-shorn ewes will not result in a direct increase in foetal thyroid hormone concentrations in late pregnancy through diffusion across the placenta. Thus, if higher concentrations of maternal thyroid hormones in this period are responsible for the heavier birthweights observed they are most likely altering maternal metabolism. Symonds *et al.* (1989) concluded that the increased rates of lipolysis and NEFA oxidation in shorn ewes could be influenced by the higher plasma concentration of T3 and T4. This extra lipolysis and NEFA oxidation could result in more glucose becoming available for foetal growth.

*Growth hormone*

Growth hormone promotes growth of the animal by affecting protein formation, cell multiplication, and cell differentiation (Guyton 1991). Symonds *et al.* (1986) found no effect of shearing on plasma concentrations of growth hormone in housed ewes. No data are available for the pastoral situation.

*Summary of shearing effect on maternal hormones*

Based on the limited data available it appears that pregnancy shearing has no effect on the concentration of growth hormone. In the housed situation insulin concentrations have tended to be lower post-shearing however, under pastoral conditions no such effect has been found. Cortisol concentrations post-shearing (reported to be elevated post-shearing in non-pregnant animals) warrant further investigation to see if the same response is observed in pregnant animals. Thyroid hormone concentrations have been found to be higher post-shearing under both housed and pastoral conditions. Thyroid hormones play an important role in metabolism and any changes in their concentrations could have an effect on maternal metabolism and thus foetal nutrition. Therefore further work is warranted in determining the exact role thyroid hormones play in the pregnancy shearing response.

**Purpose and scope of the investigation**

As previously stated, peri-natal mortality of lambs in New Zealand is between 5 to 25%. Any treatment that can substantially reduce these losses is potentially worth $100 million to the New Zealand sheep industry. Early mid-pregnancy shearing studies in New Zealand have shown that this technique has the potential to increase lamb birthweights. However, to date, the results have been variable in both the magnitude of the response and the consistency of achieving a birthweight response.

The objectives of this study were therefore to address several issues related to mid-pregnancy shearing, in particular to examine:

1. The causes of the variability in the birthweight response to mid-pregnancy shearing with the aim of trying to predict conditions in which a birthweight response will occur.
2. The effect of mid-pregnancy shearing on the thermoregulatory capability of the new born lamb.
3. The effect of mid-pregnancy shearing on lamb survival rates to weaning.
4. A possible metabolic mechanism for the birthweight response.

Studies were conducted both in the field and using calorimetry with approval from the Massey University Animal Ethics Committee.

# Chapter two - The effect of ewe nutrition during mid- and late-pregnancy on the birthweight response from mid-pregnancy shearing


## Abstract

This study was designed to determine whether dam nutrition during mid- to late-pregnancy influences birthweight responses from pregnancy shearing. Romney-cross ewes were either shorn during mid-pregnancy (n=68) or left unshorn (n=66). Ewes were offered either a maintenance level of feed (a level of nutrition that enabled the dam to maintain conceptus free liveweight) or a high level of feed (a level of nutrition that enabled the dam to gain 100 g/day of conceptus free liveweight in addition to expected foetal growth) during the mid-pregnancy (post shearing) period (from day 70 of pregnancy (P70) until P101). At the end of this period ewes were offered either maintenance or a high level of nutrition during late pregnancy (P102-P139).

Pregnancy shearing was found to increase lamb birthweight (average birthweight 5.4 ±0.1 versus 5.1 ±0.1 kg, $P<0.05$) without differentially affecting the birthweight of singles or twins. Dam feeding level post-shearing did not affect the birthweight response to mid-pregnancy shearing. Pregnancy shearing treatment had no effect on the summit metabolic rate of twin lambs. However, when results of this study are compiled with those of previous mid- to late- pregnancy shearing studies under similar conditions, it appears that the birthweight response to pregnancy shearing is greatest where light weight lambs are born to unshorn (control) ewes.

## Introduction

In New Zealand each year at least 15% of newborn lambs die before weaning, many of these deaths being associated with low birthweights and/or a poor ability of the newborn lamb to tolerate its new environment. Indoor studies in the UK have shown that shearing of the dam during pregnancy can increase lamb birthweights (Vipond *et al.* 1987; Symonds *et al.* 1986; Black and Chestnutt 1990). However, shearing of the housed ewe probably relieves the ewe of heat stress and thus removes a detrimental effect on foetal growth. The removal of heat stress is a situation not likely to occur in New Zealand's outdoor farming conditions, where removal of the dam's fleece during the winter period is more likely to induce cold stress. Cold stress of the dam during gestation is known to increase lamb birthweights (Thompson *et al.* 1982). Under New Zealand pastoral conditions, Morris and McCutcheon (1997) and Morris *et al.* (2000) have identified mid-pregnancy (P50 – 100) as the optimum time to achieve a consistent birthweight response from pregnancy shearing. However, across all studies involving mid-pregnancy shearing an inconsistent birth-rank response has occurred (Morris and McCutcheon 1997; Morris *et al.* 2000; Revell *et al.* 2002).

Dam nutrition during mid- and/or late-pregnancy has been shown to affect both foetal growth and lamb birthweights (Russel *et al.* 1967; Rattray and Trigg 1979; Cooper *et al.* 1998). In the studies of Morris and McCutcheon (1997), Morris *et al.* (2000) and Revell *et al.* (2002) ewes were offered differing levels of nutrition during the mid- to late-pregnancy period. Therefore, the variable shearing effect on lamb birthweight may have been influenced by ewe nutrition. The relationship between the birthweight response to mid-pregnancy shearing and ewe nutrition post-shearing under outdoor pastoral conditions has not been examined. Revell *et al.* (2002) showed that mid-pregnancy shearing had no effect on ewe intake in a study in which the birthweight response was only found in singletons.

Many lamb losses are due to the inability of the newborn lamb to maintain heat production at a level equal to, or greater than, that lost to the environment into which it is born. The results of Stott and Slee (1985) and Symonds *et al.* (1992) suggest that shearing of housed pregnant ewes may result in their lambs having enhanced cold-resistance. Revell *et al.* (2002) found that twin lambs born to shorn dams under New

Zealand conditions had higher summit metabolic rates than lambs born to their unshorn counterparts. However the opposite relationship was found in singletons. Any increased cold resistance in addition to increased lamb birthweight should substantially increase the survival rates of otherwise light-weight lambs (predominantly multiple-born lambs).

This study was designed to investigate the effect of mid-pregnancy shearing treatment and ewe feed allowance on ewe herbage intake, lamb birthweight and the cold resistance of newborn lambs. It was hypothesised that differing feeding regimens post-shearing are responsible for the variable responses achieved in lamb birthweight from mid- to late-pregnancy shearing.

## Methods

*Experimental design and animals*

The experimental design was a 2 x 2 x 2 x 2 factorial, incorporating two shearing policies (shorn on day 70 of pregnancy (P70) versus unshorn), two pregnancy ranks (single versus twin), two ewe feeding levels between P70 and P101 of pregnancy (maintenance versus high) and two ewe feeding levels between P102 and P139 (maintenance versus high). One hundred and sixty (80 twin-bearing and 80 single-bearing) progesterone-synchronised (CIDR, type G, Livestock Improvement Corporation, Hamilton, New Zealand), mixed-aged (3 – 5 years) Border Leicester x Romney ewes were used in the trial. Ewes were selected on the basis of pregnancy diagnosis by ultrasound on P56. All selected ewes had been mated to Coopworth rams in the three-day period after CIDR removal and were selected from an original flock of 330 ewes. The trial was conducted at Massey University's Keeble Farm (latitude 41° 10'S), 5km south of Palmerston North, New Zealand. The trial period was 20 March (mating) until 2 November (weaning) 1998.

*Treatments*

Half of the single-bearing ewes (n=40) and half of the twin-bearing ewes (n=40) were shorn at P70 using a standard comb (Sunbeam New Zealand Ltd, maximum depth of teeth 4mm). The other 80 ewes were left unshorn (approximately 7 months wool growth) to serve as controls. Unfasted live weights (all ewes were weighed within an hour of being removed from pasture) of shorn ewes were adjusted for the weight of the fleece removed (at P70) to allow a comparison with the unshorn ewes.

At P70 ewes were stratified by age and liveweight and then randomly allocated to feeding treatments. From P70 until P101 (feeding period one), half of the single-bearing ewes and half of the twin-bearing ewes were offered a 'maintenance' (M) level of feed, with the other half being offered a 'high' (H) level. Group M was fed to permit weight gain equivalent to the expected conceptus growth (Rattray *et al.* 1974; McCutcheon *et al.* 1986; Nicol 1987). Group H was fed to permit weight gain equivalent to the expected conceptus growth plus approximately 100g of maternal weight per day. At day P102 (start of feeding period two), each treatment group was sub-divided into two, with half of the ewes allocated to feeding level H, as described previously, and the other half to feeding level M, with each group being balanced for ewe age and liveweight. The first feeding period (P70-101) coincides with the period of rapid placental growth (placental weight peaks at approximately P90 – 100) and the second feeding period (P102- 139) coincides with the time of exponential foetal growth (Geenty 1997). Thus four feeding regimens (M-M, M-H, H-M and H-H) were established (diagrammatically shown in Figure 2.1). Target liveweights for single M-M, twin M-M, single M-H, twin M-H, single H-M, twin H-M, single H-H and twin H-H ewes at P139 were 67, 75, 71, 79, 70, 78, 74 and 82 kg respectively. Ewes were placed in these feeding regimens to allow examination of the relationship between shearing treatment and feeding in both mid- and late-pregnancy.

Ewes were removed from the trial if they showed clinical signs of facial eczema, failed to lamb within 14 days of the lambing period beginning, had triplets, or died (10, 9, 5, and 2 ewes respectively). Thus data from 134 ewes (M-M (n=34), M-H (n=33), H-H (n=33) and H-M (n=34)) and their lambs were used in this study.

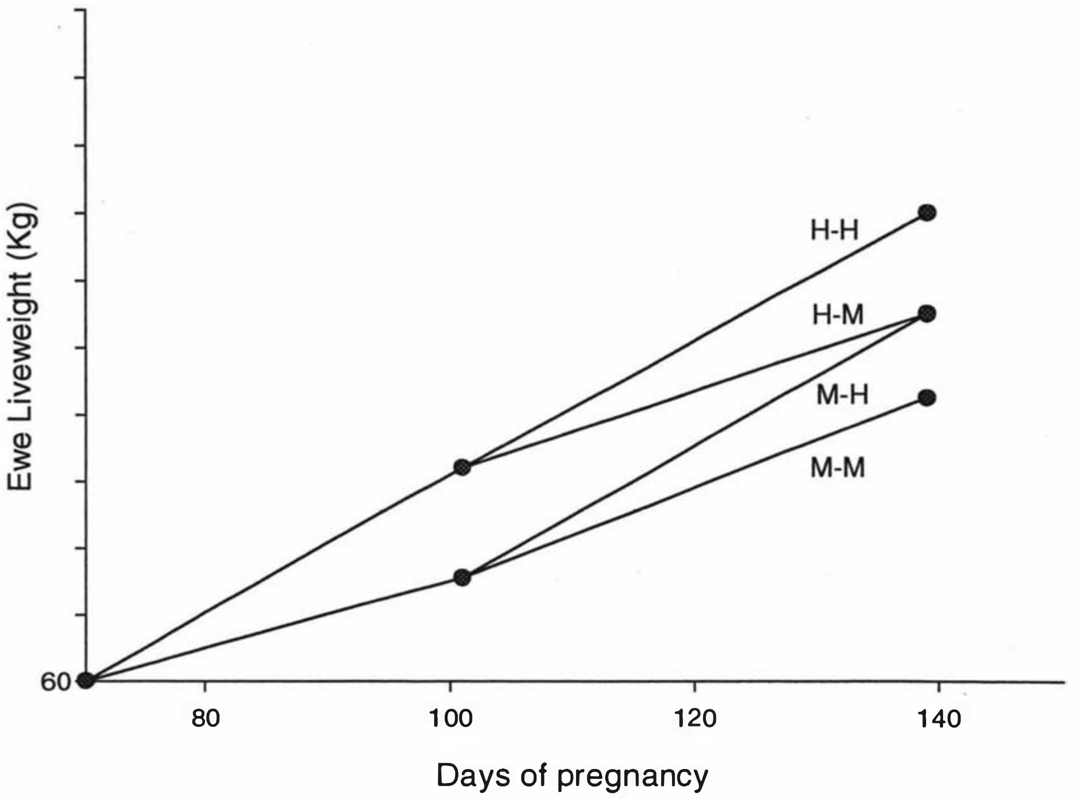



**Figure 2.1**. Ewe-group feeding regimens.

*Pasture*

Fourteen hectares of predominantly ryegrass (*L. perenne*) and white clover (*T. repens*) pasture were used for grazing the pregnant ewes from P70 to P139. Throughout this period, ewes fed at M level were grazed in two paddocks with a total area of 3.0 ha. Daily allocation of pasture for group M ewes was via electric fencing (break feeding). Group H ewes were rotationally grazed in 6 paddocks with a total area of 11.0 ha.

Once weekly pre- and post-grazing herbage masses (50 readings for each) for pastures offered to group M ewes were measured using a plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand). Pre-and post-grazing sward heights for group M pastures were measured during each of the three faecal collection periods (described later in the "animal measurement" section) using a sward stick (Jenquip, Feilding, New Zealand) (50 readings for both pre- and post-herbage mass). Once-weekly average herbage masses of pastures offered to group H ewes were recorded (50 readings in each paddock that ewes were grazed in during that week). An average sward height of group H pastures was taken during each of the three faecal collection periods (50 readings in each paddock in which ewes grazed during that period).

At P140, the H-H and M-M ewes were separated from groups M-H and H-M and set-stocked at an average pasture cover of 1200 kgDM/ha (pasture covers not falling below 900 kgDM/ha) and a stocking rate of 14.5 stock units su./ha until weaning. At the same time H-M and M-H ewes were set stocked at 37 su. /ha with an average cover of 2000 kgDM/ha (these ewes were separated from the other ewes and placed under a higher stocking density to allow for more intensive measurement of their lambs (described later in the "animal measurement section")) until the lambs were 48 hours old. The ewes and lambs were then removed and set stocked until weaning on an average herbage cover of 1200 kgDM/ha (pasture covers not falling below 900 kgDM/ha) at a stocking rate of 14.5 su./ha.

*Climatic data*

Throughout the period P70 – 139 daily maximum and minimum air temperatures were recorded at a weather station located approximately 3 km north of the trial site. The average maximum and minimum temperatures during this period were $14.2 \pm 1.1^{0}$C and $6.4 \pm 2.1^{0}$C respectively. During the lambing period (L1-14), air temperature (°C) (Tinytalk II temperature data logger, Gemini Data Loggers (UK) Ltd.) and average wind speed (km/hr) (Anemometer, Rauchfuss Institute and Staff Ltd, Australia) at approximately 1m above ground level were recorded at hourly intervals, at a site directly adjacent to the H-M and M-H lambing paddocks, to enable calculation of a wind chill factor.

*Animal measurements*

*Ewes*

Ewes were weighed (unfasted) at: mating; P56, 70, 77, 84, 96, 101, 108, 115, 126, 133, and 139; 38 days after the mid-point of lambing (L38) and L76. Ewe condition score (Jefferies, 1961, scale 0 – 5 including half units) was determined on P56, P101 and P139. Herbage intake of ewes was assessed indirectly by the use of intra-ruminal chromic sesquioxide capsules (3.0 cm core of pressed tablet, 65% $Cr_2O_3$ matrix and 9.00 mm orifice; Captec (NZ) Ltd, Auckland) as described by Morris *et al.* (1993). A capsule was administered to each ewe at P66 and faecal samples collected (mid-morning) over three 5-day periods from P73 to P89 to permit estimation of herbage intake. A second capsule was inserted at P90 and faecal samples collected over three 5-day periods between P97 and P114. A third capsule was inserted at P115 and faecal samples collected over three 5-day periods from P122 to P139. The samples were bulked (within ewe) for each sample period, oven dried at 60°C for three days and analysed for chromium content (Parker *et al.* 1989).

During the faecal collection periods, four-oesophageal fistulated (OF), castrated Romney sheep grazed with the ewes. One sample of consumed herbage (extrusa) from each of the fistulated sheep was collected from each of the two pasture treatments (M and H) in each of the nine periods of faecal sampling. Collected extrusa from each feeding group within each period was bulked and used for determination of *in vitro* digestibility as described by Morris *et al.* (1993). Intake measurements were taken to determine if mid-pregnancy shearing increased dam intake.

Rectal temperatures of all ewes were taken at P66, 67, 73, 75, 77, 84, 90, 99, 105, 112, 126, 133 and 139. This involved placing a small digital thermometer (Accu-Beep Digital, Becton Dickinson Consumer products, New Zealand) into the rectum of the ewes (prior to faecal sampling) for approximately 2 minutes until a stable reading was obtained. On each recording day the order of rectal temperature measurement for the 2 ewe groups was alternated (ewes had their rectal temperatures measured while they were in their feeding level groups).

All of the ewes were shorn at L54 and fleece weights recorded. Total annual fleece weights for ewes shorn at both P70 and L54 were calculated by adding together the weights of the two fleeces collected at each of these shearings. This combined weight was then compared to the annual fleece weights of ewes not shorn during mid-pregnancy.

*Lambs*

All newborn lambs were identified to their dam, tagged, sexed, weighed and their birth-rank recorded, either within an hour of birth (M-H and H-M lambs) or during twice daily monitoring at 8am and 4pm (H-H and M-M lambs). The mid-point of lambing was 16 August (L1). To estimate the effect of mid-pregnancy shearing on gestation length, day 1 of gestation was defined as the day after CIDR removal.

A random cohort of 45 lambs from groups M-H and H-M (20 M-H and 25 H-M), were monitored for rectal temperatures at 1, 3, 6, 9, 12, 18, 24, 36 and 48 hours of age with a digital rectal thermometer. Within the first hour of birth the crown-rump length and girth (the circumference of the torso directly behind the front legs while in the standing position) of these lambs were measured. To aid in identification from a distance, a unique number was sprayed onto the midside of each lamb.

A second random cohort of 51 different lambs from groups M-H and H-M (26 M-H and 25 H-M) were used to determine summit metabolic rate (SMR) via open circuit calorimetry (McCutcheon *et al.* 1983). Within the first hour of birth these lambs were also measured for crown-rump length and girth. At least 2 hours before SMR was measured (within 36 hours of birth) the lambs were brought indoors and placed in warm ambient conditions (20°C, in still air) to ensure that lambs were as near to their basal level of heat production as possible before testing began.

Immediately prior to the lambs being placed in the calorimeter, birth coat depth on the left midside area was measured using callipers. The lamb's head was then placed in a plastic hood, which was sealed around the neck using a plastic collar. Air was drawn into and from the hood for measurement of oxygen consumption. Once the lamb was placed in the calorimetry crate, a rectal probe was inserted (Revell *et al.* 2002). The body of the lamb was exposed to an ambient temperature of 5°C. The lambs were allowed to acclimatise to these conditions for 12 minutes with rectal temperature and oxygen consumption readings taken every four minutes. At the end of this 12-minute period the lambs were thoroughly soaked in cold water. A standardised stimulus of chilled water via a sprinkler at 0.3 l/minute and wind (via a fan) at 1.0 m/s was applied for a maximum of 44 minutes, with rectal temperature and oxygen consumption measurements taken at four-minute intervals. If the lambs reached their SMR before the end of this period they were removed from the calorimetry crate. Lambs which failed to reach SMR were then subjected to wind at 1.5 m/s and chilled artificial rain at 1.45 l/minute. Rectal temperature and oxygen consumption were measured at four-minute intervals over the following 40 minutes or until the lamb reached SMR, which ever occurred first. At the end of the calorimetry session, a single, wet coat depth measurement was taken at the same site as the dry coat depth measurement. Summit metabolic rate (W/kg) was determined from the highest value of heat production achieved when the lamb's rectal temperature was falling at a rate of at least 1°C per 20 minutes.

Rate of increase in heat production (W/kg/minute) in response to the standard stimulus was calculated for each lamb. The average heat production for lambs during the first 12 minutes (in which lambs were not exposed to artificial wind and/or rain) was determined (line A, Figure 2.2), as was the standard deviation of these four measurements. Then when the lambs were subjected to artificial rain and water, the last heat production value obtained in which heat production was greater than two standard deviations from the previous reading (point B, Figure 2.2) was identified. The difference between this value and that of the average heat production value recorded in the first 12 minutes (i.e. B-A, W/kg) was then divided by the time elapsed since the stimulus (artificial rain and wind) began (point C), to determine the rate of increase in heat production (W/kg/min).

SMR is the maximal heat of heat production (W/kg) in the newborn lamb. Any treatment that enhances SMR should result in less lamb losses due to starvation-exposure. An increase in SMR results in the newborn lamb being better able to withstand cooler weather conditions before a drop body temperature occurs (which can lead to hypothermia). Additionally, a failure to reach SMR (in the standard conditions used) means that the newborn lamb has an ability to produce body heat at a level greater than it is lost to the environment during the testing procedure. If there are differences in the rate of failure to reach SMR between treatment groups this would suggest a higher SMR within a treatment group(s). Furthermore, any treatment that increases the rate of change heat production (W/kg/minute) in response to adverse environmental conditions has the potential to increase survival rates in newborn lambs.

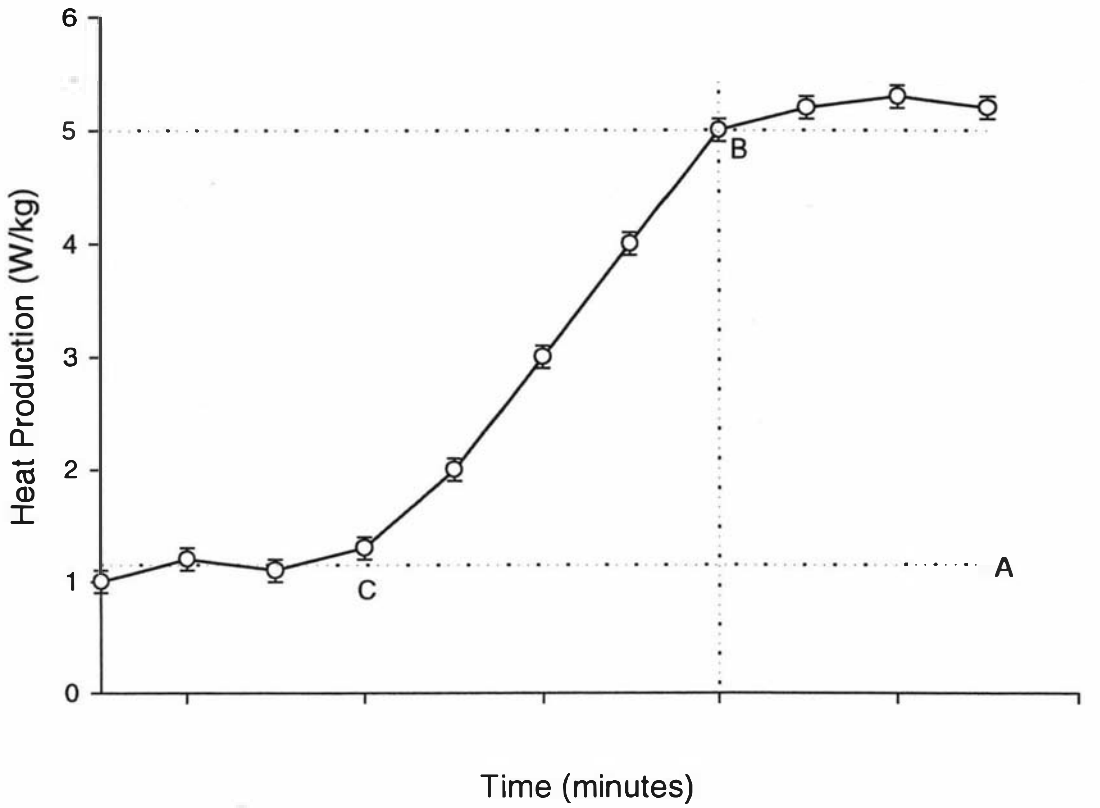



**Figure 2.2.** Stylised graph of an increase in heat production observed in lambs when subjected to the standard stimuli (an increase in heat production to the standardised stimuli is measured as the difference in heat production between point B and line A divided by the time elapsed between line B and point C). Vertical bars represent the standard deviation of the first four points, not of each point.

*Data analysis*

All measurements on ewes and lambs were subjected to analysis of variance (unless stated below) using the Generalised Linear Model procedure from the statistical package 'Minitab' (Minitab, 1998). The main effects of pregnancy status (or birth-rank) (single vs twin), shearing treatment (unshorn vs shorn), and feeding level P70-101 (period one) and P102-139 (period two), and interactions between these parameters were included in the original models. All non-significant (P>0.05) interactions were then removed and the models re-fitted.

Pregnancy rank and birth-rank were determined as the number of lambs per ewe identified and weighed within 12 hours of age. Pregnancy and birth rank "status" did not change if a lamb died between L1 and L84.

Regardless of ewe feeding level (H or M) it was found that the rectal temperature of the group of ewes measured first was on average $0.2^0$C lower that that of ewes measured in the second group. The rectal temperatures of ewes in the group measured first were increased by $0.2^0$C to remove the effect of order of sampling.

Sex of the lamb was used as a fixed effect in the models used to partition variation in birthweight and liveweight at both L38 and L76.

Lamb birthweight was used as a covariate for both crown rump length and girth.

For lamb rectal temperatures, a wind chill index (Oliver and Fairbridge 1987) was used as a covariate in the generalised linear model.

Sex of the lamb was a fixed effect and dry wool depth a covariate in the model for summit metabolic rate of twin lambs (due to only one single lamb reaching SMR).

The proportion of lambs reaching summit metabolism was analysed as a binomial trait using the SAS (SAS, 1985) procedure for categorical data modelling (CATMOD) to test the effects of birth rank (single vs twin), shearing treatment (unshorn vs shorn dam) and feeding regimen (HM vs MH), and interactions between these effects. Non-significant (P>0.05) interactions were removed and the model re-fitted

In all tables the respective means of the main effects and any significant interactions are shown. However, due to the interrelationship between the four feeding regimens the data regarding ewe feeding are presented under the four feeding regimen headings (M-M, M-H, H-M, and H-H) rather the feeding level (M or H) for either period one or two. Some significant interactions between main effects are listed in the text but are not presented in the tables.

## Results

*Pasture conditions*

The average weekly pre- and post-grazing herbage mass for ewes fed at maintenance (M ewes) during gestation was 1703±55 and 848±41 kgDM/ha respectively. The average weekly pre- and post-grazing herbage mass for ewes fed at the high level (H ewes) during gestation was 1750±37 and 1589±50 kgDM/ha respectively. The average pre- and post- grazing sward heights for the M ewes were 8.1±1.1 and 3.8±0.4 cm respectively, with the average sward heights for the H ewes being 10.1±0.6 cm.

*Animal Measurements*

*Ewe liveweight*

The average ewe live weight at P70 was 60.5 ± 0.6 kg. During mid- to late- pregnancy, twin-bearing ewes were approximately 3 to 5 kg ($P<0.05$) heavier than single-bearing ewes (Table 2.1). However, during lactation (particularly late lactation) single-bearing ewes were heavier than their twin-bearing counterparts. Shearing treatment had no effect on ewe liveweight at any stage during pregnancy or lactation.

As expected at P101 ewes fed at H level during feeding period one were significantly ($P<0.05$) heavier than ewes fed at M. At P139 H-H ewes were significantly ($P<0.05$) heavier than all other ewes. Ewes in all feeding regimens met their liveweight targets at P139 (Figures 2.3 and 2.4). At L38, M-H and H-H ewes were significantly heavier ($P<0.05$) than M-M ewes, with H-M ewes tending to be intermediate. At L76, there was a significant ($P<0.05$) interaction between feeding level and feeding period. Thus M-H ewes were heavier than M-M ewes, but the H-M and H-H groups did not differ. That is, the effects of feeding level in period two were contingent upon whether ewes were fed M or H in period one.

**Table 2.1.** The effect of pregnancy rank, shearing treatment and feeding regimen on ewe liveweights (kg) at P101, P139, L38 and L76 (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).

| | | Ewe Liveweight | | | |
|---|---|---|---|---|---|
| | | P101 | P139 | L38 | L76 |
| | (n) | | | | |
| Pregnancy rank | | | | | |
| 1 | 64 | $63.2^{a}$ ± 0.8 | $69.5^{a}$ ±0.9 | 59.9 ±1.0 | $58.0^{b}$ ±0.9 |
| 2 | 70 | $66.4^{b}$ ± 0.8 | $74.5^{b}$ ±0.8 | 57.6 ±1.0 | $54.9^{a}$ ±0.9 |
| Shearing treatment | | | | | |
| Unshorn | 66 | 64.4 ±0.8 | 71.5 ±0.9 | 59.3 ±1.0 | 55.9 ±0.9 |
| Shorn | 68 | 65.2 ±0.8 | 72.5 ±0.9 | 58.2 ±1.0 | 57.0 ±0.9 |
| Feeding regimen[1] | | | | | |
| M-M | 34 | } $63.1^{a}$ ± 0.8[2] | $68.5^{a}$ ±1.2 | $55.3^{a}$ ±1.4 | $53.5^{a}$ ±1.2 |
| M-H | 33 | | $72.3^{a}$ ±1.2 | $62.0^{c}$ ±1.4 | $59.2^{b}$ ±1.3 |
| H-M | 34 | } $66.4^{b}$ ± 0.8 | $70.3^{a}$ ±1.2 | $56.9^{ab}$ ±1.3 | $56.5^{ab}$ ±1.2 |
| H-H | 33 | | $76.8^{b}$ ±1.2 | $60.7^{bc}$ ±1.4 | $56.5^{ab}$ ±1.3 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

[2] During feeding period one M-M and M-H ewes were managed as one group. H-H and H-M ewes were also managed as one group during that period.

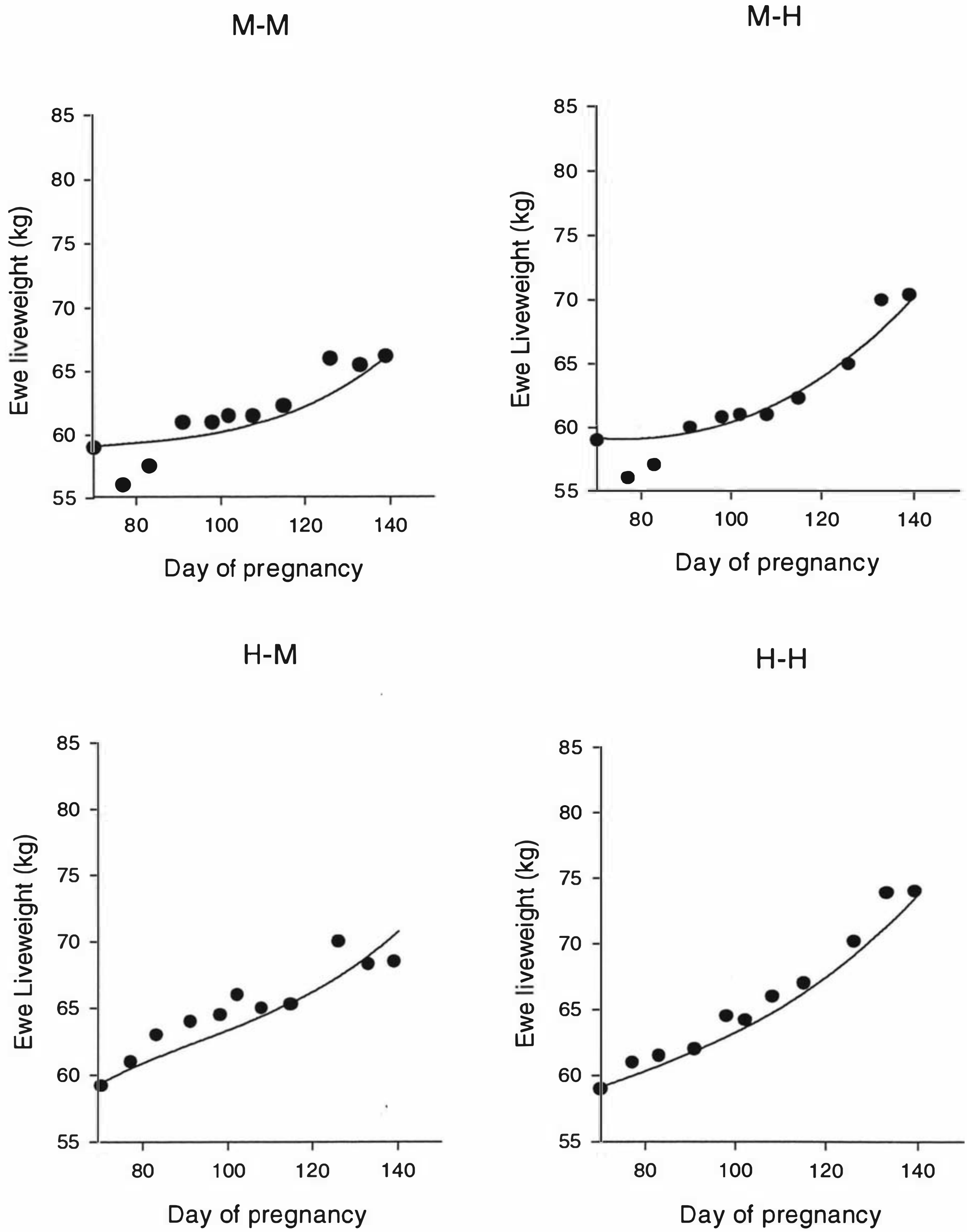



**Figure 2.3.** Target (-) and actual (•) ewe liveweights for single-bearing ewes on the differing feeding regimens.

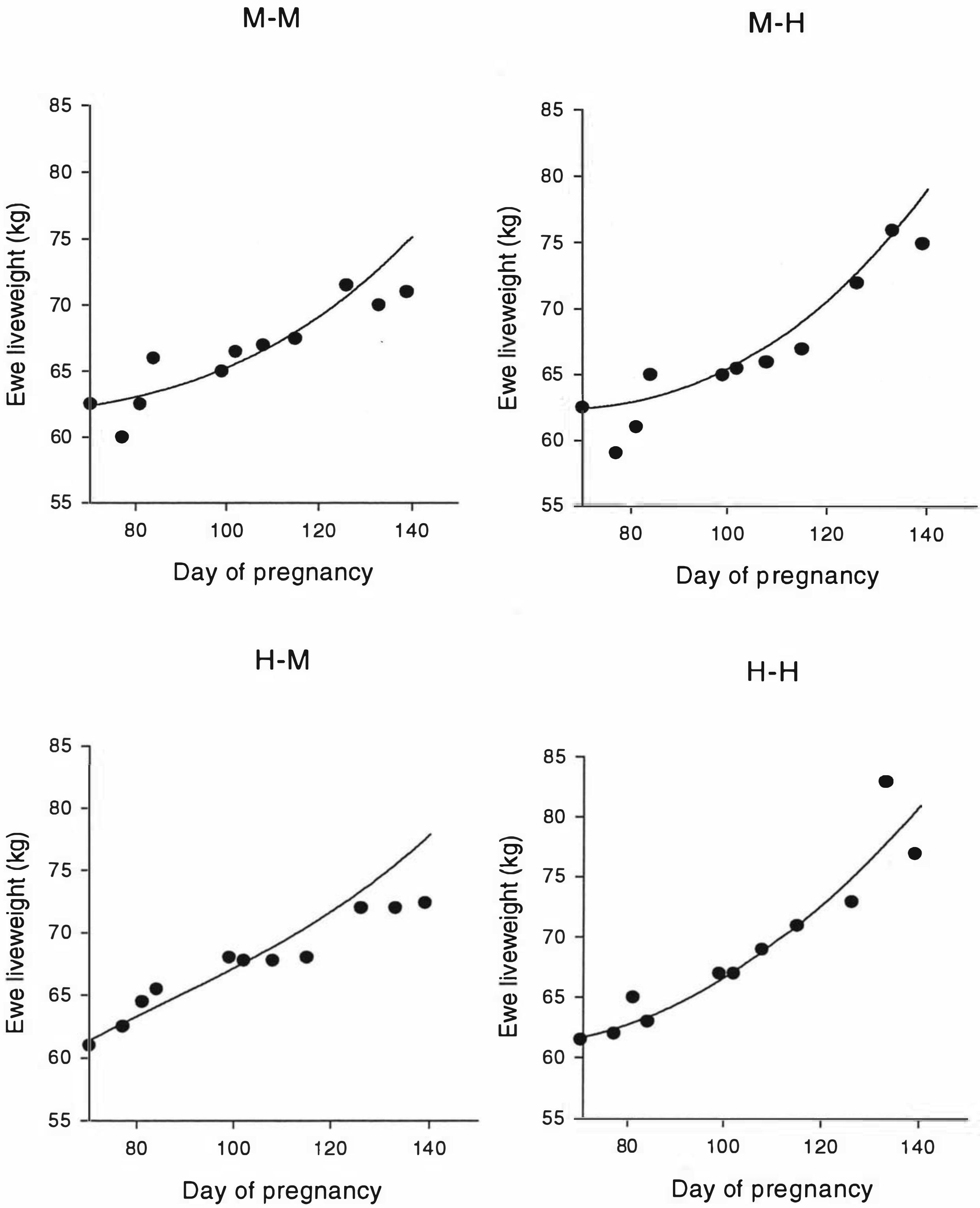



**Figure 2.4.** Target (-) and actual (•) ewe liveweights for twin-bearing ewes on the differing feeding regimens.

*Ewe intake*

For the type of pasture grazed and for the season, the *in vitro* dry matter digestibility (DMD), the organic matter digestibility (OMD) and the digestible organic matter in dry matter (DOMD) values of the pasture samples collected from the OF sheep were unexpectedly low. When the ewe intakes calculated using these figures were compared to ewe liveweight changes, it became apparent that the DMD, OMD and DOMD values of the OF pasture samples were incorrect and that the intake of the ewes must have been much higher than those calculated. Therefore the DMD, OMD and DOMD values reported by Parker *et al.* (1991) on similar pasture at the same time of year were used to calculate ewe intake. The aim of the intake measurements were to determine if pregnancy shearing altered relative ewe intakes, not to determine the absolute differences in ewe intake of the four nutritional groups.

At no stage during the mid- to late- pregnancy period did pregnancy rank have any effect on ewe digestible organic matter intake DOMI (Table 2.2). During P86-90, P97-101, P122-126, P129-133 and P135-139, shorn ewes had significantly (P<0.05) higher DOMI (8 – 12.5%) than their unshorn counterparts.

As expected during P73-77, P86-90, and P97-101 ewes fed at the H level during feeding period one had significantly (P<0.05) higher DOMI (21 - 55 %) than ewes fed at M. Similarly, during feeding period two, ewes fed at H had consistently higher intakes than ewes fed at M.

During P129-133 a significant interaction (P<0.05) between feeding level period one and two occurred. Thus there was no difference in the intake of M-H or H-H ewes (which had significantly (P<0.05) greater intakes than M-M and H-M ewes) but, for ewes fed at M during period two, those fed at M in period one (i.e. M-M) had significantly (P<0.05) greater intakes than those fed at H in period one (i.e. H-M).

During both P73-77 and P80-84 there was a significant (P<0.05) interaction between feeding level in period one and birth-rank (data not shown). For both birth-ranks, feeding ewes at H significantly (P<0.05) increased intakes compared to ewes fed at M. However, feeding single-bearing ewes at the H level compared to M level significantly

(P<0.05) increased ewe intake (59 – 70%), to a greater extent than occurred in twin-bearing ewes (29-44%).

During P129-133 there was a significant (P<0.05) interaction between feeding level during period two and birth-rank (data not shown). For both birth-ranks feeding ewes at H significantly (P<0.05) increased intakes compared to ewes fed at M. However, feeding single-bearing ewes at the H level compared to M level significantly (P<0.05) increased (20%) ewe intake to a greater extent than occurred in twin-bearing ewes (4%).

During P80-84 there was significant interaction between birth-rank and shearing treatment (data not shown). Shearing significantly (P<0.05) increased (24%) ewe intake of single-bearing ewes but had no effect on twin-bearing ewes.

**Table 2.2.** The effect of pregnancy rank, shearing treatment and ewe feeding regimen on ewe Digestible Organic Matter Intakes (DOMI) (kg DOMI ewe$^{-1}$ day$^{-1}$) (Mean ±SE). Means within treatments having different superscripts are different ($P<0.05$).

| | | Digestible organic matter intake | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (n) | P73-77 | P80-84 | P86-90 | P97-101 | P104-108 | P110-114 | P122-126 | P129-133 | P135-139 |
| Pregnancy-rank | | | | | | | | | | |
| 1 | 64 | 0.81 ±0.02 | 0.96 ±0.03 | 0.93 ±0.02 | 0.81 ±0.03 | 0.82 ±0.03 | 0.79 ±0.03 | 0.68 ±0.02 | 0.68 ±0.02 | 0.81 ±0.02 |
| 2 | 70 | 0.81 ±0.02 | 0.90 ±0.03 | 0.89 ±0.02 | 0.81 ±0.03 | 0.85 ±0.03 | 0.81 ±0.03 | 0.70 ±0.02 | 0.64 ±0.02 | 0.81 ±0.02 |
| Shearing treatment | | | | | | | | | | |
| Unshorn | 66 | 0.78 ±0.02 | $0.88^{a}\pm0.03$ | $0.87^{a}\pm0.02$ | $0.76^{a}\pm0.03$ | 0.80 ±0.03 | 0.79 ±0.03 | $0.65^{a}\pm0.02$ | $0.63^{a}\pm0.02$ | $0.79^{a}\pm0.02$ |
| Shorn | 68 | 0.83 ±0.02 | $0.99^{b}\pm0.03$ | $0.95^{b}\pm0.02$ | $0.85^{b}\pm0.03$ | 0.84 ±0.03 | 0.82 ±0.03 | $0.73^{b}\pm0.02$ | $0.69^{b}\pm0.02$ | $0.87^{b}\pm0.02$ |
| Feeding regimen[1] | | | | | | | | | | |
| M-M | 34 | } $0.63^{a}\pm0.02$[2] | } $0.77^{a}\pm0.03$ | } $0.81^{a}\pm0.02$ | } $0.71^{a}\pm0.03$ | $0.73^{a}\pm0.04$ | $0.76^{b}\pm0.05$ | $0.51^{a}\pm0.03$ | $0.53^{b}\pm0.03$ | $0.79^{a}\pm0.03$ |
| M-H | 33 | | | | | $0.91^{b}\pm0.04$ | $0.86^{bc}\pm0.05$ | $0.88^{b}\pm0.03$ | $0.81^{c}\pm0.03$ | $0.89^{b}\pm0.03$ |
| H-M | 34 | } $0.98^{b}\pm0.03$ | } $1.11^{b}\pm0.03$ | } $1.01^{b}\pm0.02$ | } $0.91^{b}\pm0.03$ | $0.67^{a}\pm0.04$ | $0.70^{a}\pm0.05$ | $0.50^{a}\pm0.03$ | $0.46^{a}\pm0.03$ | $0.72^{a}\pm0.03$ |
| H-H | 33 | | | | | $0.98^{b}\pm0.04$ | $0.90^{c}\pm0.05$ | $0.88^{b}\pm0.03$ | $0.83^{c}\pm0.03$ | $0.92^{b}\pm0.03$ |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-102; the second letter denotes the feeding level from P102-139.

[2] During feeding period one M-M and M-H ewes were managed as one group. H-H and H-M ewes were also managed as one group during that period.

*Ewe condition score*

The average ewe condition score (CS) at P56 was 2.2 ± 0.1. Pregnancy rank did not influence CS at P101 but, by late pregnancy (P139), single-bearing ewes had significantly (P<0.05) greater CS than their twin-bearing counterparts (Table 2.3). At both P101 and P139 shorn ewes had 0.2 unit higher CS (P<0.05) than their unshorn counterparts.

At P101 ewes fed H during feeding period one had significantly (P<0.05) greater CS than M ewes. At P139, H-H ewes had significantly (P<0.05) greater CS than M-M ewes, while M-H and H-M ewes were intermediate.

**Table 2.3.** The effect of pregnancy rank, shearing treatment and feeding regimen on ewe condition scores at P101 and P139 (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).

| | | Ewe condition score | |
|---|---|---|---|
| | (n) | P101 | P139 |
| Pregnancy rank | | | |
| 1 | 64 | 2.8 ±0.05 | $2.7^{b}$ ±0.05 |
| 2 | 70 | 2.8 ±0.05 | $2.6^{a}$ ±0.05 |
| Shearing treatment | | | |
| Unshorn | 66 | $2.7^{a}$ ±0.05 | $2.5^{a}$ ±0.05 |
| Shorn | 68 | $2.9^{b}$ ±0.05 | $2.7^{b}$ ±0.05 |
| Feeding regimen[1] | | | |
| M-M | 34 | } $2.7^{a}$ ±0.05[2] | $2.5^{a}$ ±0.1 |
| M-H | 33 | | $2.6^{ab}$ ±0.1 |
| H-M | 34 | } $2.9^{b}$ ±0.05 | $2.6^{ab}$ ±0.1 |
| H-H | 33 | | $2.8^{b}$ ±0.1 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

[2] During feeding period one, M-M and M-H ewes were managed as one group. H-H and H-M ewes were also managed as one group during that period.

*Ewe fleece weight*

Shearing treatment, pregnancy rank and ewe feeding regimen had no effect on annual fleece weight (Table 2.4). Single-bearing, pregnancy-shorn ewes grew significantly (P<0.05) more wool (0.2 kg) during P70-L56 than their twin-bearing counterparts. Shorn H-H ewes grew more (P<0.05) wool than M-M ewes during P70-L56 while H-M and M-H ewes were intermediate.

**Table 2.4.** The effect of pregnancy rank, shearing treatment and feeding regimen on annual fleece weights (kg) for all ewes and the effect of pregnancy rank and feeding regime on second shear fleece weights (July – November) of pregnancy-shorn ewes (P70 – L56) (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).

| | (n) | Annual fleece weight (kg) | (n) | Second shear fleece weight (kg) (July – November) |
|---|---|---|---|---|
| Pregnancy rank | | | | |
| 1 | 64 | 4.3 ±0.1 | 31 | $1.4^{b}$ ±0.1 |
| 2 | 70 | 4.1 ±0.1 | 37 | $1.2^{a}$ ±0.1 |
| Shearing treatment | | | | |
| Unshorn | 66 | 4.2 ±0.1 | | |
| Shorn | 68 | 4.2 ±0.1 | | |
| Feeding regime[1] | | | | |
| M-M | 34 | 4.2 ±0.1 | 17 | $1.1^{a}$ ±0.1 |
| M-H | 33 | 4.1 ±0.1 | 16 | $1.4^{ab}$±0.1 |
| H-M | 34 | 4.2 ±0.1 | 17 | $1.3^{ab}$±0.1 |
| H-H | 33 | 4.3 ±0.1 | 18 | $1.4^{b}$ ±0.1 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

*Ewe rectal temperatures*

Pregnancy rank had no effect on ewe rectal temperature until late pregnancy (P133 and P139) when the rectal temperatures of twin-bearing ewes were significantly (P<0.05) higher than those of single-bearing ewes (Table 2.5). At P84, P99, P126 and P139 the rectal temperatures of unshorn ewes was significantly higher (P<0.05) than those of shorn ewes. However, at all other measurement days shearing treatment had no effect.

During feeding period one (P70-101) ewe feeding level had an inconsistent effect on rectal temperature, with ewes fed at H having significantly (P<0.05) higher temperatures at both P77 and P99 while ewes fed at M had significantly (P<0.05) higher temperatures at P84. At P75 feeding level had no effect. During feeding period two there was also no clear relationship between ewe feeding regimen and rectal temperature.

There was a significant (P<0.05) interaction between ewe shearing treatment and feeding level during feeding period one at P73 (data not shown) on rectal temperature. Shearing treatment had no effect on ewe rectal temperature for ewes fed at M during feeding period one, but for ewes fed at H, shorn ewe exhibited significantly (P<0.05) lower rectal temperatures (by 0.3°C) than their unshorn counterparts.

At P105 there was a significant (P<0.05) interaction between shearing treatment and feeding level during feeding period one (data not shown). Feeding level period one had no effect on the rectal temperature of shorn ewes. In contrast unshorn ewes fed at M during period one had significantly (P<0.05) higher rectal temperatures than those fed at H (by $0.2^{0}$C).

**Table 2.5.** The effect of pregnancy rank, shearing treatment and feeding regimen on ewe rectal temperatures (°C)(Mean ±SE) at different times from mid-pregnancy until parturition. The maximum and minimum air temperature (°C) for each day of measurement is shown. Means within treatments having different superscripts are different ($P<0.05$).

| | (n) | Ewe rectal temperature P73 | P75 | P77 | P84 | P99 | P105 | P112 | P126 | P133 | P139 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pregnancy rank | | | | | | | | | | | |
| 1 | 64 | 39.3 ±0.0 | 38.4 ±0.4 | 39.0 ±0.0 | 39.0 ±0.0 | 39.1 ±0.0 | 39.0 ±0.0 | 38.4 ±0.4 | 39.0 ±0.0 | $39.0^{a}$ ±0.0 | $39.1^{a}$±0.0 |
| 2 | 70 | 39.3 ±0.0 | 39.0 ±0.4 | 38.9 ±0.0 | 39.1 ±0.0 | 39.1 ±0.0 | 39.1 ±0.0 | 39.0 ±0.4 | 39.1 ±0.0 | $39.1^{b}$ ±0.0 | $39.2^{b}$±0.0 |
| Shearing treatment | | | | | | | | | | | |
| Unshorn | 66 | 39.3 ±0.0 | 39.1 ±0.4 | 39.0 ±0.0 | $39.1^{b}$±0.0 | $39.2^{b}$±0.0 | 39.1 ±0.0 | 39.1 ±0.4 | $39.1^{b}$±0.0 | 39.1 ±0.0 | $39.3^{b}$±0.0 |
| Shorn | 68 | 39.2 ±0.0 | 38.3 ±0.4 | 38.9 ±0.0 | $38.9^{a}$±0.0 | $39.0^{a}$±0.0 | 39.0 ±0.0 | 38.3 ±0.4 | $39.0^{a}$±0.0 | 39.0 ±0.0 | $39.2^{a}$±0.0 |
| Feeding regimen[1] | | | | | | | | | | | |
| M-M | 34 | } 39.3 ±0.0[2] | } 38.7 ±0.0 | } $38.8^{a}$ ±0.0 | } $39.1^{b}$±0.0 | } $38.9^{a}$±0.0 | $39.2^{b}$ ±0.1 | 37.8 ±0.6 | $39.0^{a}$ ±0.0 | $39.1^{ab}$±0.0 | 39.2 ±0.0 |
| M-H | 33 | | | | | | $39.1^{ab}$±0.1 | 39.0 ±0.6 | $39.1^{b}$ ±0.0 | $39.0^{a}$ ±0.0 | 39.2 ±0.0 |
| H-M | 34 | } 39.3 ±0.0 | } 38.7 ±0.0 | } $39.1^{b}$ ±0.0 | } $38.9^{a}$±0.0 | } $39.2^{b}$±0.0 | $38.9^{a}$ ±0.1 | 39.0 ±0.6 | $39.0^{ab}$±0.0 | $39.2^{b}$ ±0.0 | 39.2 ±0.0 |
| H-H | 33 | | | | | | $39.0^{ab}$±0.1 | 39.0 ±0.6 | $39.1^{b}$ ±0.0 | $39.0^{a}$ ±0.0 | 39.2 ±0.0 |
| Air Temperature | | | | | | | | | | | |
| Maximum | | 13.2 | 12.8 | 13.9 | 13.3 | 9.8 | 11.8 | 17.3 | 15.7 | 14.9 | 13.7 |
| Minimum | | 1.0 | 7.6 | 4.6 | 7.2 | 7.7 | 3.0 | 10.2 | 9.7 | 10.5 | 7.8 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

[2] During feeding period one M-M and M-H ewes were managed as one group. H-H and H-M ewes were also managed as one group during that period

*Gestation length*

Single-born lambs had a 0.8 day ($P<0.05$) longer gestation period than twin-born lambs (Table 2.6). However, shearing treatment had no effect on gestation length. Lambs born to M-M ewes had a significantly ($P<0.05$) longer gestation period than lambs born to M-H ewes with the gestation lengths of H-M and H-H lambs being intermediate.

**Table 2.6.** The effect of pregnancy rank, dam shearing treatment and feeding regimen on gestation length (days) (Mean ±SE). Means within treatments having different superscripts are different ($P<0.05$).

| | (n) | Gestation length |
|---|---|---|
| Pregnancy rank | | |
| 1 | 64 | $149.0^{b} \pm 0.2$ |
| 2 | 140 | $148.2^{a} \pm 0.2$ |
| Shearing treatment | | |
| Unshorn | 102 | $148.4 \pm 0.2$ |
| Shorn | 102 | $148.8 \pm 0.2$ |
| Feeding regime[1] | | |
| M-M | 51 | $149.0^{b} \pm 0.3$ |
| M-H | 50 | $147.9^{a} \pm 0.3$ |
| H-M | 52 | $148.8^{ab} \pm 0.3$ |
| H-H | 51 | $148.5^{ab} \pm 0.3$ |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

*Lamb liveweights*

Single-born lambs were 1.0 kg ($P<0.05$) heavier than twin-born lambs at birth and remained heavier through to weaning (Table 2.7). Lambs born to shorn dams were 0.3 kg ($P<0.05$) heavier than lambs born to unshorn dams at birth but there was no difference by L38. There was a significant ($P<0.05$) interaction between feeding level in period one and feeding level in period two on lamb birthweight. Feeding ewes at H level during period two after the ewe had been fed at H during period one (i.e. H-H) significantly ($P<0.05$) increased lamb birthweight by 0.5 kg in comparison to lambs born to ewes fed M during period two (i.e. H-M). However, there was no difference in birthweight of lambs born to ewes fed at either H or M during period two if they had been fed at M during period one. There was also no interaction between shearing treatment and feeding regimen.

**Table 2.7.** The effect of birth-rank, dam shearing treatment and feeding regimen on lamb liveweight (kg) at birth, L38 and L76 (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).

| | Lamb liveweight | | | | | |
|---|---|---|---|---|---|---|
| | Birth | | L38 | | L76 | |
| | (n) | | (n) | | (n) | |
| Birth-rank | | | | | | |
| 1 | 64 | $5.7^{b}$ ±0.1 | 56 | $15.7^{b}$ ±0.3 | 53 | $23.9^{b}$ ±0.4 |
| 2 | 140 | $4.7^{a}$ ±0.1 | 117 | $12.4^{a}$ ±0.2 | 114 | $19.7^{a}$ ±0.3 |
| Shearing treatment | | | | | | |
| Unshorn | 102 | $5.1^{a}$ ±0.1 | 83 | 14.1 ±0.2 | 79 | 21.9 ±0.4 |
| Shorn | 102 | $5.4^{b}$ ±0.1 | 90 | 14.0 ±0.2 | 88 | 21.8 ±0.3 |
| Feeding regimen[1] | | | | | | |
| M-M | 51 | $5.3^{b}$ ±0.1 | 44 | 13.9 ±0.3 | 43 | 21.1 ±0.5 |
| M-H | 50 | $5.1^{ab}$ ±0.1 | 40 | 14.4 ±0.3 | 39 | 22.7 ±0.5 |
| H-M | 52 | $4.9^{a}$ ±0.1 | 48 | 13.6 ±0.3 | 44 | 21.4 ±0.5 |
| H-H | 51 | $5.4^{b}$ ±0.1 | 41 | 14.3 ±0.3 | 41 | 22.0 ±0.5 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

*Lamb crown-rump length, girth and wool depth*

Birth rank, dam shearing treatment and feeding regimen had no effect on either crown-rump lengths or girths (Table 2.8). Birth rank and dam feeding regimen had no effect on dry or wet wool depth (Table 2.8). Lambs born to shorn dams had greater (P<0.05) wet wool depths than lambs born to unshorn dams but did not differ in dry wool depths.

**Table 2.8.** The effect of birth-rank, dam shearing treatment and feeding regimen on crown-rump length (CRL) (mm), girth (mm), and dry and wet wool depth (mm) measurements of new-born lambs (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).

| | (n) | CRL | Girth | (n) | Dry depth | Wet depth |
|---|---|---|---|---|---|---|
| Birth-rank | | | | | | |
| 1 | 32 | 537.6 ±16.2 | 408.5 ±4.7 | 14 | 7.7 ±0.6 | 5.7 ±0.4 |
| 2 | 70 | 509.6 ±10.1 | 408.0 ±2.9 | 37 | 7.2 ±0.3 | 5.9 ±0.3 |
| Shearing treatment | | | | | | |
| Unshorn | 51 | 514.8 ±12.4 | 407.3 ±3.6 | 26 | 6.9 ±0.4 | $5.1^{a}$±0.3 |
| Shorn | 51 | 532.4 ±11.5 | 409.2 ±3.4 | 25 | 7.8 ±0.4 | $6.4^{b}$±0.4 |
| Feeding regimen[1] | | | | | | |
| M-H | 50 | 528.8 ±12.3 | 407.9 ±3.6 | 26 | 7.2 ±0.5 | 5.4 ±0.3 |
| H-M | 52 | 518.4 ±11.5 | 408.6 ±3.4 | 25 | 7.7 ±0.5 | 6.1 ±0.3 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

*Lamb rectal temperature*

Birth rank, dam feeding regimen and shearing treatment had no effect on lamb rectal temperatures at 1, 3, 6 or 9 hours after birth (Table 2.9). Likewise there was no effect of any of the treatments on lamb rectal temperatures at 12, 18, 24, 36 or 48 hours after birth (data not shown).

**Table 2.9.** The effect of birth-rank, dam shearing treatment and feeding regimen on average lamb rectal temperatures (°C) (Mean ±SE) at 1, 3, 6 and 9 hours after birth. Means within treatment having differing superscripts are different (P<0.05).

| | | Hours after birth | | | |
|---|---|---|---|---|---|
| | | 1 | 3 | 6 | 9 |
| | (n) | | | | |
| Birth-rank | | | | | |
| 1 | 16 | 39.5 ±0.4 | 39.8 ±0.2 | 39.7 ±0.2 | 39.6 ±0.1 |
| 2 | 29 | 39.2 ±0.3 | 39.8 ±0.2 | 39.7 ±0.1 | 39.6 ±0.1 |
| Shearing treatment | | | | | |
| Shorn | 23 | 39.5 ±0.4 | 39.7 ±0.2 | 39.6 ±0.2 | 39.6 ±0.1 |
| Unshorn | 22 | 39.3 ±0.4 | 39.8 ±0.2 | 39.5 ±0.2 | 39.6 ±0.1 |
| Feeding regimen[1] | | | | | |
| H-M | 25 | 39.3 ±0.4 | 39.7 ±0.2 | 39.4 ±0.2 | 39.5 ±0.1 |
| M-H | 20 | 39.4 ±0.4 | 39.9 ±0.2 | 39.7 ±0.2 | 39.8 ±0.1 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

*Calorimetry*

Ewe feeding regimen and shearing treatment did not affect the proportion of lambs failing to reach summit metabolism. A higher proportion ($P<0.05$) of single-born lambs failed to reach summit metabolism than their twin-born counterparts (92 vs 48% respectively, Table 2.10). Birth rank, dam feeding regimen and shearing treatment had no effect on the rate of increase in heat production of lambs when exposed to the standardised stimulus of wind and water (Table 2.11).

Among the twin-born lambs that did reach summit metabolism, dam shearing treatment did not affect SMR (W/kg) (Table 2.11). However, lambs born to H-M ewes had approximately 5.0 W/kg ($P<0.05$) higher SMR than lambs born to M-H ewes.

**Table 2.10.** The effect of birth-rank, dam shearing treatment and feeding regimen on the proportion (%) of lambs (<36hrs of age) that failed to reach summit metabolism. Means with different superscripts are different ($P<0.05$).

| Treatment | (n) | Proportion |
|---|---|---|
| Birth-rank | | |
| 1 | 14 | $2.56^{1} \pm 1.03^{b}$ $(92)^{2}$ |
| 2 | 37 | $-0.05 \pm 0.32^{a}$ (48) |
| Shearing treatment | | |
| Unshorn | 26 | $0.47 \pm 0.40$ (61) |
| Shorn | 25 | $0.40 \pm 0.40$ (60) |
| Feeding regimen[3] | | |
| M-H | 26 | $-0.15 \pm 0.39$ (46) |
| H-M | 25 | $1.15 \pm 0.47$ (76) |

[1] Logit transformed
[2] Back transformed (%)
[3] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

**Table 2.11.** The effect of birth-rank, dam shearing treatment and feeding regimen on the rate of increase in heat production (W/kg/min) and the effect of shearing treatment and dam feeding regimen on summit metabolic rate (W/kg) of twin-born lambs (Means ±SE). Means within treatment having differing superscripts are different ($P<0.05$).

| | Rate of change in heat production | | Summit metabolic rate | |
|---|---|---|---|---|
| | (n) | | (n) | |
| Birth-rank | | | | |
| 1 | 14 | 0.35 ±0.06 | | |
| 2 | 37 | 0.43 ±0.03 | | |
| Shearing treatment | | | | |
| Unshorn | 26 | 0.40 ±0.04 | 8 | 17.5 ±1.0 |
| Shorn | 25 | 0.37 ±0.04 | 8 | 17.8 ±0.9 |
| Feeding regimen[1] | | | | |
| M-H | 26 | 0.39 ±0.04 | 12 | 15.0[a]±0.8 |
| H-M | 25 | 0.38 ±0.04 | 4 | 20.3[b]±1.3 |

[1] M = maintenance level, H = high level. The first letter denotes the feeding level from P70-101; the second letter denotes the feeding level from P102-139.

**Discussion**

The aim of this study was to investigate the effects of mid-pregnancy shearing and ewe herbage allowance on ewe intake, lamb birthweight and cold resistance of the newborn lamb. It was hypothesised that the differing feeding conditions of ewes post-shearing were responsible for the variable results achieved in the lamb birthweight response observed in previous mid- to late-pregnancy shearing studies. Ewe feeding level post shearing was divided into two time periods, P70-101 and P102-139. Each of the periods were examined separately to determine whether the birthweight response to pregnancy shearing is influenced by feeding level during either or both of these periods.

As expected, during the first feeding period (P70-101) H ewes (i.e. H-H and H-M groups, which were run together) had greater intakes than M (i.e. M-M and M-H) ewes and, during the second feeding period (P102-139), H-H and M-H ewes had higher intakes than M-M and H-M ewes. These intakes resulted in all four groups achieving their liveweight targets at parturition, allowing the successful testing of the hypothesis.

The lack of a difference in birthweights of lambs born to either M-M or H-H ewes, suggests that the extra intake observed in H-H ewes was partitioned towards improving ewe body weight and thus condition rather than increasing foetal growth. However, high levels of feeding in late pregnancy increased lamb birthweight if the ewe had been fed at high levels during mid-pregnancy (H-H) in comparison to lambs born to ewes fed maintenance in late pregnancy (H-M). In contrast no such relationship was found for lambs born to ewes fed at maintenance during mid-pregnancy (i.e. M-H vs M-M). This may indicate that a higher level of feeding during mid-pregnancy increases placental development and thus facilitates a birthweight response to a high level of nutrition in late pregnancy. Mellor (1983) stated that in well-fed ewes the placenta apparently limits fetal growth during the last 3 –4 weeks of pregnancy. Interestingly, lambs born to M-H and H-M ewes tended to have lower birthweights than those born to M-M and H-H ewes, perhaps indicating a negative effect of a sudden change in ewe intake during pregnancy.

Pregnancy shearing was found to increase lamb birthweight (by a modest 0.3 kg), without differentially affecting the birthweights of singles or twins (i.e. no significant shearing treatment by birth rank interaction). In contrast, Morris and McCutcheon

(1997) observed that pregnancy shearing increased the birthweight of twin lambs only, and Morris *et al.* (2000) and Revell *et al.* (2002) reported the response only in singles. Morris *et al.* (1999), in a study involving twin-bearing ewes only, also observed a birthweight response to pregnancy shearing.

No interaction between the effects of shearing treatment and ewe feeding regimen was observed. This indicates that for ewes in good condition (average liveweight above 60kg and average CS greater than 2.5) the shearing effect on lamb birthweight is not influenced by dam nutrition, as long as the ewe is fed at a level equal to, or above, maintenance. Thus, the findings of this study do not support the hypothesis, that feeding levels post-shearing affect the birthweight response to mid-pregnancy shearing.

Both shearing treatment and dam nutrition were found to have no effect on newborn lamb rectal temperature under the pastoral conditions in this study. A possible explanation for this may have been the mild conditions experienced during the lambing period, as severe hypothermia was rarely observed in these lambs. However, shearing treatment was also found to have no effect on: the proportion of lambs reaching summit metabolism; the rate of increase in heat production under standard stimuli; or summit metabolic rate in the controlled calorimetry studies. These results indicate that mid-pregnancy shearing does not affect the ability of the new-born lamb to respond to adverse environmental stimuli. In contrast Revell *et al.* (2002) found that twin lambs born to shorn dams had higher summit metabolic rates than their counterparts born to unshorn ewes. However, they reported the opposite relationship with singletons. Under housed conditions the results of Stott and Slee (1985), Symonds *et al.* (1992) and Egan *et al.* (1997) indicate enhanced thermoregulatory capability in lambs born to shorn dams. The greater wet fleece depth and tendency to have a greater dry fleece depth of lambs born to shorn dams in this study may indicate a survival advantage in adverse weather conditions, as a greater depth of fleece should improve insulation (McCutcheon *et al.* 1981).

The low proportion of singleton lambs reaching summit metabolism in the present study in comparison to twin born lambs was most likely due to their larger body size and thus more favourable surface area to volume ratio, which enabled them to maintain body temperature under the standard stimuli used. In the future, studies should be conducted in conditions that result in a far greater proportion of lambs reaching summit metabolism. This will result in a more accurate measurement of SMR.

As previously stated, dam nutrition had no effect on the birthweight response to pregnancy shearing in the present study. This indicates that another mechanism may be responsible for the inconsistent birthweight response (across studies) from the pregnancy shearing technique. Revell *et al.* (2002) observed greater gestation lengths (1-1.5 days) in pregnancy-shorn single-bearing ewes when a birthweight response of 0.8 kg was found. This finding indicates a possible mechanism for the birthweight response to pregnancy shearing. However, Rattray *et al.* (1974) reported that in late pregnancy fetal growth was approximately 150 to 200g/day. This observation, coupled with the finding in the present study (where a birthweight response was observed without a change in gestation length), indicates that an increase in gestation length cannot fully explain the birthweight response found from pregnancy shearing.

Shearing resulted in a small but significant increase in ewe intake during both mid- and late-pregnancy, indicating another possible mechanism for the birthweight effect. The increase in dam intake observed in the present study contrasts with the findings of several studies in which no intake response was observed. These include Dabiri *et al.* (1995b) (who failed to find a birthweight response), Husain *et al.* (1997) (who reported a birthweight response) and Revell *et al.* (2002) (who noted a birthweight response in singletons only). However, Dabiri *et al.* (1996) (who did not report a birthweight response) found that shearing at day 118 of pregnancy increased ewe intakes in the late pregnancy period but not in the period immediately post-shearing. Similarly, in the present study an intake response was not observed until 10-14 days post-shearing. Furthermore there was no difference in the birthweights of lambs born to M-M vs H-H dams (where intake differences were far greater than those between shorn and unshorn dams). This observation, coupled with the lack of an interaction between shearing and feeding treatments, and the fact that others have recorded a birthweight response without an increase in dam intake, indicates that the birthweight response to mid-pregnancy shearing is not due to an increase in dam intake. However, it is interesting to note that a change in feeding level (either a decrease or increase) of the dam during pregnancy (i.e. H-M and M-H respectively) adversely affected lamb birthweight in comparison to lambs born to dams offered on a consistent level of nutrition (M-M and H-H). This suggests that the physiological response of the dam to a sudden change (and thus the effect this has on foetal development) depends greatly on the stimuli effecting the change.

Shearing during winter can expose ewes to cold stress and in extreme cases causes ewe death (Dabiri *et al.* 1995b; Gregory 1995). Cold exposure during pregnancy tends to increase gestation lengths (Thompson and Goode 1981; Thompson *et al.* 1982), and has been observed to increase lamb birthweights (Thompson *et al.* 1982). Therefore it is possible that the production responses observed from mid- to late-pregnancy shearing under pastoral conditions are due to a cold stress response in the dam. Gregory (1995) suggested that a recently shorn sheep would be exposed to its lower critical temperature (LCT) under calm, dry conditions even when fed at twice maintenance. With a 1.0 cm stubble depth, LCT of a 40 kg ewe is $17^0$C in calm conditions (Gregory 1995). Shorn ewes in the present study would have been exposed to conditions below their LCT (as indicated by temperatures shown in Table 2.5). They also tended to have lower rectal temperatures than their unshorn counterparts (albeit a small difference) and had higher intakes. However, in the present study there was no clear relationship between ewe rectal temperature (a possible indicator of cold stress) and dam shearing treatment.

When the results of this study are compiled with similar studies (Morris and McCutcheon 1997; Morris *et al.* 2000; Revell *et al.* 2000; Revell *et al.* 2002) (Figure 2.5.) a trend emerges for both birth-ranks. It appears that the birthweight response to mid- to late-pregnancy shearing is greatest in conditions in which the unshorn dam is likely to give birth to lightweight lamb(s). In conditions were the unshorn dam gives birth to a relatively heavier lamb(s) the response from shearing is minimal. It may thus be hypothesised that the birthweight response to mid- to late-pregnancy shearing is greatest in conditions likely to result in low lamb birthweights. That is, pregnancy shearing in some way alleviates conditions of "maternal constraint" which would otherwise lead to a lamb(s) of low birthweight.

**Conclusion**

Mid-pregnancy shearing was found to increase lamb birthweight. The results reported in this chapter in combination with other studies indicate that the birthweight response to pregnancy shearing is not due to either an increase in dam intake or gestation length. When data from this study are compiled with those of similar studies, they indicate that the birthweight response to pregnancy shearing is greatest in conditions in which the unshorn dam gives birth to a lamb(s) of low birthweight. This may explain the variable results achieved across studies and will be tested though the experiment described in the next chapter. In contrast to past studies, pregnancy shearing did not affect the new-born lamb's thermoregulatory capability. However, greater lamb birthweight itself should improve the survival rates of otherwise lightweight lambs. Since this is the first study in which no thermoregulatory response was found, and due to the fact that only half of the lambs tested, reached summit metabolism, in subsequent studies the effect of pregnancy shearing on new-born lamb thermoregulatory responses will be re-tested.

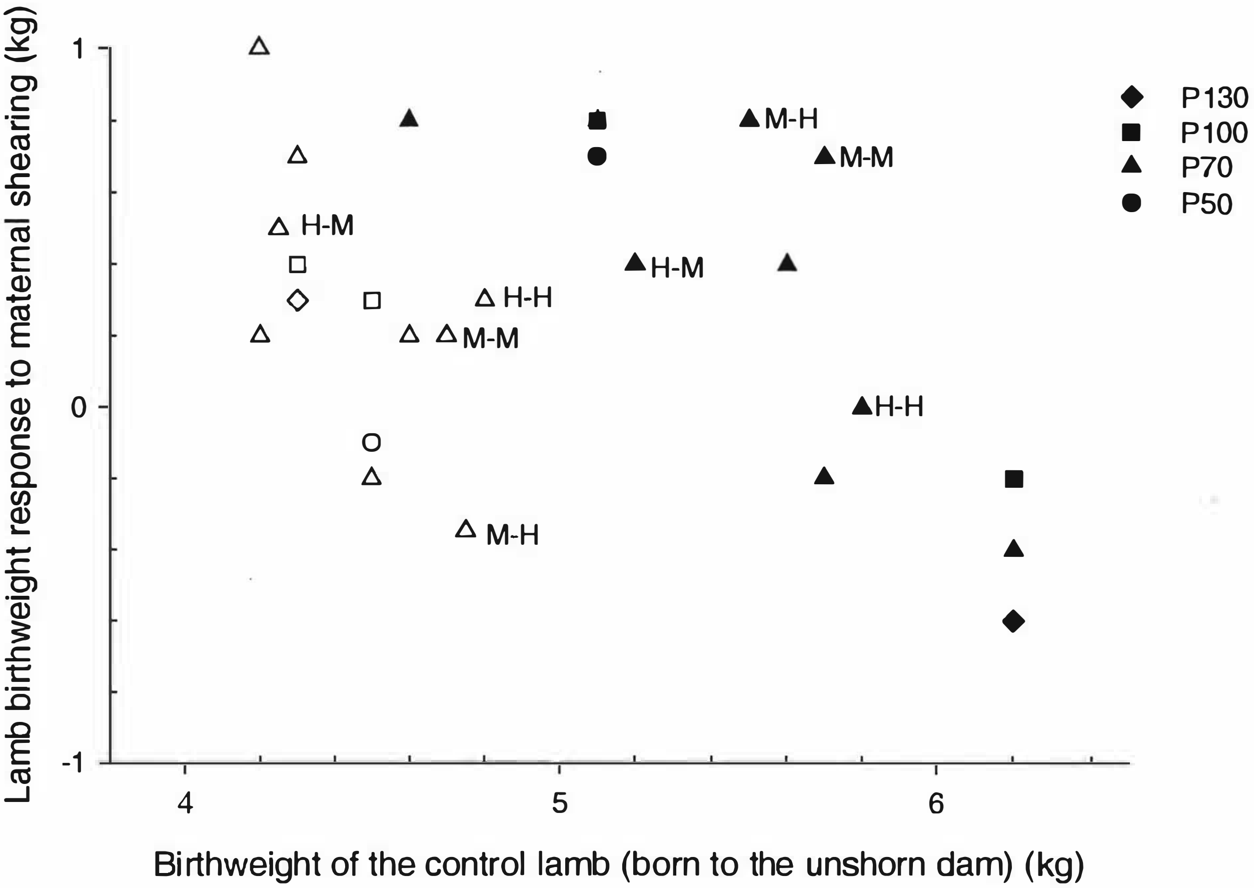



**Figure 2.5.** Birthweight responses to mid- to late-pregnancy shearing (singles - closed symbols, twins - open symbols) as a function of the birthweights of control lambs (each point represents a separate trial or treatment [shearing date] within a trial (Morris and McCutcheon 1997, Morris *et al.* 2000, Revell *et al.* 2000, Revell *et al.* 2002)). Shearing responses for each of the feeding regimens in this study are indicated by their letters (maintenance-maintenance (M-M), maintenance-high (M-H), high-maintenance (H-M), high-high (H-H)).

# Chapter three - Maternal constraint and the birthweight response to mid-pregnancy shearing


**Abstract**

Pregnancy shearing has been shown to increase lamb birthweights. However, results have been variable between studies. This study was designed to examine the birthweight response under two differing maternal treatments (one designed to restrict foetal growth the other designed not to limit foetal growth) with the aim of explaining the variation observed in pregnancy shearing studies. Mixed aged Romney cross ewes were either shorn during mid pregnancy (n=55) or left unshorn (n=50). At shearing, ewes were split into either a 'maintenance' group (64 kg at shearing and fed to permit total ewe liveweight gain equivalent to expected conceptus growth during mid- to late-pregnancy) (n=52) or a 'low' group (54 kg at shearing and fed to permit total ewe liveweight to increase at half the expected conceptus growth during mid- to late-pregnancy) (n=53) respectively.

Mid-pregnancy shearing was found to increase the birthweights of singletons (5.6 versus 4.9 kg) but not twins, and lambs born to maintenance group ewes (by 0.6 kg) but not low group ewes. Additionally, mid-pregnancy shearing had no effect on the birthweights or thermoregulatory capacity of twin-born lambs.

When the results of this study are considered with those of previous New Zealand pregnancy shearing studies they suggest that there are two criterion (and not one as previously concluded) that must be met to achieve a birthweight response to pregnancy shearing. First, the dam must have the potential to respond (i.e. have been destined to give birth to an otherwise lightweight lamb(s)) and, secondly, the ewe must have the means to respond (i.e. an adequate level of maternal reserves and/or level of nutrition to partition towards additional foetal growth).

## Introduction

It was shown in Chapter 2 that there was no interaction between dam shearing treatment and nutrition (when dams were offered either maintenance or high levels of nutrition) affecting lamb birthweight. However, when comparisons were made across studies, the birthweight response to pregnancy shearing was apparently greatest when the control (unshorn) ewe gave birth to a relatively light weight lamb(s). This suggests that, under circumstances in which foetal growth is below potential, shearing during pregnancy could be used as a technique to enhance foetal growth and hence birthweights. Put another way, pregnancy shearing may be effective only when maternal constraint is operating to restrict foetal growth (which often occurs on New Zealand farms).

Results from the UK indicate that shearing of housed ewes during pregnancy enhances cold resistance of their new-born lambs (Stott and Slee 1985; Symonds *et al.* 1992; Egan *et al.* 1997). Similarly, Revell *et al.* (2002) found that mid-pregnancy shearing (under New Zealand conditions) increased summit metabolic rates (or SMR) of twin-born lambs but had the opposite effect on their single-born counterparts. In contrast, in Chapter 2 it was found that mid-pregnancy shearing had no effect on SMR.

The study reported here was designed to test the hypothesis advanced in Chapter 2, namely that the shearing effect on lamb birthweight is greatest in conditions where ewes are otherwise destined to give birth to lambs of low birthweights. Thus an attempt was made to manage ewes in such a way as to limit foetal growth, and then to determine whether pregnancy shearing alleviated that constraint. This study also offered a further opportunity to test the effect of pregnancy shearing on the SMR of new-born lambs.

## Methods

*Experimental design and animals*

The experimental design was a 2 x 2 x 2 factorial, incorporating: a mid-pregnancy (day 70 of pregnancy; P70) shearing policy (shorn versus unshorn (with 7 months wool growth)); two pregnancy ranks (single vs twin); and two groups of ewes ('maintenance' versus 'low') managed between P70 and P140 to produce different birthweights in lambs born to unshorn ewes. One hundred and twenty (40 single-bearing and 80 twin-bearing) mixed aged (3 to 5 years) Border Leicester x Romney ewes were used. They were progesterone-synchronised (CIDR, type G, Livestock Improvement Corporation, Hamilton, New Zealand) and injected with PMSG (200 i.u) at CIDR withdrawal. Ewes were selected at pregnancy diagnosis by ultrasound on P56 (P0 = day of CIDR withdrawal), from a commercial flock of 180 ewes. The trial was conducted at Massey University's Keeble Farm (latitude 41° 10'S), 5km south of Palmerston North, New Zealand (June – November 1999).

The lightest 20 single-bearing ewes were allocated at P70 to the low (L) single-bearing liveweight group (average liveweight = 54 kg); the remaining ewes (64 kg) became the maintenance (M) single-bearing group. The lightest 40 twin-bearing ewes were placed in the L twin-bearing group (54 kg), with the remainder being placed into the M twin-bearing liveweight group (63 kg). Half of the ewes within each of the four groups were shorn at P70 with a cover comb (Sunbeam New Zealand Ltd, maximum depth of teeth 9 mm). Groups were balanced for ewe age.

From P70 until P140, single- and twin-bearing M ewes were fed to permit total weight gain equivalent to the expected conceptus growth (Rattray *et al,* 1974; McCutcheon *et al.* 1986; Nicol 1987), i.e. at P140 the conceptus of single- and twin-bearing ewes was assumed to weigh approximately 8.5 and 14.5 kg respectively. Thus the expectation was that M ewes would maintain their conceptus-free liveweight. Low group ewes were offered a level of herbage designed to permit total ewe liveweight to increase at half the expected conceptus growth (i.e. a net loss of maternal conceptus-free weight). Liveweight targets at P140 for M single- and twin-bearing ewes were 72 kg and 77 kg respectively, while those for L single- and twin-bearing ewes were 58 kg and 61 kg respectively. The intention was that L group ewes would have light lambs, which, according to the hypothesis being tested, would exhibit greater birthweight responses to shearing than lambs born to M ewes.

During the trial period, ewes were removed from the study if they died (n= 2), had severe loss of body weight during the feeding period (2), had triplets (1) or failed to lamb within 14 days of the start of the lambing period (10). Therefore, the data presented in this study are based on 105 ewes (21 single-bearing L ewes (as one ewe originally diagnosed as a twin bearing ewe gave birth to only one lamb), 19 single-bearing M ewes, 32 twin-bearing L ewes and 33 twin-bearing M ewes) and their lambs.

*Pasture*

From P70 to P140 all ewes were grazed on 4.4 ha of predominantly ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pasture (90% grass, 4% clover and 6% dead matter by dry weight). Herbage mass and sward height measurements were taken at regular intervals throughout the trial period, using a plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand) and a sward stick (Jenquip, Feilding, New Zealand) respectively.

Throughout the period P70 to P140, group M ewes were offered an average pre-grazing herbage mass of 2795±206 kgDM/ha with an average post-grazing mass of 770±68 kgDM/ha in two paddocks with a total area of 2.7 ha (stocking rate = 19.3 su./ha). Average pre- and post-grazing sward heights were 14.9±0.9 and 2.1±0.1 cm respectively for the M group. Group L ewes were offered an average pre-grazing herbage mass of 2620±219 kgDM/ha with an average post-grazing mass of 740±68 kgDM/ha in one paddock with a total area of 1.7 ha (31.2 su./ha). Average pre- and post-grazing sward heights were 13.9±0.9 and 1.4±0.1 cm respectively for L group ewes. To ensure ewes met their liveweight targets, herbage allowances were calculated based on the recommendations of Nicol (1987). Herbage allowances for both M and L ewes were controlled through daily allocation of grazing area, using electric fences (i.e. break fencing).

At P140, a random cohort of 60 twin-bearing (30 L and 30 M) ewes were set stocked at 50 su./ha with an average pasture cover of 2000 kgDM/ha until their lambs were 48 hours old (this allowed easy access to these lambs for measurement of crown rump length (CRL), girth and summit metabolism (discussed later)). When calorimetric measurements had finished, the ewes and lambs were removed from the lambing paddocks and set stocked at 14.5 su./ha with an average pasture cover of 1200 kgDM/ha until weaning (pasture cover not falling below 900 kgDM/ha). At P140 all of the single-bearing M and L ewes and the remaining 5 twin-bearing ewes were set stocked at an average pasture cover of 1200 kgDM/ha (pasture cover not falling below 900 kgDM/ha) at a stocking rate of 14.5 su./ha until weaning.

*Animal measurements*

*Ewes*

Ewes were weighed (unfasted) and condition scores were determined (Jefferies 1961) at P70, P105, P140, 36 days after the mid-point of lambing (L36) and L84. Live weights of shorn ewes were adjusted for the removal of the fleece to allow a comparison with the unshorn ewes.

The herbage intakes of 46 twin-bearing (19 M and 27 L) ewes were assessed indirectly by the use of intra-ruminal chromic sesquioxide capsules (3.0 cm core of pressed tablet, 65% $Cr_2O_3$ matrix and 9.00 mm orifice; Captec (NZ) Ltd, Auckland) as described by Morris *et al.* (1993). A capsule was inserted in each ewe at P115 and faecal samples collected (mid-afternoon) over three 5-day periods from P122 to P138 to permit calculation of herbage intake. The samples were bulked within ewe for each sample period, oven dried at $60^0$C and analysed for chromium content (Parker *et al.* 1989).

During the faecal collection periods, five oesophageal-fistulated (OF), castrated Romney sheep were grazed with the ewes. One sample of consumed pasture (extrusa) from each of the OF sheep was collected from each of the two feeding regimens in all three periods of faecal sampling. Collected extrusa was used for determination of *in vitro* digestibility as described by Morris *et al.* (1993). The aim of these intake measurements was not to determine differences in intakes between group M and L ewes but to determine if mid-pregnancy shearing increased dam intake in late pregnancy.

Rectal temperatures of all ewes were taken at P125, P131, P134, and P137. This involved placing a digital thermometer into the rectum (prior to faecal sampling) of the ewes for approximately 2 minutes until a stable reading was obtained. The rectal temperatures of ewes were measured while ewes were in their liveweight groups. On each measurement day the order of rectal temperature measurement between each group (M and L) was rotated.

*Lambs*

All new-born lambs were identified to their dam, tagged, sexed, weighed and their birth-rank recorded within 12 hours of birth. The mid-point of lambing was August 17 (L1). All lambs were weighed at L36 and L84 (weaning). At L36 male lambs were castrated. A cohort of 95 twin-born lambs (45 M and 50 L) had girth (behind the front legs) and crown rump length (CRL) measurements taken when birthweights were recorded.

Summit metabolic rates (SMR) were determined on a cohort of 62 twin-born lambs from those who had, had girth and CRL were measured (32 M and 30 L) taken before they reached 36 hours of age. Prior to SMR measurement, a dry wool depth measurement on the left mid-side area was taken. Wool was clipped (residual depth 2 mm) from the sides and back of lambs that were heavier than 4 kg to help ensure that these lambs reached their SMR. The calorimetry procedure used was the same as that in Chapter 2 except, that after the 12 minute acclimatisation period chilled water at a rate of 1.45 litres/minute and wind (via a fan) at 1.5 m/s was applied for a maximum of 90 minutes. At the end of the calorimetry session each lamb was thoroughly dried, before being returned to its dam. Clipped lambs had woollen covers (Lamb Woolover, New Zealand Woolover Ltd, Temuka, New Zealand ) placed on them for 14 days to avoid excessive heat loss.

*Climatic Data*

During the late pregnancy period (P122-140) daily maximum and minimum air temperatures were recorded at a weather station located approximately 3 km north of the trial site. Average maximum and minimum air temperature during this period was $12.9 \pm 1.6^{0}$C and $3.8 \pm 0.8^{0}$C respectively

*Data analysis*

All data were analysed by analysis of variance (unless stated below) using the Generalised Linear Model procedure of the statistical package 'Minitab' (Minitab 1998). The main effects of pregnancy status or birth rank (single vs twin), shearing treatment (unshorn vs shorn), and ewe group (maintenance vs low), and interactions between these parameters, were included in the original models. All non-significant ($P>0.05$) interactions were removed and the models refitted.

Pregnancy rank and birth rank were determined retrospectively based on number of lambs identified and weighed within 12 hours of age. Pregnancy and birth rank status did not change if a lamb died between birth and L84.

Gestation length, calculated as the interval from the day after CIDR removal until the day of parturition, was fitted as a covariate as was birthweight, in models to partition variation for both girth and crown rump length.

The proportion of twin lambs failing to reach summit metabolism was analysed as a binomial trait using the SAS (SAS 1985) procedure for categorical data modeling (CATMOD).

## Results

*Ewe liveweight and condition score*

Pregnancy rank had no effect on ewe liveweight at P69 (Table 3.1). However, twin-bearing ewes were heavier (P<0.05) than single-bearing ewes at P105 and P140 but lighter (P<0.05) than single-bearing ewes during lactation. As expected, M ewes were significantly (P<0.05) heavier (by 9 - 15 kg) than L ewes at all measurement dates. Shearing treatment had no effect on ewe liveweight during either pregnancy or lactation.

Pregnancy rank had no effect on ewe condition score at any of the measurement dates during pregnancy (Table 3.2). During lactation, single-bearing ewes had higher (P<0.05) condition scores than their twin-bearing counterparts. Condition scores for M ewes were consistently greater (P<0.05) than those of L ewes during both pregnancy and lactation. Shearing treatment had no effect on condition score during either pregnancy or lactation.

**Table 3.1.** The effect of pregnancy rank, ewe group and shearing treatment on ewe liveweights (kg) at P69, P105, P140, L36 and L84 (Mean ±SE). Means within treatments having different superscripts are different (P<0.05).

| | | Ewe liveweight | | | | |
|---|---|---|---|---|---|---|
| | (n) | P69 | P105 | P140 | L36 | L84 |
| Pregnancy rank | | | | | | |
| 1 | 40 | 58.9 ± 0.8 | $59.3^a$±0.7 | $65.1^a$±0.8 | $65.6^b$±1.0 | $67.7^b$±1.0 |
| 2 | 65 | 59.0 ± 0.6 | $61.2^b$±0.6 | $67.4^b$±0.6 | $61.4^a$±0.7 | $63.9^a$±0.7 |
| Ewe group[1] | | | | | | |
| M | 52 | $63.6^b$± 0.7 | $66.6^b$±0.7 | $73.9^b$±0.7 | $70.2^b$±0.8 | $71.2^b$±0.9 |
| L | 53 | $54.3^a$± 0.7 | $53.9^a$±0.6 | $58.5^a$±0.7 | $56.9^a$±0.8 | $60.3^a$±0.8 |
| Shearing treatment | | | | | | |
| Unshorn | 50 | 59.1 ± 0.7 | 59.7 ±0.7 | 65.9 ±0.7 | 63.7 ±0.8 | 65.7 ±0.8 |
| Shorn | 55 | 58.8 ± 0.7 | 60.7 ±0.6 | 66.5 ±0.7 | 63.4 ±0.8 | 65.8 ±0.7 |

[1] M = maintenance group, L = low group.

**Table 3.2.** The effect of pregnancy rank, ewe group and shearing treatment on ewe condition score at P69, P105, P140, L36 and L84 (Mean ±SE). Means within treatments having different superscripts are significantly different (P<0.05).

| | | Ewe condition score | | | | |
|---|---|---|---|---|---|---|
| | (n) | P69 | P105 | P140 | L36 | L84 |
| Pregnancy rank | | | | | | |
| 1 | 40 | 2.2 ±0.1 | 2.4 ±0.0 | 2.3 ±0.3 | $2.6^{b}$±0.1 | $2.7^{b}$±0.1 |
| 2 | 65 | 2.2 ±0.1 | 2.3 ±0.0 | 2.4 ±0.3 | $2.2^{a}$±0.1 | $2.3^{a}$±0.1 |
| Ewe group[1] | | | | | | |
| M | 52 | $2.4^{b}$±0.1 | $2.6^{b}$±0.0 | $2.9^{b}$±0.3 | $2.7^{b}$±0.1 | $2.7^{b}$±0.1 |
| L | 53 | $2.0^{a}$±0.1 | $2.1^{a}$±0.0 | $1.7^{a}$±0.3 | $2.1^{a}$±0.1 | $2.2^{a}$±0.1 |
| Shearing treatment | | | | | | |
| Unshorn | 50 | 2.1 ±0.1 | 2.4 ±0.0 | 2.5 ±0.3 | 2.3± 0.1 | 2.5 ±0.1 |
| Shorn | 55 | 2.2 ±0.1 | 2.3 ±0.0 | 2.2 ±0.3 | 2.4± 0.1 | 2.4 ±0.1 |

[1] M = maintenance group, L = low group.

*Ewe intake*

Ewe group had no effect on digestible organic matter intake (DOMI) during P122-126 or P129-133 (Table 3.3). However, M ewes had significantly (P<0.05) greater DOMI than L ewes during P135-139. Shearing treatment had no effect on DOMI of twin-bearing ewes (no intake measurements were taken on single-bearing ewes).

**Table 3.3.** The effect of ewe group and shearing treatment on ewe digestible organic matter intakes (DOMI) of twin-bearing ewes in late pregnancy (kg DOMI ewe$^{-1}$ day$^{-1}$) (Mean ±SE). Means within treatments having different superscripts are significantly different (P<0.05).

| | | Digestible organic matter intake | | |
|---|---|---|---|---|
| | (n) | P122 – 126 | P129-133 | P135-139 |
| Ewe group[1] | | | | |
| M | 19 | 0.40 ± 0.04 | 0.49 ± 0.04 | $0.61^{b}$ ± 0.03 |
| L | 27 | 0.44 ± 0.03 | 0.42 ± 0.03 | $0.49^{a}$ ± 0.02 |
| Shearing Treatment | | | | |
| Unshorn | 21 | 0.46 ± 0.03 | 0.43 ± 0.03 | 0.53 ± 0.03 |
| Shorn | 25 | 0.39 ± 0.03 | 0.47 ± 0.03 | 0.56 ± 0.02 |

[1] M = maintenance group, L = low group.

*Ewe rectal temperatures*

Pregnancy rank affected ewe rectal temperature on one measurement day (P135) only, when twin-bearing ewes had higher (P<0.05) rectal temperatures than their single-bearing counterparts (Table 3.4). At P124, P130 and P135, M ewes had between 0.1 and 0.2°C lower (P<0.05) rectal temperatures than L ewes, although ewe group had no effect on rectal temperature at P137. Shearing treatment had no effect on ewe rectal temperature at P125, P130 or P137 (P=0.06). On P135, shorn ewes had 0.1°C (P<0.05) lower rectal temperatures than unshorn ewes. This occurred on the day on which the lowest minimum air temperature was recorded.

**Table 3.4.** The effect of pregnancy rank, ewe group and shearing treatment on ewe rectal temperatures (°C) (Mean ±SE) at P124, P130, P135 and P137. Maximum and minimum air temperatures (°C) for the day of rectal temperature measurement are shown. Means within treatments having different superscripts are significantly different (P<0.05).

| | (n) | Ewe rectal temperature P124 | P130 | P135 | P137 |
|---|---|---|---|---|---|
| Pregnancy rank | | | | | |
| 1 | 40 | 39.6 ±0.0 | 39.4 ±0.0 | $39.4^{a}$±0.0 | 39.4±0.0 |
| 2 | 65 | 39.7 ±0.0 | 39.4 ±0.0 | $39.6^{b}$±0.0 | 39.4±0.0 |
| Ewe group[1] | | | | | |
| M | 52 | $39.5^{a}$±0.0 | $39.3^{a}$±0.0 | $39.4^{a}$±0.0 | 39.4±0.0 |
| L | 53 | $39.7^{b}$±0.0 | $39.5^{b}$±0.0 | $39.5^{b}$±0.0 | 39.4±0.0 |
| Shearing treatment | | | | | |
| Unshorn | 50 | 39.6 ±0.0 | 39.4 ±0.0 | $39.5^{b}$±0.0 | 39.4±0.0 |
| Shorn | 55 | 39.6 ±0.0 | 39.4 ±0.0 | $39.4^{a}$±0.0 | 39.4±0.0 |
| Air Temperature | | | | | |
| Maximum | | 14.0 | 10.0 | 11.9 | 17.2 |
| Minimum | | 9.3 | 2.6 | - 1.4 | 4.0 |

[1] M = maintenance group, L = low group.

**Table 3.5.** The effect of pregnancy rank, ewe group and shearing treatment on gestation length (days) (Means ±SE). Means within treatments having different superscripts are significantly different (P<0.05).

| | (n) | Gestation length |
|---|---|---|
| Pregnancy rank | | |
| 1 | 40 | 149.3 ±0.3 |
| 2 | 130 | 148.9 ±0.2 |
| Ewe group[1] | | |
| M | 86 | 148.9 ±0.3 |
| L | 84 | 149.3 ±0.2 |
| Shearing treatment | | |
| Unshorn | 79 | $148.7^{a}$±0.3 |
| Shorn | 91 | $149.2^{b}$±0.2 |

[1] M = maintenance group, L = low group.

*Gestation length and lamb liveweights*

Pregnancy rank and ewe group had no effect on gestation length (Table 3.5). The gestation period was 0.5 days (P<0.05) longer in lambs born to shorn ewes than in lambs born to unshorn ewes.

There was a significant interaction (P<0.05) between ewe group and birth rank on lamb birthweight (Table 3.6). Thus, singletons born to M ewes were 1.4 kg heavier than their twin born counterparts however, there was no significant difference (absolute difference 0.6 kg) in birthweight of single- and twin-born lambs born to L ewes.

There was also a significant interaction between dam shearing treatment and birth-rank on lamb birthweight, such that singletons born to shorn dams were 0.7 kg heavier than those born to unshorn dams (P<0.05) but there was no effect of dam shearing treatment on birthweight of twin-born lambs.

Although there was no interaction between ewe group and shearing treatment on lamb birthweight, shearing of the dam increased the birthweight of lambs born to M ewes (by 0.6 kg, P<0.05) but had no effect on the birthweights of lambs born to L ewes.

Singletons born to group M ewes were heavier (by 3 to 7 kg, $P<0.05$) than all other lambs during lactation.

**Table 3.6.** The effect of birth rank, ewe group and ewe shearing treatment and their interactions on lamb liveweight (kg) at birth, L36 and L86 (Means ±SE). Means within treatments having different superscripts are significantly different (P<0.05).

| | Lamb liveweight | | | | | |
|---|---|---|---|---|---|---|
| | Birthweight | | L36 | | L84 | |
| | (n) | | (n) | | (n) | |
| Birth rank | | | | | | |
| 1 | 40 | $5.2^{b}$ ±0.2 | 33 | $15.5^{b}$±0.4 | 29 | $25.5^{b}$±0.5 |
| 2 | 130 | $4.3^{a}$ ±0.1 | 114 | $12.1^{a}$±0.2 | 111 | $21.7^{a}$±0.3 |
| Ewe group[1] | | | | | | |
| M | 85 | $5.2^{b}$ ±0.1 | 75 | $14.9^{b}$±0.3 | 73 | $24.9^{b}$±0.4 |
| L | 85 | $4.3^{a}$ ±0.1 | 72 | $12.8^{a}$±0.3 | 67 | $22.3^{a}$±0.4 |
| Shearing treatment | | | | | | |
| Unshorn | 78 | $4.5^{a}$ ±0.1 | 70 | 13.6 ±0.3 | 65 | 23.5 ±0.4 |
| Shorn | 92 | $5.0^{b}$ ±0.1 | 77 | 14.1 ±0.3 | 75 | 23.7 ±0.4 |
| Ewe group x Birth rank | | | | | | |
| M – 1 | 19 | $5.9^{c}$ ±0.2 | 16 | $17.2^{c}$±0.6 | 15 | $27.1^{c}$±0.7 |
| M – 2 | 66 | $4.5^{b}$ ±0.1 | 59 | $13.0^{b}$±0.3 | 58 | $22.8^{b}$±0.4 |
| L – 1 | 21 | $4.6^{ba}$±0.2 | 17 | $14.0^{b}$±0.5 | 14 | $23.9^{b}$±0.8 |
| L – 2 | 64 | $4.0^{a}$ ±0.1 | 55 | $11.3^{a}$±0.3 | 53 | $20.6^{a}$±0.4 |
| Shearing x Birth rank | | | | | | |
| Unshorn – 1 | 22 | $4.9^{b}$ ±0.2 | 20 | $15.2^{b}$±0.5 | 16 | $25.5^{b}$±0.7 |
| Unshorn – 2 | 56 | $4.2^{a}$ ±0.1 | 50 | $12.0^{a}$±0.3 | 49 | $21.6^{a}$±0.4 |
| Shorn – 1 | 18 | $5.6^{c}$ ±0.2 | 13 | $16.0^{b}$±0.6 | 13 | $25.6^{b}$±0.8 |
| Shorn – 2 | 74 | $4.4^{ab}$±0.1 | 64 | $12.3^{a}$±0.3 | 62 | $21.8^{a}$±0.4 |
| Ewe group x Shearing | | | | | | |
| M – Unshorn | 42 | $4.9^{b}$ ±0.2 | 38 | $14.5^{b}$±0.4 | 37 | $24.4^{b}$±0.5 |
| M – Shorn | 43 | $5.5^{c}$ ±0.2 | 37 | $15.7^{b}$±0.5 | 36 | $25.5^{b}$±0.6 |
| L – Unshorn | 36 | $4.2^{a}$ ±0.2 | 32 | $12.7^{a}$±0.4 | 28 | $22.6^{a}$±0.6 |
| L – Shorn | 49 | $4.4^{ab}$±0.2 | 40 | $12.6^{a}$±0.4 | 39 | $21.9^{a}$±0.6 |

[1] M = maintenance group, L = low group.

*Girth, crown rump length, dry and wet wool depth*

Both shearing treatment and ewe group had no effect on either girth, crown rump length (CRL), and dry or wet wool depth of the twin-born lambs (measurements not taken on singletons)(Table 3.7).

**Table 3.7.** The effect of ewe group and shearing treatment on girth (cm), crown rump length (CRL) (cm), dry (Dry) and wet (Wet) wool depth measurements (mm) of new-born twin lambs (Mean ±SE). Means within treatments having different superscripts are significantly different (P<0.05).

| | (n) | Girth | CRL | (n) | Dry | Wet |
|---|---|---|---|---|---|---|
| Ewe group[1] | | | | | | |
| M | 45 | 39.7±0.2 | 52.2 ±0.6 | 30 | 7.0 ±0.3 | 5.2 ±0.2 |
| L | 50 | 39.4±0.2 | 53.4 ±0.5 | 28 | 7.0 ±0.3 | 5.5 ±0.2 |
| Shearing treatment | | | | | | |
| Unshorn | 48 | 39.8 ±0.2 | 52.8 ±0.5 | 32 | 6.9 ±0.3 | 5.3 ±0.2 |
| Shorn | 47 | 39.3 ±0.2 | 52.8 ±0.5 | 26 | 7.1 ±0.3 | 5.4 ±0.2 |

[1] M = maintenance group, L = low group.

*Summit metabolism*

Sex of the lamb, ewe group and shearing treatment had no effect on the proportion of twin lambs failing to attain summit metabolism (Table 3.8), though the proportion tended to be higher in lambs born to M and shorn ewes. Among those lambs that did reach summit metabolism, SMR was not influenced by either ewe group or shearing treatment (Table 3.9).

**Table 3.8.** The effect of sex of the lamb, ewe group and ewe shearing treatment on the proportion (%) of twin-born lambs (less than 36hrs of age) that did not reach summit metabolism (Mean ±SE).

| | (n) | Proportion |
|---|---|---|
| Sex | | |
| Male | 34 | -1.75[1] ± 0.48 (14)[2] |
| Female | 28 | -3.29 ± 1.02 (4) |
| Ewe group[3] | | |
| M | 30 | -1.61 ± 0.49 (17) |
| L | 32 | -3.43 ± 1.02 (3) |
| Shearing Treatment | | |
| Unshorn | 32 | -3.43 ± 1.02 (3) |
| Shorn | 30 | -1.61 ± 0.49 (17) |

[1] Logit-transformed.
[2] Back-transformed (%).
[3] M = maintenance group, L = low group.

**Table 3.9.** The effect of ewe group and shearing treatment on summit metabolism (W/kg) of twin-born lambs less than 36 hrs of age (Mean ± SE). Means within treatments having different superscripts are significantly different (P<0.05).

| | (n) | Summit metabolism | |
|---|---|---|---|
| Ewe group[1] | | | |
| M | 25 | 16.01 | ± 0.57 |
| L | 31 | 15.37 | ± 0.49 |
| Shearing treatment | | | |
| Unshorn | 31 | 15.70 | ± 0.49 |
| Shorn | 25 | 15.68 | ± 0.57 |

[1] M = maintenance group, L = low group.

**Discussion**

This study was designed to test the hypothesis that the shearing effect on lamb birthweight is greatest in conditions where ewes are otherwise destined to give birth to lambs of low birthweights (i.e. that pregnancy shearing alleviates maternal constraint to foetal growth). This study also offered an opportunity to further test the effect of mid-pregnancy shearing on the SMR of newborn lambs.

Group M was managed to minimise maternal constraint on lamb birthweight. However, group L was designed to place maternal constraint on lamb birthweight (lower dam body weight and herbage allowance during the mid- to late-pregnancy period) in order to produce lighter lambs than those born to group M ewes. The key hypothesis above would be supported if there was a greater birthweight response to pregnancy shearing in lambs born to L ewes compared to those born to M ewes.

The increase in average ewe liveweight and change in condition score during the mid- to late-pregnancy period (from P70 to P139) was far greater in M ewes than L, indicating a higher intake. However, in late pregnancy when ewe intakes were measured, group M had higher intakes than that of group L ewes during only one of the three measurement periods. Both ewe groups were offered similar allowances during the first two measurement periods, to avoid possible pregnancy toxaemia losses in group L ewes, to ensure group L achieved their liveweight targets (as they were observed to be behind their target) and to stop group M exceeding theirs. Successful management of feed allowance during the mid- to late-pregnancy period resulted in both ewe groups (M and L) meeting their liveweight targets at parturition. Lambs born to M ewes were heavier than those born to group L ewes (by 1.3 kg in singles and 0.5 kg in twins) indicating successful manipulation of lamb birthweight.

In the present study, pregnancy shearing was found to increase the birthweights of singletons but had no effect on the birthweight of twins. This finding is in agreement with that of Morris *et al.* (2000) and Revell *et al.* (2002). However it contrasts with Morris and McCutcheon (1997) who found a twin-specific response and with the findings of Chapter 2, where the birthweight response was not birth-rank specific. Morris *et al.* (1999) found in a study with twin-bearing ewes only, that pregnancy shearing significantly increased lamb birthweight.

If the hypothesis being tested (that the birthweight response from mid-pregnancy shearing is greatest in conditions in which ewes are otherwise destined to give birth to lambs of low birthweight) is to be supported we would expect to find a greater birthweight response to pregnancy shearing in lambs born to L dams than those born to M dams. However, mid-pregnancy shearing increased the birthweight of lambs born to M ewes but did not increase the birthweight of lambs born to L ewes. Therefore the hypothesis being tested is not supported.

As in Chapter 2 with the hypothesis not being supported, we must examine other possible mechanisms for the birthweight response to pregnancy shearing. In Chapter 2, it was suggested that the birthweight response could be due to a maternal reaction to cold stress. In cold conditions recently shorn ewes are more likely to be exposed to conditions below their lower critical temperature (LCT) than unshorn ewes (Gregory 1995). In this study, rectal temperatures were taken 50-70 days post-shearing and it was observed that only on one occasion did shorn ewes have lower rectal temperatures than their unshorn counterparts. This occurred on the only measurement day in which the minimum air temperature fell below zero degrees Celsius. However, this minor difference is unlikely to be of physiological significance. Since rectal temperatures were not taken in the period directly following shearing, it is unknown if dams in the present study were under cold stress during that period and whether maternal cold stress was responsible for the birthweight response observed.

In agreement with the findings of Husain *et al.* (1997) and Revell *et al.* (2002) a birthweight response from pregnancy shearing was observed without an increase in ewe intake. In contrast, it was observed in Chapter 2 that during both mid- and late-pregnancy, shearing of the dam slightly increased intake. However, it was concluded that this increase in intake was not accountable for the birthweight response observed. In contrast Dabiri *et al.* (1996) (who did not find a birthweight response) reported that in late pregnancy, shorn ewes had higher intakes than their unshorn counterparts. Rumen restriction in late pregnancy (Forbes 1968) may limit a ewes ability to increase intake. In the study of Dabiri *et al.* (1996) dams were shorn at day 118 of pregnancy, resulting in less insulation during the late pregnancy period (than those in the present study), suggesting that it is possible that those ewes were subjected to conditions below there LCT. The high pasture allowances for dams in Chapter 2, may also be a contributing factor for the higher intake reported in shorn ewes in that study.

In the present study, mid-pregnancy shearing was found to increase gestation length. This agrees with the findings of Revell *et al.* (2002) but contrasts the findings of Chapter 2. Rattray *et al.* (1974) reported that in late pregnancy foetal growth is approximately 150-200 g/d. The extra half a day gestation observed in this study therefore only accounts for a minor portion of the difference in birthweight found. Similarly, the data presented by Revell *et al.* (2002) indicates that an increase in gestation length was not responsible for the birthweight response observed in that study. As found in Chapter 2, the results of the present study do not identify the mechanism responsible for the birthweight effect.

When birthweights for each birth-rank, within each ewe group, are plotted on a similar figure as in Chapter 2 (Figure 3.1), it appears that there are two criteria not one (thus explaining why the hypothesis being tested was not supported), that affects the ability of dam to respond to mid-pregnancy shearing: firstly; the dam must have the potential to respond (i.e. be otherwise destined to give birth to a lamb(s) of low birthweight, as suggested in Chapter 2) and secondly; she must have the means to respond to the shearing stimuli (i.e. an adequate level of maternal reserves and/or an adequate level of nutrition, allowing extra nutrients to be partitioned towards additional foetal growth). This helps explain why the dam in poor body condition and/or under nutritional stress (e.g. shorn twin L ewe) is unable to respond to the pregnancy shearing stimuli. Similarly, when the ewe is under a degree of physiological stress (e.g. single bearing L ewes) the birthweight response is not as large as expected. The reduced shearing response may still be observed in the single bearing dam due to energy requirement for additional foetal growth being less than that of a twin-bearing dam. In support of this new hypothesis, Revell *et al.* (2002) found no effect of pregnancy shearing on twin lamb birthweights. Lambs born to unshorn dams in that study met criterion one, of the new hypothesis (low birthweights 4.2 kg). However, these ewes did not meet criterion 2, as it was reported that dam liveweights did not change between mid- and late-pregnancy (indicating that these ewes may have been under nutritional stress). Similarly, Morris *et al.* (2000) who also failed to get a birthweight response in twins reported ewe liveweight did not change during late pregnancy. The results of these two studies further support the new hypothesis and are a possible explanation of the birth-rank specific results found in some studies.

In the present study the SMR testing procedure was improved compared to that used in Chapter 2 (lambs heavier than 4 kg were clipped). This resulted in a far greater proportion of lambs reaching summit metabolism in the standard conditions used, allowing a more accurate measurement of SMR.

In agreement with the findings of Chapter 2, dam shearing treatment failed to have any effect on either the proportion of twin lambs reaching summit metabolism or the level of summit metabolism itself. This contrasts with Revell *et al.* (2002) who observed that twin lambs born to shorn dams had higher summit metabolism than those born to unshorn dams but, found the opposite relationship for singletons. Similarly, Stott and Slee (1985), Symonds *et al.* (1992) and Egan (1997) found that lambs born to shorn housed dams had enhanced thermoregulatory capability in comparison to lambs born to unshorn dams. The results of the present study and that of Chapter 2, and the conflicting results of Revell *et al.* (2002) suggest that under pastoral conditions pregnancy shearing may not have any effect the thermoregulatory capability of the newborn lamb. However, any increase in birthweight of twin lambs (which are generally lighter than their single-born counterparts) should reduce lamb losses due to starvation exposure. This would suggest any effect of pregnancy shearing on lamb survival rates might be solely due to increases in the birthweight of twin born lambs. Morris *et al.* (1999) found in a large scale study involving twin-born lambs only, that lamb survival to weaning tended to be improved by pregnancy shearing. It is possible that the thermoregulatory responses observed in the indoor studies are due some other mechanism (i.e. relief from heat stress of the dam) that does not occur under pastoral conditions.

**Conclusion**

Mid-pregnancy shearing was found to increase the birthweights of singletons but not twins. The results of this study further supports the conclusions made in Chapter 2, that the birthweight response to pregnancy shearing is not due to either an increase in ewe intake or gestation length. When the data in this study are compiled with that of previous studies it becomes apparent that there are two criterion not one, that affect the ability of the dam to respond to mid-pregnancy shearing. It is therefore hypothesized; that first, the dam must have the potential to respond and secondly; that she must have the means to respond to the mid-pregnancy shearing stimuli. Pregnancy shearing was found to have no effect on the SMR of newborn lambs. This result coupled with the findings in Chapter 2 suggest that under outdoor pastoral conditions pregnancy shearing has no effect on the new-born lambs thermogenic capability when subjected to adverse stimuli. An increase in lamb birth is not synonymous with an increase in lamb survival rates to weaning. Therefore further studies involving large numbers of lambs are required to determine if an increase in lamb birthweight though mid-pregnancy shearing will increase lamb survival rates to weaning.

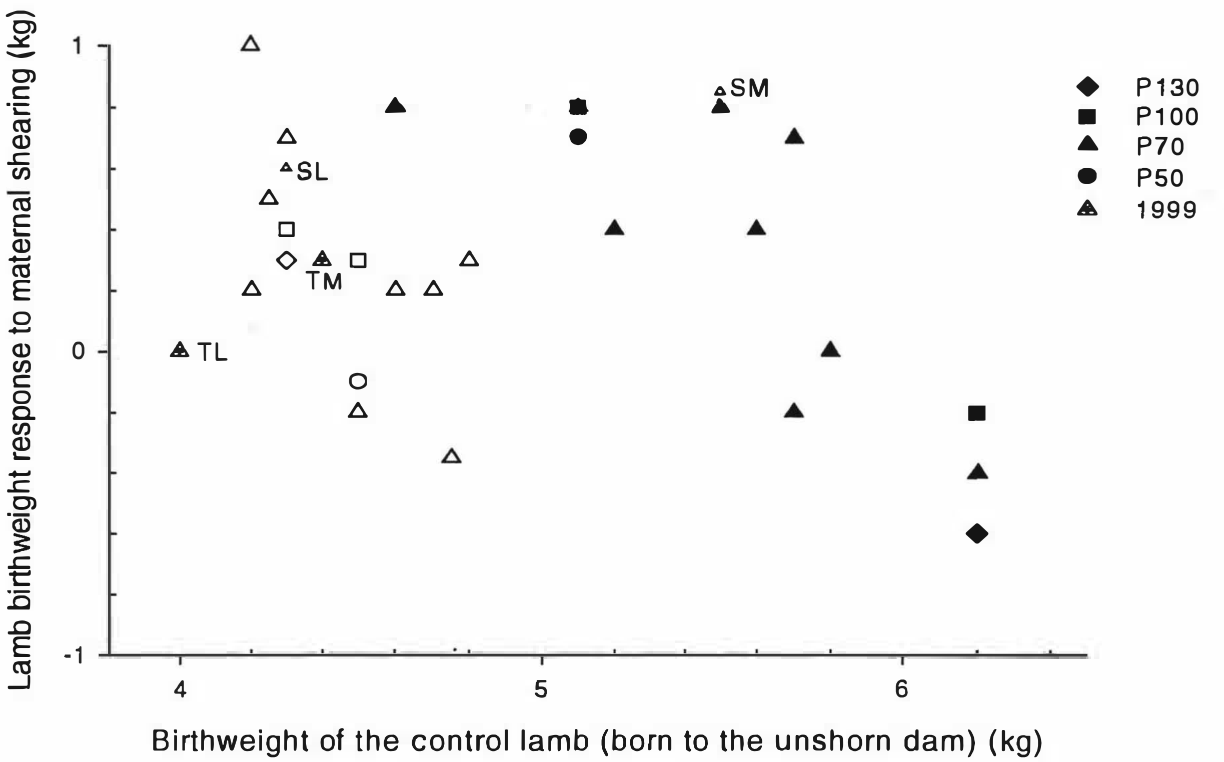



**Figure 3.1.** Birthweight responses to mid- to late-pregnancy shearing (singles- closed symbols, twins- open symbols) as a function of the birthweights of control lambs (each point represents a separate trial or treatment [shearing date] within a trial (Morris and McCutcheon 1997, Morris *et al.* 2000, Revell *et al.* 2000, Revell *et al.* 2002 and Chapter 2)). Shearing responses for each of the feeding regimes in this study are indicated by their subscripts (single maintenance (SM), single low (SL), twin maintenance (TM), twin low (TL).

# Chapter four - The effect of mid-pregnancy shearing on lamb birthweight and survival rates to weaning under commercial conditions


## Abstract

Under intensive pastoral studies mid-pregnancy shearing has been shown to increase lamb birthweight but has failed to have any effect on the newborn lamb's thermoregulatory capability. However, an increase in the birthweight of an otherwise lightweight lamb should result in higher survival rates to weaning. This study was designed to investigate the effect of mid-pregnancy shearing on lamb birthweight and survival rates to weaning under commercial conditions at two different sites. At Riverside, 311 single-, 671 twin- and 48 triplet-bearing ewes were either shorn at mid-pregnancy (n = 486) or left unshorn (n = 544). Similarly, at Tuapaka 235 single-, 556 twin-, and 63 triplet-bearing ewes were either shorn at mid-pregnancy (n = 419) or left unshorn (n = 435).

Mid-pregnancy shearing significantly ($P<0.05$) increased the birthweights of twin-born lambs at each site (by 0.4 and 0.1 kg respectively at Riverside and Tuapaka) without effecting the birthweights of singleton or triplet born lambs. Twin lambs, born to shorn dams at Riverside were heavier ($P<0.05$) at weaning (by 0.9 kg) than their counterparts born to unshorn dams. Mid-pregnancy shearing tended to increase survival rates of twin-born lambs at both sites but, not significantly so. Autopsies undertaken at Tuapaka found no effect of dam shearing treatment on losses due to starvation-exposure. However, weaning percentages were significantly lower ($P<0.05$) in singletons born to shorn dams than their counterparts born to unshorn dams (possibly due to increased losses due to dystocia). At both sites mid-pregnancy shorn ewes had greater ($P<0.05$) annual fleece weights (by 0.2 kg) than their unshorn counterparts.

These findings show that the mid-pregnancy shearing under commercial conditions can increase birthweights of at least twin-born lambs. However, for this increase in birthweight to effect survival rates to weaning, lamb birthweights must otherwise be destined to be low and within a birthweight range in which survival rates to weaning are

not near optimal. Conversely, any increase in birthweights of otherwise heavy birthweight lambs (i.e. singletons) may in fact reduce survival rates. This would suggest that the mid-pregnancy shearing technique is best suited to farming situations with relatively high lambing percentages or where single and multiple ewes are identified and given differing shearing treatments.

**Introduction**

In both Chapters 2 and 3 mid-pregnancy shearing was shown to increase lamb birthweight. Chapter 3 was designed to produce lambs from unshorn ewes of differing birthweights, to test the hypothesis advanced in Chapter 2, namely that the birthweight response to pregnancy shearing is greatest in conditions in which the unshorn dam gives birth to a relatively lightweight lamb(s). However, a birthweight response to shearing was not observed in lambs born to ewes in the treatment designed to produce low birthweight lambs. Based on this result and those found in previous pregnancy shearing studies it was then hypothesised that there are two criterion, not one, that affect the birthweight response to mid-pregnancy shearing: first, the dam must have the potential to respond (i.e. give birth to an otherwise lightweight lamb(s)); and, secondly, the dam must have the means to respond (i.e. adequate maternal reserves and/or an adequate level of nutrition, allowing extra nutrients to be partitioned towards additional foetal growth).

Morris *et al.* (1999) found that pregnancy shearing tended to increase survival rates in twin-born lambs. They stated that selectively increasing the birthweight of an otherwise lightweight lamb(s) should improve newborn lamb survival rates. In both Chapters 2 and 3, mid-pregnancy shearing was shown to have no effect on either the proportion of lambs reaching summit metabolism or summit metabolic rate (SMR). However, other mechanisms such has thermal insulation, level of body reserves and surface area to body mass ratio are additionally involved in the ability of the newborn lamb to withstand adverse conditions.

This study was designed to investigate the effect of mid-pregnancy shearing on both lamb birthweight and survival rates to weaning under commercial conditions (utilizing ewes of varying liveweight and body condition). The study also offered an opportunity to examine the relationship between ewe liveweight/condition score and the birthweight response to shearing, and hence to further examine the hypothesis developed in Chapter 3, namely that there are two criterion that must be met if there is to be a lamb birthweight response to mid-pregnancy shearing.

**Methods**

Similar studies were conducted at two contrasting farms. The first study was conducted at Massey University's Riverside Farm, 10 km north of Masterton, New Zealand (south latitude 40° 50', east longitude 175° 38'). The Riverside farm has a flat to rolling topography and is classed as "summer-dry". The second trial was conducted at Massey University's Tuapaka Hill Country Farm, 15km east of Palmerston North, New Zealand (south latitude 40° 21', east longitude 175° 45'). The Tuapaka farm has a rolling to steep topography. The trial period for both studies was from April (mating) to December (weaning) 2000.

*Riverside*

*Experimental design and animals*

The trial design was a 3 x 2 factorial involving pregnancy status (single- versus twin- versus triplet-bearing) and shearing treatment (shorn on average day 70 of pregnancy (P70) versus unshorn (with approximately 6 months wool growth)).

Romney ewes (5 years of age, n = 1197) were used during the trial period. All ewes conceived in a 17-day (1 oestrous cycle) mating period and were selected on this basis from a commercial flock of 1402. Average day 0 (P0) of pregnancy was defined as 9 days after ram introduction. All ewes were mated to Suffolk rams.

*Treatments*

Pregnancy diagnosis (via ultrasound) was conducted at both P50 and P86 (to try to accurately assess pregnancy status). Approximately half of the single-, twin- and triplet-bearing ewes were shorn using the cover comb (Sunbeam New Zealand Ltd, maximum stubble depth 9mm) at P70, the remainder being left unshorn. At P133 (set stocking), single-, twin- and triplet-bearing ewes were set stocked separately with equal numbers of shorn and unshorn ewes within each paddock.

Ewes were removed from the study if they died (n = 45) (26 shorn vs 19 unshorn), were identified as being non-pregnant at either of the two pregnancy scannings (n = 31), lost their tags/had no lamb birth data recorded or went missing during the trial period (n =

91). Therefore the data presented in the Riverside study is based on 1030 ewes; 311 single-bearing, 671 twin-bearing and 48 triplet-bearing.

*Pasture*

Average herbage masses offered during the trial period were measured using a plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand, 50 readings at each measurement for each paddock) at monthly intervals during pregnancy and at fortnightly intervals during lactation. Sward heights were also recorded at monthly intervals during lactation using a sward stick (Jenquip, Feilding, New Zealand, 50 readings per paddock at each measurement).

During the period P-11 (two days before ram introduction) to P133, ewes were rotationally grazed (as one mob) over a total area of 121 ha (being shifted before average cover fell below 900 kgDM/ha). In addition ewes were offered a daily pasture silage allowance of 0.5 kgDM/day during the period P57 to P133. At P133 all ewes were set stocked until weaning (L86/87, i.e. 86/87 days after the mid-point of lambing), at average stocking rates of 11.2, 9.5 and 7.7 ewes/ha for single-, twin- and triplet-bearing ewes respectively. Directly prior to set stocking, herbage mass and sward height was determined in each lambing paddock. Average herbage masses and sward heights during the study are shown in Table 4.1.

**Table 4.1**. Average herbage masses (kgDM/ha) during pregnancy (P-11 to P133), prior to set stocking (P133) and during lactation (P133 to L87) and average sward heights (cm) prior to set stocking (P133) and during lactation (P133 – L87) at Riverside.

| | Stage of study | | |
|---|---|---|---|
| | P-11 to P133 | P133 | P133 to L87 |
| Pregnancy rank | | | |
| 1 | | | |
| Herbage mass | 1609 ± 232 | 1099 ± 41 | 1158 ± 65 |
| Sward height | | 3.8 ± 0.7 | 2.4 ± 0.6 |
| 2 | | | |
| Herbage mass | 1609 ± 232 | 1140 ± 18 | 1174 ± 29 |
| Sward height | | 3.3 ± 0.3 | 2.5 ± 0.2 |
| 3 | | | |
| Herbage mass | 1609 ± 232 | 1086 ± 41 | 1190 ± 65 |
| Sward height | | 4.2 ± 0.7 | 2.6 ±0.4 |

*Animal measurements*

*Ewes*

For a period of 10 days after shearing, shorn and unshorn ewes were inadvertently separated however, both groups were offered similar allowances. Shorn ewes were grazed in a sheltered paddock.

All ewes were weighed (unfasted, within 5 hours of removal from pasture) and condition scored (Jefferies 1961, scale 0 – 5) at P67, P101, P133, at docking (either 34 days after the midpoint of lambing (L34) or at L35, with approximately even numbers of shorn and unshorn ewes on each day), and at weaning (L86/87, approximately even numbers of shorn and unshorn ewes each day). The mid-point of lambing (L1) was 12 September 2000. All ewes (regardless of mid-pregnancy shearing treatment) were shorn at L127; these data, combined with the fleece weights of ewes shorn at P67, allowed annual fleece weights to be determined.

*Lambs*

Lambs were identified to the dam, sexed, recorded for birth-rank, weighed and tagged within 12 h of birth. Lambs were weighed at docking (L35/36) and at weaning (L86/87). Males were castrated using a rubber ring at docking.

*Tuapaka*

*Experimental design and animals*

At the second trial site (Tuapaka), the same trial design as used at Riverside farm was repeated. Minor differences in trial design will be reported here.

At Tuapaka, 1048 mixed aged Romney ewes were used during the trial period, selected from a commercial flock of 1360 on the basis of a successful conception during a 17-day mating period. All ewes were mated to Romney rams.

*Treatments*

Pregnancy diagnosis (via ultrasound) was conducted at both P49 and at P83. Set stocking was at P130. Ewes were removed from this study if they died (n = 10, 6 shorn vs 4 unshorn), were identified as being non-pregnant at either of the two pregnancy scannings (n = 13), lost their tags/had no lamb birth data recorded or went missing during the trial period (n = 171). Therefore the data presented in the Tuapaka study is based on 854 ewes (235 single-bearing, 556 twin-bearing and 63 triplet-bearing).

From P-13 to P130, ewes were rotationally grazed (as one mob) over an area of 112 ha (moved before average cover fell below 900 kgDM/ha). At P130 all ewes were set stocked until L90/91, at average stocking rates of 12, 8 and 10 ewes/ha for single-, twin- and triplet bearing (there was only one triplet paddock) ewes respectively. At set stocking, herbage mass and sward height measurements were determined in each lambing paddock. Average herbage masses and sward heights during the study are shown in Table 4.2.

**Table 4.2** Average herbage masses (kg DM/ha) during pregnancy (P-13 to P130), at set stocking (P130) and during lactation (P130 to L91) and average sward heights (cm) at set stocking (P130) and during lactation (P130 – L91) at Tuapaka.

| | Stage of study | | |
|---|---|---|---|
| | P-13 to P130 | P130 | P130 to L91 |
| Pregnancy rank | | | |
| 1 | | | |
| Herbage mass | 1111 ± 126 | 1095 ± 72 | 973 ± 14 |
| Sward height | | 5.8 ± 0.4 | 3.4 ± 0.3 |
| 2 | | | |
| Herbage mass | 1111 ± 126 | 1117 ± 73 | 988 ± 15 |
| Sward height | | 4.5 ± 0.4 | 3.2 ± 0.3 |
| 3 | | | |
| Herbage mass | 1111 ± 126 | 1582 | 1571 ± 44 |
| Sward height | | 9.1 | 6.4 ± 1.0 |

*Animal measurements*

*Ewes*

For a period of 6 days immediately after mid-pregnancy shearing unshorn and shorn ewes were inadvertently separated (as at Riverside unshorn and shorn ewes were offered similar allowances during the separation period but shorn ewes were grazed in a sheltered paddock).

Ewes were weighed and a condition score determined at P69, P101, P130, at either L28 or L29 (docking) and at weaning (L90/91). The mid-point of lambing was 19 September 2000. All ewes were shorn at L93 to determine annual fleece production.

*Lambs*

Lambs were weighed at birth, docking (L28/29) and at weaning (L90/91).

If a lamb was found dead during the lambing period it was autopsied. Lambs were diagnosed as having died from starvation-exposure, dystocia or via 'other' causes. The autopsy procedure used was based on that used by Duff (1980). The recording sheet used is attached as Appendix 2.

*Data Analysis*

All measurements on ewes and lambs were subjected to analysis of variance (unless stated below) using the Generalised Linear Model procedure of the statistical package 'Minitab' (Minitab, 1998). The main effects of pregnancy status (or birth-rank) (single vs twin vs triplet) and shearing treatment (unshorn vs shorn) and interactions between these parameters were included in the original models. All non-significant (P>0.05) interactions were then removed and the models re-fitted.

Pregnancy rank and birth-rank were determined as the number of lambs per ewe, identified and weighed within 12 hours of age (not based on numbers identified at either scanning). Neither pregnancy nor birth-rank "status" was altered if a lamb died between L1 and weaning.

Sex of the lamb was used as a fixed effect in the models to partition variation in lamb liveweight at birth, docking and weaning. Ewe liveweight at set stocking and date of birth were used as covariates in the models for lamb birthweights. Similarly, ewe liveweight at docking and at weaning, and date of birth, were used as covariates in the models for lamb liveweight at both docking and weaning.

If a ewe lost all of her lambs between birth and weaning, she was removed from the analysis used to calculate ewe liveweight and condition score at both docking and weaning.

The proportion of lambs surviving to weaning and cause of death were analysed as a binomial trait using the SAS (SAS 1985) procedure for categorical data modelling (CATMOD).

## Results

*Ewe liveweight*

*Riverside*

Triplet-bearing ewes were significantly heavier (P<0.05) than single- and twin-bearing ewes during the period from P67 to P133 (by approximately 6 to 9 kg and 4 to 6 kg respectively) (Table 4.3). Similarly, twin-bearing ewes were significantly heavier

(P<0.05) than their single-bearing counterparts during that same period (by approximately 1 to 4 kg).

At docking (L35/36) single-bearing ewes were heavier (by 2.6 kg, P<0.05) than twin-bearing ewes. At weaning (L86/87) both single- and triplet-bearing ewes were heavier than twin-bearing ewes (by 5.8 and 3.5 kg respectively, P<0.05).

Shearing treatment had no effect on ewe liveweight during either pregnancy or lactation.

*Tuapaka*

As observed at Riverside, triplet-bearing ewes were heavier than their single- and twin-bearing counterparts during P69 to P130 (by approximately 5 to 9 kg and 3 to 6 kg respectively, P<0.05, Table 4.4). During that same period, twin-bearing ewes were also heavier than their single-bearing counterparts (by approximately 3 to 4 kg, P<0.05).

During lactation, triplet-bearing ewes were significantly (P<0.05) heavier than both single- and twin-bearing ewes (by 2.5 to 6.8 kg).

Shearing treatment had no effect on ewe liveweight during pregnancy. However, at docking (L28/29) shorn ewes were lighter than their unshorn counterparts (by 3.1 kg, P<0.05) although by weaning this difference was not observed.

**Table 4.3.** The effect of pregnancy rank and shearing treatment on ewe liveweights (kg) at P67, P101, P133, L34/35 and L86/87 at Riverside (Mean ±SE). Means within treatment having different superscripts are different ($P<0.05$).

| | | Ewe Liveweight | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | P67 | P101 | P133 | | L34/35 | | L86/87 |
| | (n) | | | | (n) | | (n) | |
| Pregnancy rank | | | | | | | | |
| 1 | 311 | 62.1$^{a}$ ±0.4 | 64.0$^{a}$ ±0.4 | 66.4$^{a}$ ±0.5 | 244 | 65.3$^{b}$ ±0.6 | 257 | 69.9$^{b}$ ±0.5 |
| 2 | 671 | 64.0$^{b}$ ±0.3 | 66.6$^{b}$ ±0.3 | 70.6$^{b}$ ±0.4 | 650 | 62.7$^{a}$ ±0.3 | 635 | 64.1$^{a}$ ±0.3 |
| 3 | 48 | 68.8$^{c}$ ±1.0 | 72.0$^{c}$ ±1.1 | 75.6$^{c}$ ±1.4 | 40 | 64.0$^{ab}$ ±1.4 | 40 | 67.6$^{b}$ ±1.4 |
| Shearing treatment | | | | | | | | |
| Unshorn | 544 | 65.2 ±0.6 | 67.3 ±0.5 | 70.1 ±0.7 | 479 | 63.8 ±0.7 | 490 | 66.9 ±0.7 |
| Shorn | 486 | 64.7 ±0.5 | 67.6 ±0.6 | 71.6 ±0.7 | 455 | 64.5 ±0.7 | 442 | 67.6 ±0.7 |

**Table 4.4.** The effect of pregnancy rank and shearing treatment on ewe liveweights (kg) at P69, P101, P130, L28/29 and L90/91 at Tuapaka (Mean ±SE). Means within treatment having different superscripts are different (P<0.05).

| | | Ewe Liveweight | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | P69 | P101 | P130 | | L28/29 | | L90/91 |
| | (n) | | | | (n) | | (n) | |
| Pregnancy rank | | | | | | | | |
| 1 | 235 | 58.0[a] ±0.4 | 63.7[a]±0.6 | 64.7[a] ±0.5 | 200 | 57.2[a]±0.9 | 202 | 60.0[a] ±0.5 |
| 2 | 556 | 60.9[b] ±0.3 | 66.6[b]±0.4 | 68.4[b] ±0.3 | 526 | 59.1[a]±0.5 | 519 | 59.5[a] ±0.3 |
| 3 | 63 | 63.8[c] ±0.8 | 71.4[c]±1.2 | 74.1[c] ±1.0 | 52 | 64.0[b]±1.7 | 52 | 62.5[b] ±0.9 |
| Shearing treatment | | | | | | | | |
| Unshorn | 435 | 60.6 ±0.4 | 68.0 ±0.7 | 69.2 ±0.5 | 401 | 61.6[b]±0.9 | 395 | 60.6 ±0.5 |
| Shorn | 419 | 61.3 ±0.5 | 66.5 ±0.6 | 69.0 ±0.5 | 377 | 58.5[a]±0.9 | 378 | 60.7 ±0.5 |

*Ewe condition score*

*Riverside*

Triplet-bearing ewes had significantly (P<0.05) greater condition scores (CS) than their single- bearing counterparts from P67 to P133 (by 0.2 units, Table 4.5). Triplet-bearing ewes also had greater CS (P<0.05) than twin-bearing ewes at P67 (by 0.1 CS units). Similarly, twin-bearing ewes had higher CS than their single-bearing counterparts at P133 (by 0.1 unit, P<0.05).

At docking (L34/35) single-bearing ewes had significantly (P<0.05) greater (by 0.2 units) CS than twin-bearing ewes and by weaning (L90/91) single-bearing ewes had higher CS than both twin- and triplet-bearing ewes (by 0.4 and 0.3 units respectively, P<0.05).

Shearing treatment only affected ewe CS at P133, when shorn ewes had a 0.1 unit higher (P<0.05) CS than their unshorn counterparts.

*Tuapaka*

At P69, twin-bearing ewes had higher CS (by 0.1 units, P<0.05) than their single-bearing counterparts. By P101, twin- and triplet-bearing ewes had higher CS than single-bearing ewes (by 0.1 and 0.2 CS units respectively, P<0.05, Table 4.6) but no difference was observed at P130. Pregnancy-rank had no effect on ewe CS at either docking or weaning.

Unshorn ewes had a 0.1 unit greater CS (P<0.05) than shorn ewes at P101 and during lactation (at both L28/29 and L90/91).

**Table 4.5.** The effect of pregnancy rank and shearing treatment on ewe condition score at P67, P101, P133, L34/35 and L86/87 at Riverside (Mean ±SE). Means within treatment having different superscripts are different ($P<0.05$).

| | | Ewe Condition score | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | P67 | P101 | P133 | | L34/35 | | L86/87 |
| | (n) | | | | (n) | | (n) | |
| Pregnancy rank | | | | | | | | |
| 1 | 311 | $2.5^{a}$ ±0.02 | $2.6^{a}$ ±0.03 | $2.7^{a}$ ±0.03 | 244 | $2.5^{b}$ ±0.03 | 257 | $2.9^{b}$ ±0.04 |
| 2 | 671 | $2.6^{a}$ ±0.02 | $2.7^{ab}$ ±0.02 | $2.8^{b}$ ±0.02 | 650 | $2.3^{a}$ ±0.03 | 635 | $2.5^{a}$ ±0.02 |
| 3 | 48 | $2.7^{b}$ ±0.06 | $2.8^{b}$ ±0.07 | $2.9^{b}$ ±0.08 | 40 | $2.5^{ab}$ ±0.08 | 40 | $2.6^{a}$ ±0.09 |
| Shearing treatment | | | | | | | | |
| Unshorn | 544 | 2.6 ±0.03 | 2.7 ±0.04 | $2.8^{a}$ ±0.04 | 479 | 2.3 ±0.04 | 490 | 2.6 ±0.05 |
| Shorn | 486 | 2.6 ±0.03 | 2.7 ±0.04 | $2.9^{b}$ ±0.04 | 455 | 2.4 ±0.04 | 442 | 2.7 ±0.05 |

**Table 4.6.** The effect of pregnancy rank and shearing treatment on ewe condition score at P69, P101, P130, L28/29 and L90/91 at Tuapaka (Mean ±SE). Means within treatment having different superscripts are different (P<0.05).

| | | Ewe Condition score | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (n) | P69 | P101 | P130 | (n) | L28/29 | (n) | L90/91 |
| Pregnancy rank | | | | | | | | |
| 1 | 235 | $2.5^{a} \pm 0.03$ | $2.7^{a} \pm 0.03$ | $2.6 \pm 0.02$ | 200 | $2.3 \pm 0.03$ | 202 | $2.4 \pm 0.03$ |
| 2 | 556 | $2.6^{b} \pm 0.02$ | $2.8^{b} \pm 0.02$ | $2.6 \pm 0.01$ | 526 | $2.2 \pm 0.02$ | 519 | $2.3 \pm 0.02$ |
| 3 | 63 | $2.6^{ab} \pm 0.05$ | $2.9^{b} \pm 0.06$ | $2.6 \pm 0.04$ | 52 | $2.2 \pm 0.05$ | 52 | $2.4 \pm 0.06$ |
| Shearing treatment | | | | | | | | |
| Unshorn | 435 | $2.6 \pm 0.03$ | $2.9^{b} \pm 0.03$ | $2.6 \pm 0.02$ | 401 | $2.3^{b} \pm 0.03$ | 395 | $2.4^{b} \pm 0.03$ |
| Shorn | 419 | $2.6 \pm 0.03$ | $2.8^{a} \pm 0.03$ | $2.6 \pm 0.03$ | 377 | $2.2^{a} \pm 0.03$ | 378 | $2.3^{a} \pm 0.03$ |

*Annual ewe fleece weight*

*Riverside and Tuapaka*

At Riverside single-bearing ewes had greater annual fleece weights than twin-bearing ewes (0.2 kg, P<0.05) (Table 4.7) in contrast, no birth-rank response was observed at Tuapaka. Mid-pregnancy shearing increased (P<0.05) annual fleece weight by 0.2 kg at both Tuapaka and Riverside.

**Table 4.7**. The effect of pregnancy rank and ewe shearing treatment on ewe annual fleece weight (kg) at Riverside and Tuapaka (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).

| | Annual ewe fleece weight | | | |
|---|---|---|---|---|
| | Riverside | | Tuapaka | |
| | (n) | | (n) | |
| Pregnancy rank | | | | |
| 1 | 257 | $4.1^{b}$ ±0.0 | 201 | 4.2 ±0.1 |
| 2 | 632 | $3.9^{a}$ ±0.0 | 518 | 4.2 ±0.0 |
| 3 | 40 | $4.0^{ab}$ ±0.1 | 52 | 4.3 ±0.1 |
| Shearing treatment | | | | |
| Unshorn | 489 | $3.9^{a}$ ±0.1 | 393 | $4.1^{a}$ ±0.1 |
| Shorn | 440 | $4.1^{b}$ ±0.1 | 378 | $4.3^{b}$ ±0.1 |

*Lamb birthweights and liveweights*

*Riverside*

There was a significant interaction between ewe shearing treatment and birth-rank on lamb birthweight, such that shearing the ewe significantly (P<0.05) increased the birthweights of twin-born lambs (by 0.4 kg each) but had no effect of the birthweights of either singletons or triplets (although both singletons and triplets born to shorn ewes tended to be heavier than those born to unshorn ewes) (Table 4.8).

As expected singletons were significantly (P<0.05) heavier than both twin- and triplet- born lambs at both docking (L34/35) and at weaning (L86/87) (by 4.6 to 9.3 kg) and twins were heavier (P<0.05) than triplets (by 1.9 to 3.3 kg).

Mid-pregnancy shearing increased lamb liveweights (P<0.05) at both docking and weaning (by 0.6 kg and 1.2 kg respectively).

*Tuapaka*

Lambs born to shorn ewes were significantly (P<0.05) heavier at both birth and docking (by 0.1 and 0.5 kg respectively) than lambs born to unshorn ewes however, this difference was not observed at weaning. Although there was no significant interaction between shearing treatment and birth rank, shearing significantly (P<0.05) increased the birthweights of twin born lambs but not singletons or triplet born lambs.

Singletons were significantly (P<0.05) heavier than both twin- and triplet-born lambs (by 0.9 and 1.7 kg respectively) at birth (Table 4.8). As expected twins were heavier (P<0.05) than triplets (by 0.8 kg). Singletons remained heavier (P<0.05) than both twin- and triplet-born lambs (by approximately 1.4 to 4.5 kg) though to weaning. Similarly, twin-born lambs were heavier (P<0.05) (by 0.7 kg) than triplet-born lambs at docking (L28/29) but not at weaning.

*The relationship between ewe liveweight and condition score during mid-pregnancy and mid-pregnancy shearing treatment in twin-born lambs*

At Riverside twin lambs born to shorn dams in the 50-59.5, 60-69.5 and the greater than or equal to 70 kg liveweight range at P67 were significantly heavier (P<0.05, Table 4.9) than their counterparts born to unshorn ewes within each of these liveweight ranges (by 0.5, 0.4 and 0.5 kg respectively). In contrast, at Tuapaka there was no effect of dam shearing treatment on lamb birthweight within the ewe liveweight ranges.

Twin lambs born to shorn ewes at Riverside with a CS of 2.5 or 3 at P67, were significantly heavier ($P<0.05$, Table 4.10) than their counterparts born to unshorn ewes (by 0.6 and 0.3 kg respectively) of the same CS. Similarly, at Tuapaka lambs born to shorn ewes with a CS of 3 at P69 were significantly heavier ($P<0.05$) than their counterparts born to unshorn ewes (by 0.3 kg).

**Table 4.8**. The effect of birth-rank and ewe shearing treatment on lamb liveweight (kg) at birth, docking (L34/35) and weaning (L86/87) at Riverside and at birth, docking (L28/29) and weaning (L90/91) at Tuapaka (Mean ±SE). Means within treatments having differing superscripts are different ($P<0.05$).

| | Lamb Liveweight | | | | | |
|---|---|---|---|---|---|---|
| | Birthweight | | Docking | | Weaning | |
| | (n) | | (n) | | (n) | |
| **Riverside** | | | | | | |
| Birth rank | | | | | | |
| 1 | 311 | $6.1^{c}$ ±0.0 | 244 | $19.6^{c}$ ±0.2 | 257 | $33.9^{c}$ ±0.3 |
| 2 | 1342 | $4.9^{b}$ ±0.0 | 1082 | $15.0^{b}$ ±0.1 | 1078 | $27.9^{b}$ ±0.1 |
| 3 | 144 | $4.0^{a}$ ±0.0 | 82 | $13.1^{a}$ ±0.3 | 86 | $24.6^{a}$ ±0.5 |
| Shearing treatment | | | | | | |
| Unshorn | 932 | $4.9^{a}$ ±0.0 | 715 | $15.6^{a}$ ±0.2 | 728 | $28.2^{a}$ ±0.3 |
| Shorn | 865 | $5.2^{b}$ ±0.0 | 693 | $16.2^{b}$ ±0.2 | 693 | $29.4^{b}$ ±0.3 |
| Birth rank x Shearing | | | | | | |
| 1 x Unshorn | 181 | $6.0^{d}$ ±0.1 | 141 | $19.4^{d}$ ±0.2 | 154 | $33.5^{d}$ ±0.4 |
| 1 x Shorn | 130 | $6.2^{d}$ ±0.1 | 103 | $19.8^{d}$ ±0.3 | 103 | $34.4^{d}$ ±0.4 |
| 2 x Unshorn | 676 | $4.7^{c}$ ±0.0 | 538 | $14.6^{b}$ ±0.1 | 533 | $27.4^{b}$ ±0.2 |
| 2 x Shorn | 666 | $5.1^{b}$ ±0.0 | 544 | $15.3^{c}$ ±0.1 | 545 | $28.3^{c}$ ±0.2 |
| 3 x Unshorn | 75 | $3.9^{a}$ ±0.1 | 36 | $12.9^{a}$ ±0.4 | 41 | $23.7^{a}$ ±0.7 |
| 3 x Shorn | 69 | $4.2^{a}$ ±0.1 | 46 | $13.4^{a}$ ±0.5 | 45 | $25.6^{ab}$ ±0.7 |
| **Tuapaka** | | | | | | |
| Birth rank | | | | | | |
| 1 | 235 | $5.6^{c}$ ±0.1 | 200 | $13.6^{c}$ ±0.2 | 202 | $26.6^{b}$ ±0.3 |
| 2 | 1112 | $4.7^{b}$ ±0.0 | 889 | $12.2^{b}$ ±0.1 | 893 | $22.9^{a}$ ±0.1 |
| 3 | 189 | $3.9^{a}$ ±0.1 | 105 | $11.5^{a}$ ±0.2 | 104 | $22.1^{a}$ ±0.4 |
| Shearing treatment | | | | | | |
| Unshorn | 774 | $4.7^{a}$ ±0.0 | 602 | $12.2^{a}$ ±0.1 | 606 | 23.8 ±0.2 |
| Shorn | 762 | $4.8^{b}$ ±0.0 | 592 | $12.7^{b}$ ±0.1 | 593 | 23.9 ±0.2 |
| Birth rank x Shearing | | | | | | |
| 1 x Unshorn | 120 | $5.5^{d}$ ±0.1 | 109 | $13.4^{c}$ ±0.2 | 110 | $26.4^{b}$ ±0.4 |
| 1 x Shorn | 115 | $5.7^{d}$ ±0.1 | 91 | $13.8^{c}$ ±0.3 | 92 | $26.7^{b}$ ±0.4 |
| 2 x Unshorn | 576 | $4.7^{b}$ ±0.0 | 450 | $12.1^{b}$ ±0.1 | 453 | $22.7^{a}$ ±0.2 |
| 2 x Shorn | 536 | $4.8^{c}$ ±0.0 | 439 | $12.3^{b}$ ±0.1 | 440 | $23.0^{a}$ ±0.2 |
| 3 x Unshorn | 78 | $3.8^{a}$ ±0.1 | 43 | $12.0^{ab}$ ±0.3 | 43 | $22.2^{a}$ ±0.6 |
| 3 x Shorn | 111 | $3.9^{a}$ ±0.1 | 62 | $11.0^{a}$ ±0.4 | 61 | $21.9^{a}$ ±0.5 |

**Table 4.9.** The effect of ewe liveweight (kg) group at mid-pregnancy (P67 and P69 at Riverside and Tuapaka respectively) and shearing treatment on twin lamb birthweight (kg) (Mean ±SE). Means within farms with different superscripts are different (P<0.05).

| | Twin lamb birthweight | | | | | |
|---|---|---|---|---|---|---|
| | Riverside | | | Tuapaka | | |
| | (n) | P67 | | (n) | P69 | |
| Ewe group x Shearing | | | | | | |
| 40-49.5 x Unshorn | 12 | $4.4^{ab}$ | ±0.22 | 22 | $4.2^{a}$ | ±0.16 |
| 40-49.5 x Shorn | 20 | $4.2^{a}$ | ±0.17 | 12 | $4.3^{ab}$ | ±0.21 |
| 50-59.5 x Unshorn | 182 | $4.5^{a}$ | ±0.06 | 222 | $4.5^{a}$ | ±0.05 |
| 50-59.5 x Shorn | 174 | $5.0^{bd}$ | ±0.06 | 216 | $4.7^{ac}$ | ±0.05 |
| 60-69.5 x Unshorn | 354 | $4.7^{ac}$ | ±0.04 | 288 | $4.8^{bc}$ | ±0.05 |
| 60-69.5 x Shorn | 342 | $5.1^{de}$ | ±0.04 | 246 | $4.9^{b}$ | ±0.05 |
| ≥ 70 x Unshorn | 120 | $4.9^{bc}$ | ±0.07 | 32 | $5.0^{bd}$ | ±0.13 |
| ≥ 70 x Shorn | 118 | $5.4^{e}$ | ±0.07 | 50 | $4.9^{bc}$ | ±0.11 |

**Table 4.10.** The effect of ewe condition score group (scale 1 – 5) at mid-pregnancy (P67 and P69 at Riverside and Tuapaka respectively) and shearing treatment on twin lamb birthweight (kg) (Mean ±SE). Means within farms with different superscripts are different (P<0.05).

| | Twin lamb birthweight | | | | | |
|---|---|---|---|---|---|---|
| | Riverside | | | Tuapaka | | |
| Treatments | (n) | P67 | | (n) | P69 | |
| Ewe CS group x Shearing | | | | | | |
| ≤ 2 x Unshorn | 124 | $4.6^{ac}$ | ±0.07 | 68 | $4.5^{a}$ | ±0.10 |
| ≤ 2 x Shorn | 114 | $4.9^{abc}$ | ±0.07 | 64 | $4.7^{ab}$ | ±0.10 |
| 2.5 x Unshorn | 340 | $4.6^{a}$ | ±0.04 | 344 | $4.7^{a}$ | ±0.04 |
| 2.5 x Shorn | 358 | $5.2^{e}$ | ±0.04 | 294 | $4.8^{a}$ | ±0.05 |
| 3 x Unshorn | 160 | $4.9^{bc}$ | ±0.06 | 110 | $4.6^{a}$ | ±0.08 |
| 3 x Shorn | 154 | $5.2^{e}$ | ±0.06 | 146 | $4.9^{b}$ | ±0.07 |
| ≥ 3.5 x Unshorn | 46 | $4.7^{acd}$ | ±0.11 | 42 | $4.8^{ab}$ | ±0.12 |
| ≥ 3.5 x Shorn | 28 | $5.1^{bde}$ | ±0.15 | 20 | $4.8^{ab}$ | ±0.17 |

*Lamb survival*

**Riverside**

There was a significant ($P<0.05$) interaction between the effects of ewe shearing treatment and birth-rank on lamb survival rates (Table 4.11), such that twins ($P=0.16$) and triplets ($P=0.11$) born to shorn ewes had higher survival rates (but not significantly so within rank) than their counterparts born to unshorn dams, while the opposite relationship was observed in singletons ($P=0.18$).

**Tuapaka**

There was a significant interaction ($P = 0.07$) between the effects of ewe shearing treatment and birth-rank on lamb survival rates (Table 4.11). The survival rates of singletons born to shorn dams were significantly lower ($P<0.05$) than those of their counterparts born to unshorn dams (80.0 vs 91.7% respectively). However, survival rates of twin lambs born to shorn dams tended to be higher than those found in lambs born to unshorn dams (82.6 vs 78.6% respectively) but were not significantly ($P=0.10$) different within rank.

**Table 4.11.** The effect of birth-rank and ewe shearing treatment on proportion (%) of lambs surviving to weaning at both Riverside and Tuapaka (Mean ±SE). Means within treatments having differing superscripts are different (P<0.05).

| | Lamb Survival to weaning | | | |
|---|---|---|---|---|
| | Riverside | | Tuapaka | |
| | (n) | Proportion | (n) | Proportion |
| Birth rank | | | | |
| 1 | 311 | $1.56^{1}$ ±0.15 $(82.6)^{b\,2}$ | 235 | 1.81 ±0.19 $(85.9)^{b}$ |
| 2 | 1342 | 1.40 ±0.07 $(80.3)^{b}$ | 1112 | 1.41 ±0.08 $(80.5)^{b}$ |
| 3 | 144 | 0.38 ±0.17 $(59.3)^{a}$ | 189 | 0.19 ±0.14 $(54.7)^{a}$ |
| Shearing treatment | | | | |
| Unshorn | 932 | 1.26 ±0.08 (77.9) | 774 | 1.28 ±0.09 (78.3) |
| Shorn | 865 | 1.40 ±0.09 (80.2) | 762 | 1.27 ±0.09 (78.0) |
| Birth rank x Shearing | | | | |
| 1 x Unshorn | 181 | 1.74 ±0.20 $(85.1)^{b}$ | 120 | 2.40 ±0.33 $(91.7)^{c}$ |
| 1 x Shorn | 130 | 1.34 ±0.21 $(79.2)^{b}$ | 115 | 1.39 ±0.23 $(80.0)^{b}$ |
| 2 x Unshorn | 676 | 1.31 ±0.10 $(78.8)^{b}$ | 576 | 1.30 ±0.10 $(78.6)^{b}$ |
| 2 x Shorn | 666 | 1.50 ±0.10 $(81.8)^{b}$ | 536 | 1.55 ±0.11 $(82.6)^{b}$ |
| 3 x Unshorn | 75 | 0.13 ±0.22 $(53.2)^{a}$ | 78 | 0.21 ±0.22 $(55.1)^{a}$ |
| 3 x Shorn | 69 | 0.67 ±0.25 $(66.2)^{a}$ | 111 | 0.18 ±0.19 $(54.5)^{a}$ |

[1] Logit-transformed.
[2] Back-transformed (%).

*Cause of death at Tuapaka*

Fewer single- and twin-born (P<0.05) lambs died of starvation-exposure than their triplet-born counterparts (by 42.3 and 18.9% respectively) (Table 4.12). Ewe shearing treatment had no effect on lamb losses due to starvation-exposure.

There was a significant interaction (P<0.05) between ewe shearing treatment and birth rank on lamb deaths due to dystocia, despite a small number of lambs in this category. A greater proportion of singletons born to shorn ewes died of dystocia than their counterparts born to unshorn ewes (55 versus 0% respectively) (Table 4.12). This relationship was not observed in either twin- or triplet-born lambs.

Neither dam shearing treatment or birthrank had any effect of lamb losses due to other causes.

**Table 4.12.** The effect of birth-rank and ewe shearing treatment on cause of lamb mortality (%) in autopsied lambs at Tuapaka (Mean, ±SE). Means within treatments having differing superscripts are different (P<0.05).

| | | Cause of death | | |
|---|---|---|---|---|
| | | Starvation exposure | Dystocia | Other |
| Treatments | (n) | | | |
| Birth rank | | | | |
| 1 | 13 | -1.20 ±0.65 (23.1)[a] | -0.47 ±0.57 (38.4)[b] | -0.47 ±0.57 (38.5) |
| 2 | 86 | -0.14 ±0.22 (46.5)[a] | -1.33 ±0.27 (20.9)[ab] | -0.73 ±0.23 (32.6) |
| 3 | 52 | 0.64 ±0.30 (65.4)[b] | -2.04 ±0.43 (11.5)[a] | -1.20 ±0.33 (23.1) |
| Shearing treatment | | | | |
| Unshorn | 74 | 0.05 ±0.23 (51.4) | -1.37 ±0.29 (20.2) | -0.79 ±0.24 (28.4) |
| Shorn | 77 | 0.03 ±0.22 (50.6) | -1.50 ±0.30 (18.2) | -0.92 ±0.26 (31.2) |
| Birth rank x Shearing | | | | |
| 1 x Unshorn | 4 | 0 ±1.00 (50.0)[ab] | N/C[3] ( 0)[a] | 0 ±1.00 (50.0)[ab] |
| 1 x Shorn | 9 | -2.08 ±1.06 (11.1)[a] | 0.22 ±0.67 (55.5)[d] | -0.69 ±0.71 (33.4)[ab] |
| 2 x Unshorn | 49 | -1.22 ±0.29 (46.9)[ab] | -0.91 ±0.31 (28.6)[cd] | -1.12 ±0.33 (24.5)[ab] |
| 2 x Shorn | 37 | -0.16 ±0.33 (45.9)[ab] | -2.11 ±0.53 (10.8)[bc] | -0.27 ±0.33 (43.3)[b] |
| 3 x Unshorn | 21 | 0.48 ±0.45 (61.9)[b] | -2.99 ±1.02 ( 4.7)[ab] | -0.69 ±0.46 (33.4)[ab] |
| 3 x Shorn | 31 | 0.74 ±0.38 (67.7)[b] | -1.64 ±0.49 (16.1)[bc] | -1.64 ±0.49 (16.1)[a] |

[1] Logit-transformed.
[2] Back-transformed (%).
[3] N/C (None recorded).

## Discussion

The aims of this study were to investigate the effect of mid-pregnancy shearing on lamb birthweight and survival rates to weaning under commercial conditions, and to test the hypothesis developed in Chapter 3; namely, that there are two criteria that must be met to achieve a birthweight response to mid-pregnancy shearing. Firstly, the dam must have the potential to respond (i.e. be destined give birth to an otherwise lightweight lamb(s)). Secondly, the dam must have the means to respond (an adequate level of nutrition and/or adequate maternal reserves allowing extra nutrients to be partitioned towards additional foetal growth).

At both Riverside and Tuapaka, shorn and unshorn ewes were inadvertently separated for a short period post mid-pregnancy shearing. During this period unshorn and shorn ewes on each property were offered similar allowances, although shorn ewes grazed in sheltered paddocks. In Chapter 2, it was reported that herbage intakes of shorn ewes did not differ from those of unshorn ewes during the 10-day post mid-pregnancy shearing period. Revell *et al.* (2002) also found that shearing treatment had no effect on dam intake. Similarly, Dabiri *et al.* (1996) reported that intakes of pregnancy-shorn ewes did not differ from those of their unshorn counterparts in the immediate post-shearing period. These results indicate that it is unlikely ewe intakes differed during the short separation periods at both Riverside and Tuapaka. Therefore the separation itself is unlikely to have affected lamb birthweight. It is also sound management practice to provide mid-pregnancy shorn ewes with shelter to avoid losses in the immediate post-shearing period (Geytenbeck 1962, Gregory 1995).

At both Riverside and Tuapaka mid-pregnancy shearing was found to increase the birthweights of twin born lambs only. This birthrank specific response has been found in previous studies (Morris and McCutcheon 1997, Morris *et al.* 2000, Revell *et al.* 2002 and in Chapter 3). Addition of the singleton birthweight data from both farms to the graph developed in both Chapters 2 and 3 (Figure 4.1) indicates that a birthweight response is not expected in singletons. A possible explanation for the lack of a birthweight response in triplet born lambs is rumenal compression, resulting in an inability of the dam to either increase intake or allow for additional foetal growth.

The hypothesis developed in Chapter 3, can also be tested by examining the relationship between dam liveweight at mid-pregnancy shearing and the twin lamb birthweight response to mid-pregnancy shearing (Table 4.9). At Riverside, the only twin lamb group not to achieve a birthweight response were those born to ewes which weighed less than 50 kg at mid-pregnancy. Twin lambs born to these unshorn ewes, were among the lightest lambs born (4.4 kg and thus had potential to be heavier, meeting criterion 1) however, it is likely that these ewes had limited maternal reserves (and therefore did not meet criterion 2). Lambs born to unshorn dams weighing more than 50 kg at mid-pregnancy were still relatively light (average birthweight 4.9 kg or below) indicating they met criterion 1. Nevertheless, these heavier ewes were more likely to have had the body reserves available to partition toward extra foetal growth (and therefore met criterion 2). Therefore, the results found at Riverside support the hypothesis developed in Chapter 3. However, at Tuapaka, there was no relationship between ewe liveweight and the birthweight response to mid-pregnancy shearing.

The hypothesis developed in Chapter 3 can be further tested by examining the relationship between dam body condition score at mid-pregnancy and the twin lamb birthweight response (Table 4.10). At Riverside a birthweight response was not observed in lambs born to ewes with a CS of 2.0 or below, at mid-pregnancy shearing. There was the potential to respond (i.e. relatively light birthweights (average birthweight 4.6 kg or less)) in these groups. However, these dams appeared to have insufficient maternal reserves to partition extra nutrients towards foetal growth, and thus a birthweight response is not observed (they did not meet criterion 2). Additionally, a birthweight response was not observed in twin lambs born to ewes with a CS of 3.5 or above. These lambs met criterion 1 (relatively lightweight 4.7 kg) and the dams were of good body condition (indicating they met criterion 2 also). However, a 0.4 kg non-significant difference in birthweight between lambs born to unshorn and shorn ewes (4.7 vs 5.1 kg respectively) with a CS of 3.5 or above was observed.

Examination of the birthweight response based on ewe CS at Tuapaka shows that the only group to achieve a birthweight response were those born to ewes with a CS of

3. Lambs born to unshorn ewes with a CS of 3 were relatively lightweight (4.6 kg) and thus they met criterion 1. Dams with a CS of 3 were of good body condition (by definition) and were likely to have the additional body reserves available to partition extra nutrients towards increased foetal growth (meeting criterion 2). In support of the results observed at Riverside, a birthweight response was not seen in ewes with a CS of 2 or below. A birthweight response was also not seen in lambs born to ewes with a CS of 3.5 or above at Tuapaka. The average birthweights of lambs born to unshorn ewes in this group was 4.8 kg, which was the heaviest unshorn lamb birthweight group. Therefore a possible explanation for the lack of a birthweight response in this group is that lambs born to unshorn ewes in this group were at, or near, potential and thus they did not met criterion 1.

In contrast to that found at Riverside, at Tuapaka, a birthweight response in twins was not observed in any lamb group based on ewe liveweight at mid-pregnancy (Table 4.9) or in ewes with a CS of 2.5. Therefore the question to be asked, is why does the hypothesis appear to be better supported at Riverside than at Tuapaka? The liveweights of twin-bearing ewes at Tuapaka only increased on average by 8.9 kg from mating to set stocking, in contrast to a 12 kg increase at Riverside. The expected weight of a twin conceptus at term is 14 kg (Nicol 1987). This indicates that at Tuapaka the average twin bearing ewe lost in the order 5 kg of maternal weight during pregnancy, suggesting that many of these ewes did not have the maternal reserves available to partition towards enhanced foetal growth in response to mid-pregnancy shearing (and thus did not meet criterion 2).

In agreement with both Chapters 2 and 3, mid-pregnancy shearing did not affect ewe liveweights during pregnancy at either Riverside or Tuapaka. In addition the small and inconsistent increase (0 to 12%) in dam intakes post shearing, observed in Chapter 2 and the lack of a dam shearing treatment effect on ewe intake observed in Chapter 3 and by Revell *et al.* (2002) indicate that mid-pregnancy shearing has only a minimal effect on feed demand. The use of the mid-pregnancy shearing should not therefore, require a decrease in stocking rates or the provision of extra feed (or both).

In both Chapters 2 and 3, dam shearing treatment had no effect on either the proportion of lambs reaching summit metabolism or summit metabolic rate. This may indicate that under adverse weather conditions, mid-pregnancy shearing will not improve lamb survival independently of a birthweight effect on survival. An increase in the birthweight of an otherwise lightweight lamb(s) may increase survival rates regardless of any effect on SMR. A heavier, larger lamb has a smaller surface area to body mass ratio (and therefore should lose body heat less readily to the environment) and has greater body reserves and is therefore less likely to succumb to starvation-exposure. However, mid-pregnancy shearing was found to have no effect on loses due to starvation exposure at Tuapaka.

Morris *et al.* (1999) found that survival rates of twins born to pregnancy-shorn ewes tended to be higher (82 vs 85-83%) than their counterparts born to unshorn ewes. Similarly, in the present study at both sites, mid-pregnancy shearing tended to increase twin lamb survival rates to weaning (by 3 – 4%) but not significantly so. Dalton *et al.* (1980) showed that the multiple-born lamb birthweight range of 4.0 – 5.0 kg resulted in the highest lamb survival rates. At Riverside, mid-pregnancy shearing increased average twin lamb birthweights from 4.7 kg to 5.1 kg (Table 4.8) and at Tuapaka an increase from 4.7 to 4.8 kg was observed. Therefore, in the present study an increase in twin lamb survival rates based on an increase in birthweight alone is not expected. Other possible mechanisms which could improve lamb survival independent of any birthweight or SMR effect from mid-pregnancy shearing include; changes in lamb fleece characteristics (i.e. the increase wet depth found in Chapter 2), a change in dam behaviour (i.e. the seeking of shelter), easier lambing, increased ease for lamb finding the teat, increased dam awareness of the lamb, and fewer ewes being lost to casting with consequent loss of their lambs (Wodzicka-Tomaszewska 1963a; Frengley 1964; Rutter *et al.* 1971; Alexander and Lynch 1976; Lynch and Alexander 1976; Black and Chestnutt 1990).

Dalton *et al.* (1980) showed that for singleton lambs the birthweight range associated with the highest survival rates was also 4.0 – 5.0 kg. At Tuapaka, mid-pregnancy shearing reduced survival rates in singletons (by 8%). Additionally, singletons born to shorn dams had higher rates of dystocia. Mid-pregnancy shearing increased average singleton lamb birthweights from 5.5 to 5.7 kg. Interestingly, at Riverside mid-pregnancy shearing increased singleton lamb birthweights from 6.0 to 6.2 kg but, this did not significantly reduce survival rates in singletons (although lambs born to shorn ewes appeared to have lower survival rates by 6%). It is possible that the older, larger frame size ewes, used at Riverside in comparison to those at Tuapaka are less susceptible to losses due to dystocia. However, autopsies were not undertaken at Riverside. These results may indicate that mid-pregnancy shearing is best suited to either multiple-bearing ewes only or in flocks with a high proportion of multiple-bearing ewes. In the present study all ewes, regardless of pregnancy rank were managed as one flock during pregnancy.

At Riverside lambs born to ewes shorn during mid-pregnancy were heavier at weaning (specifically twins by 0.9 kg). Similarly, Morris *et al.* (1999) found pregnancy shearing increased the weaning weights of twin-born lambs and Cloete *et al.* (1994) observed higher growth rates to 8 weeks of age. In contrast, at Tuapaka and in both Chapters 2 and 3, mid-pregnancy shearing had no effect on lamb weaning weights. It is possible that mid-pregnancy shearing results in an increase in milk production. For this to occur it would require either; dams in good body condition, access to high herbage masses (ewe liveweights, CS and herbage masses were higher at Riverside during lactation than those observed at Tuapaka) and/or an increase in dam intake. Parker *et al.* (1991) observed that ewes shorn in relatively late pregnancy had consistently higher intakes during lactation. Interestingly, Symonds *et al.* (1990) found that lamb growth rates were higher in lambs born to shorn housed dams when no difference in dam intake was observed. Symonds *et al.* (1990) reported that shorn dams had lower plasma concentrations of insulin than their unshorn counterparts. Symonds *et al.* (1990) concluded that metabolic adaptation by shorn ewes during early lactation results in endocrine changes, which are likely to increase the partitioning of nutrients towards milk production. Any increase in lamb weaning weight should increase returns to the New Zealand farmer by increasing the value of the lamb(s), decreasing the time (and therefore feed) required to achieve target liveweights or, by increasing the size of replacement animals.

On both farms, mid-pregnancy shearing increased ewe annual fleece weight by 0.2 kg. An increase in wool production has not previously been reported. Any increase in wool production will partly offset the extra cost of a twice-yearly shearing policy (if used). Shearing twice yearly will also increase wool quality in terms of both colour and strength, further increasing the value of the wool clip (as long as staple length is not reduced below 80mm).

## Conclusion

Under commercial farming conditions mid-pregnancy shearing was observed to increase the birthweights of twin-born lambs. The birthweight results found support the hypothesis developed in Chapter 3, namely; that there are two criteria that the dam must meet if a birthweight response to mid-pregnancy shearing is to be observed. Additionally, at Riverside, lambs born to mid-pregnancy shorn ewes were heavier at weaning. Mid-pregnancy shearing tended to increase survival rates in twin-born lambs at both sites but not significantly so. However, mid-pregnancy shearing reduced survival rates in singletons at Tuapaka, most likely because of increased losses due to dystocia. These findings indicate that mid-pregnancy shearing is best suited to multiple-bearing ewes only or in situations where higher lambing percentages occur.

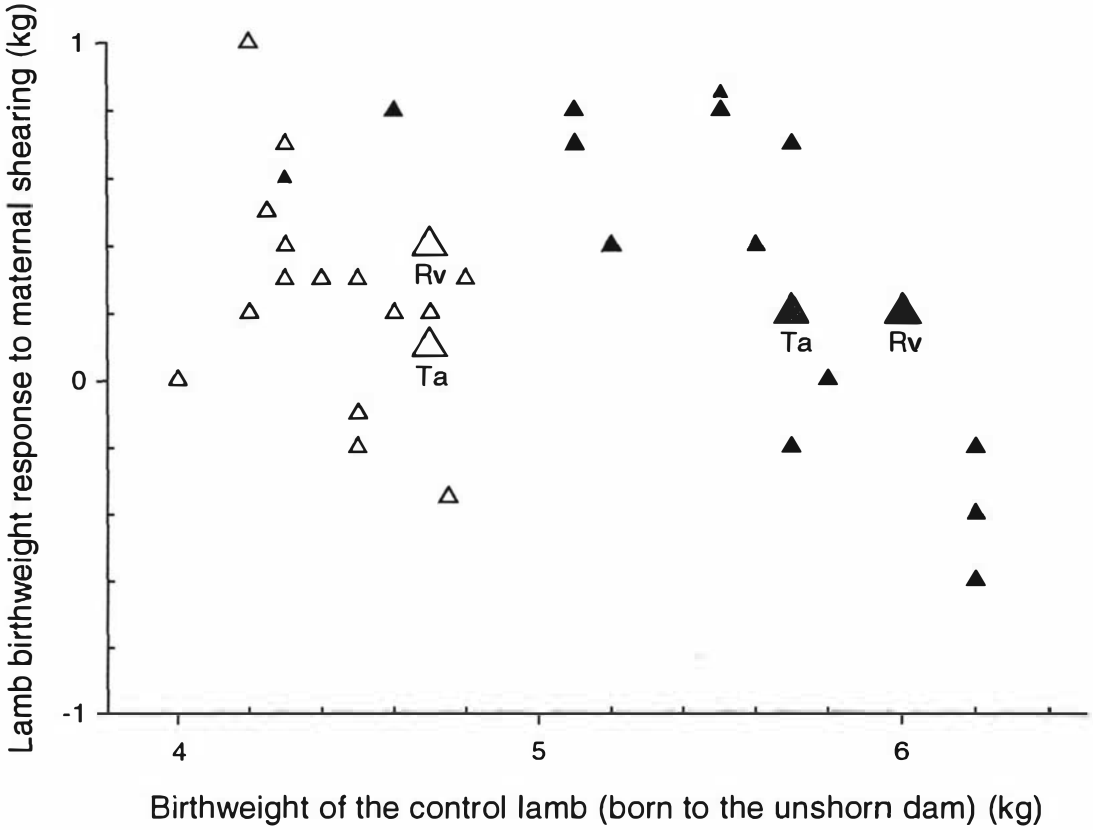



**Figure 4.1.** Birthweight responses to mid- to late-pregnancy shearing (singles- closed symbols, twins- open symbols) as a function of the birthweights of control lambs (each point represents a separate trial or treatment [shearing date] within a trial ((Morris and McCutcheon 1997, Morris *et al.* 2000, Revell *et al.* 2000, Revell *et al.* 2002 and Chapter 2 and 3)). Shearing responses for each the two farms (within each birth rank) in the present study are indicated by Tuapaka (Ta) and Riverside (Rv).

# Chapter five - Are elevated maternal thyroid hormone concentrations responsible for the lamb birthweight effect?

**Abstract**

Mid-pregnancy shearing has been shown to increase lamb birthweight. However, the mechanism responsible for this effect has not yet been identified. This study was designed to determine whether elevated maternal thyroid hormone concentrations post mid-pregnancy shearing are responsible for the birthweight effect. Forty-two twin-bearing Romney cross ewes were either: left unshorn or shorn during mid-pregnancy (at day 70 of pregnancy (P70)), and; either had T3/T4 concentrations similar to those of the pregnant unshorn ewe or were subjected to elevated T3/T4 concentrations in the short to medium term post mid-pregnancy shearing (as previously observed in pregnancy-shorn ewes). All ewes were offered a 'maintenance' level of feed (a level of nutrition that enabled the dam to maintain conceptus free liveweight) from P70 until P140.

Dam treatment was found to have no effect on lamb birthweight or the summit metabolic rate of twin lambs. However, the birthweights of all treatment groups were relatively high and under these conditions a birthweight response to mid-pregnancy shearing would not be expected. Thus, the relationship between elevated maternal thyroid hormone concentrations and lamb birthweight could not be successfully evaluated. Additionally, the period of thyroid hormone elevation was slightly shorter than that reported in previous studies. To successfully determine if elevated maternal thyroid hormones are responsible for the lamb birthweight effect, conditions must be present that would otherwise result in a lamb birthweight response to mid-pregnancy shearing.

## Introduction

It was shown in Chapters 2, 3 and 4 that mid-pregnancy shearing increases lamb birthweight (albeit a birth-rank specific response on some occasions) and it was concluded in both Chapters 2 and 3 that the birthweight response is not due to an increase in either dam intake or gestation length. Thus, the mechanism responsible for the birthweight response has not yet been identified.

Several studies have demonstrated an association between maternal thyroid status and foetal growth. Bell *et al.* (1989) found lower maternal triiodothyronine (T3) concentrations, and both lower foetal and placental growth, in ewes exposed to hot conditions compared to ewes exposed to a thermoneutral environment. Spencer and Robinson (1993) showed that daily thyroxine (T4) treatment of rats throughout pregnancy enhanced placental, foetal and postnatal growth. In an early mid-pregnancy shearing study under pastoral conditions, Morris *et al.* (2000) observed elevated maternal T3 concentrations over a 20-day period post mid-pregnancy shearing, in both single- and twin-bearing ewes. A birthweight response was subsequently found in singletons. They stated that the elevation in T3 might provide a signalling mechanism by which mid-pregnancy shearing affects foetal growth. Similarly, Symonds *et al.* (1989) found maternal T3 and T4 concentrations to be higher in pregnancy-shorn housed ewes than in their unshorn counterparts. They suggested that high plasma concentrations of T3 and T4 may have increased the rates of lipolysis and non-esterified fatty acid (NEFA) oxidation in shorn ewes. These responses could, in turn, have lead to a higher concentration of glucose in maternal blood or greater availability of maternal glucose, thus improving foetal growth. However, no birthweight response was observed in that study. The pre-mentioned studies indicate that it is possible that the birthweight response observed from mid-pregnancy shearing is due to changes in maternal thyroid hormone concentrations.

In the foetus, thyroid hormones are necessary for the functional development and maturation of brown adipose tissue (BAT) (Symonds 1995, Symonds *et al.* 1995). BAT is a major source of heat production in the newborn lamb (Symonds *et al.* 1992). Slator and Mellor (1981) found that variations in foetal thyroxine concentrations generally mirrored those found in the dam. Therefore it is possible that treatments which affects maternal thyroid hormone concentrations may affect foetal thyroid status. If this triggers a response in foetal BAT, it may have consequences for neonatal lamb survival.

This study was designed to test the hypothesis that elevated maternal thyroid hormone concentrations post-shearing are responsible for the mid-pregnancy shearing response in lamb birthweight. The study also offered the opportunity to test the effects of elevated maternal thyroid hormone concentrations on summit metabolic rate (SMR) of newborn lambs.

## Methods

*Experimental design and animals*

Sixty twin-bearing, progesterone-synchronized (CIDR, type G, Livestock Improvement Corporation, Hamilton, New Zealand) Romney ewes (5 years of age) were used in the study. They were selected from a commercial flock of 250 ewes (mated over a two-day period after CIDR removal) at pregnancy diagnosis (via ultrasound) 45 days after CIDR removal (P45). The trial was conducted at Massey University's Nutrition Block (latitude 41° 10'S), 5 km south of Palmerston North, New Zealand (May – November 2000).

*Treatments*

The experimental design involved 4 treatments imposed during mid-pregnancy (beginning at day 70 of pregnancy (P70)). Ewes were first stratified by weight, then randomly allocated into one of the following four treatment groups (n= 15 in each group) at P47.

1. Intact thyroid (sham-operated) unshorn ewes
2. Thyroidectomised unshorn ewes with elevated T4 concentrations in the immediate post-shearing period

3. Thyroidectomised ewes shorn at P70 with T4 concentrations maintained at approximately the same concentration as observed in the intact unshorn ewe
4. Thyroidectomised ewes shorn at P70 with elevated T4 concentrations in the immediate post-shearing period.

Thyroxine concentrations of Group 3 ewes were controlled (via T4 implants) at a level similar to those observed in unshorn pregnant ewes (Morris *et al.* 2000 and Group 1 ewes). Group 2 and 4 ewes were managed to ensure thyroxine concentrations were elevated (via T4 implants plus subcutaneous injections of T4) to values similar to those observed in the short to medium term (about 20 days) after mid-pregnancy shearing (as observed by Morris *et al.* (2000)). Thyroidectomised ewes were utilised to allow for the control of thyroid hormone concentrations without the potential for there being a negative feed back effect by the intact thyroid.

*Surgery and thyroxine implants*

Day of surgery (P48-52) was randomly allocated for each ewe. Anaesthesia was induced with Ketamine (10 mg/kg body weight Ketamine, Parnell Laboratories, New Zealand) and Diazepam (0.5 mg/kg body weight Diazepam (Pamlin), Parnell Laboratories, New Zealand) and maintained with Halothane (2%) (Vet Companies of Australia Pty Ltd) in oxygen, via an endotracheal tube, at a flow rate of 2 litres per minute. Thyroids were removed from all ewes in Groups 2, 3 and 4. Group 1 ewes were sham operated (incision of neck and exposure, but not removal, of the thyroids). Two thyroxine implants (one of 20 and one of 30 mg (Glaxo Laboratories Limited, Middlesex, UK)) were inserted subcutaneously under the right front leg of Group 2 , 3 and 4 ewes. During the immediate recovery period all ewes were given long acting antibiotic (Terramycin/LA, 1 ml/10 kg body weight, Pfizer Animal Health, New Zealand) and analgesic (Ketoprofen, 3mg/kg, Merial New Zealand Ltd). The Massey University Animal Ethics Committee approved this study.

*Thyroxine injections*

During the period P71-P80 ewes in Groups 2 and 4 were injected daily with 0.75 mg thyroxine (T4) (Sigma Chemical Co, USA), in 1 ml of saline (0.9% NaCl) and 1ml sesame oil (Sigma Chemical Co, USA) as per protocol developed in Appendix 1. The T4 was dissolved in the saline solution then vigorously mixed with the sesame oil to form a suspension, to allow for a slower release rate of T4. Ewes in Groups 1 and 3 were injected daily during P71-80 with a mix of 1ml saline solution and 1ml sesame oil (i.e. without thyroxine)

All thyroidectomised ewes (Groups 2, 3 and 4) had an additional two T4 implants (one 20 and one 30 mg) inserted at both P140 and at L74 (to ensure these ewes had physiological concentrations of T4). These additional implants were placed under local anesthesia (1ml, Lignocaine (2%) (Lopaine 2%), Ethical Agents, New Zealand Ltd) subcutaneously under the front right leg.

*Ewe management*

From P70 until P140, all ewes were fed (as one group) at a level to permit weight gain equivalent to the expected conceptus growth (Rattray *et al.*, 1974; McCutcheon *et al.* 1986; Nicol 1987) i.e. at P140 the conceptus of a twin-bearing ewe was assumed to weigh approximately 14.5 kg. Average ewe liveweight at mating (P0) was 59 kg. Therefore the average ewe target liveweight at P140 for all ewe groups was 73 kg. This nutritional management was chosen as it had resulted in a birthweight response in previous studies. The aim was also to avoid further stressing ewes who had had there thyroids removed.

Ewes in Groups 3 and 4 were shorn at P70 using a standard comb (Sunbeam New Zealand Ltd, maximum depth of teeth 4 mm). Ewes in Groups 1 and 2 were left unshorn (approximately 7 months wool growth). All ewes were shorn 155 days after the mid-point of lambing (L155) to allow determination of a 12-month fleece weight.

*Pasture conditions*

Pre- and post-herbage mass measurements were taken using a plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand) during the period P53 – L122. From P53 until P140 all ewes were rotationally grazed on 3.2 ha of predominantly ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pasture with average pre- and post-grazing pasture masses of 1910 ±171 and 1232 ±58 kgDM/ha respectively. From P140 until 7 days after the mid-point of lambing (L7), ewes were set stocked on an area of 2.4 ha. Average herbage masses at the start and finish of this period were 1173 ±58 and 1057 ±62 kgDM/ha respectively. From L7 to L122 (weaning), ewes and lambs were rotationally grazed on an area of 5.0 ha with average pre- and post-pasture masses of 1445 ±44 and 1204 ±42 kgDM/ha respectively.

*Animal measurements*

*Ewes*

Ewes were weighed (unfasted) at P69, P106, P140, L47 and L122. Condition score was determined (Jefferies 1961, scale 0 - 5) at P69, P130 and L122. Blood samples (10ml) were taken via jugular venepuncture (Lithium Heparin vacutainer, Becton Dickinson Vacutainer Systems, USA) from all ewes 24 h prior to surgery (P47-51) and on P71, P80, P84, P90, P113 and at P134. Blood samples were then immediately placed on ice and spun using a centrifuge within an hour of collection. The plasma was harvested and frozen until analysis. Plasma was analysed for total triiodothyronine (T3) and total thyroxine (T4) concentrations by radioimmunoassay using diagnostic kits (Coat-A-Count, Diagnostic Products Corporation, CA, USA).

Ewes were removed from the study if they died, gave birth to a singleton or triplets, or failed to lamb within 11 days of the first lamb being born (3, 7, 5 and 3 ewes respectively).

*Lambs*

Lambs were identified to their dams, tagged, weighed and had crown rump length and girth measurements taken within 12 hours of birth. Liveweights of lambs were recorded again at L47 (docking) and at weaning (L122). To estimate the effect of dam treatment on gestation length, day one of gestation was defined as the day after CIDR removal.

Summit metabolic rate (SMR) was determined via calorimetry (refer to Chapter 3 for methodology) on a cohort of 54 twin-born lambs (12, 16, 10 and 16 lambs born to dam Groups 1, 2, 3 and 4 respectively) before they reached 32 hours of age. Prior to the calorimetry procedure, wool was clipped (residual depth 2mm) from the sides and the back of all lambs that were heavier than 4 kg to help ensure that these lambs reached their SMR under the standard conditions used (Chapter 3).

*Data analysis*

All data were analysed by one-way analysis of variance using the Generalised Linear Model procedure of the statistical package 'Minitab' (Minitab 1998).

Sex of the lamb was used as a fixed effect in the model to partition variation in lamb birthweight. Ewe liveweight at P140 and gestation length were used as covariates.

Ewe liveweight at docking was used as a covariate in the model to partition variation in lamb liveweight at docking.

Lamb birthweight and gestation length were used as covariates in the model to partition variation in lamb girth measurement.

The proportion of lambs reaching summit metabolism was analysed as a binomial trait using the SAS procedure for categorical data modeling (CATMOD; SAS, 1985) to test the effects of each treatment.

If a ewe lost both of her lambs between birth and weaning or died (2 and 4 ewes respectively) she was removed from the analysis of ewe liveweight and condition score at both L47 and L122.

## Results

*Ewe liveweight and Condition Score*

Ewe treatment had no effect on either ewe liveweight (Table 5.1) or ewe CS (Table 5.2) at any stage during pregnancy or lactation. Ewe treatment had no effect on annual fleece weight (Table 5.3).

**Table 5.1.** The effect of dam treatment on the liveweight (kg) of twin-bearing ewes at P69, P106, P140, L47 and L122 (Mean ±SE).

| | Ewe Liveweight | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | P69 | P106 | P140 | | L47 | | L122 |
| | (n) | | | | (n) | | (n) | |
| Dam treatment | | | | | | | | |
| 1. Unshorn control T4 | 9 | 58.8 ±1.5 | 61.3 ±1.5 | 67.5 ±1.7 | 9 | 57.2 ±2.7 | 9 | 64.8 ±3.2 |
| 2. Unshorn elevated T4 | 12 | 61.7 ±1.4 | 62.7 ±1.3 | 69.8 ±1.5 | 11 | 63.4 ±2.4 | 11 | 72.9 ±2.9 |
| 3. Shorn control T4 | 10 | 63.1 ±1.4 | 64.2 ±1.4 | 72.6 ±1.7 | 7 | 57.1 ±3.0 | 6 | 64.0 ±3.9 |
| 4. Shorn elevated T4 | 11 | 62.3 ±1.4 | 63.1 ±1.5 | 70.7 ±1.6 | 11 | 59.2 ±2.4 | 10 | 69.0 ±3.1 |

**Table 5.2.** The effect of dam treatment on the condition score of twin-bearing ewes at P69, P130 and L122 (Mean ±SE).

| | | Ewe Condition Score | | | |
|---|---|---|---|---|---|
| | | P69 | P130 | | L122 |
| | (n) | | | (n) | |
| Dam treatment | | | | | |
| 1. Unshorn control T4 | 9 | 2.4 ±0.1 | 2.7 ±0.1 | 9 | 2.4 ±0.2 |
| 2. Unshorn elevated T4 | 12 | 2.4 ±0.1 | 2.7 ±0.1 | 11 | 2.7 ±0.2 |
| 3. Shorn control T4 | 10 | 2.6 ±0.1 | 3.0 ±0.1 | 6 | 2.5 ±0.3 |
| 4. Shorn elevated T4 | 11 | 2.4 ±0.1 | 2.8 ±0.1 | 10 | 2.5 ±0.2 |

**Table 5.3.** The effect of dam treatment on annual fleece weight (kg) (Mean ±SE).

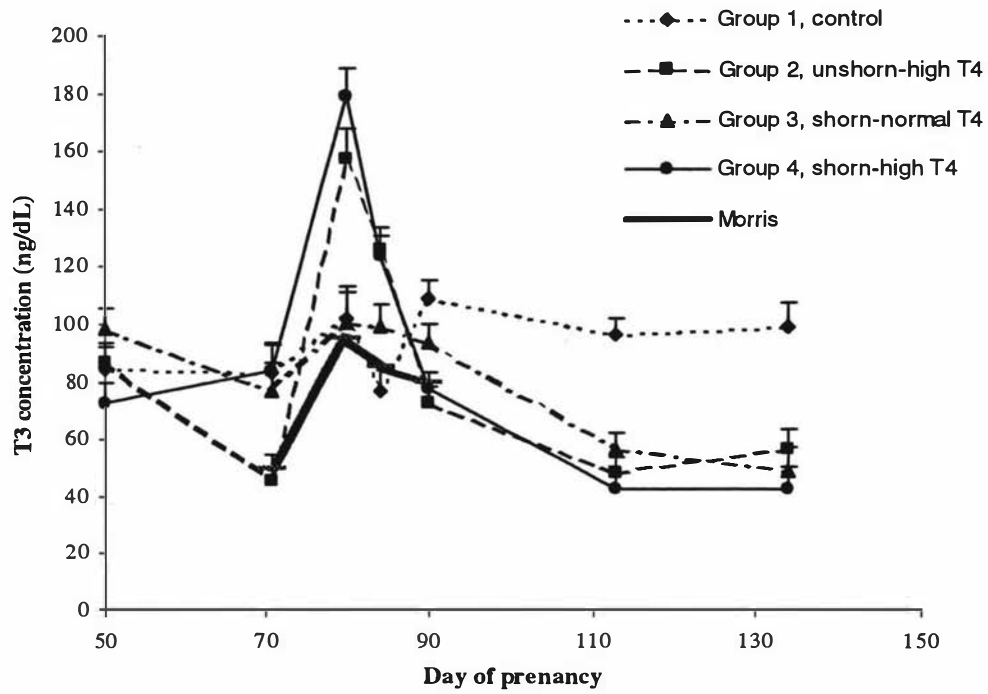
| | | Annual Fleece Weight |
|---|---|---|
| | (n) | |
| Dam treatment | | |
| 1. Unshorn control T4 | 9 | 3.5 ±0.3 |
| 2. Unshorn elevated T4 | 11 | 3.7 ±0.3 |
| 3. Shorn control T4 | 6 | 3.8 ±0.4 |
| 4. Shorn elevated T4 | 10 | 4.1 ±0.3 |

*Dam blood T3/T4 concentrations*

At surgery (P48-52) none of the groups differed significantly in plasma concentrations of either T3 or T4 (Figure 5.1). Interestingly by P71, Group 2 ewes had lower T4 concentrations (P<0.05) than Group 4 ewes, even though both groups had identical implants inserted. Additionally, T3 concentrations of Group 2 were lower (P<0.05) than those observed in both Groups 1 and 4 at P71. Daily injections of T4 (from P71 to P80) increased ($P<0.05$) T3 and T4 concentrations in both Groups 2 and 4 above those seen in either of Groups 1 or 3 for at least 10 days. By P84, T3 and T4 concentrations in Group 2 and 4 ewes were still significantly ($P<0.05$) greater than those observed in Group 1 but, not in Group 3. At P90, Group 1 had significantly higher ($P<0.05$) T3 concentrations than both Groups 2 and 4 and by late pregnancy (P113 and P134) had significantly ($P<0.05$) higher T3 concentrations than all other groups. At P113, Group 4 ewes had significantly ($P<0.05$) lower T4 concentrations than both Group 1 and 3 ewes and by P134 Group 1 ewes had significantly higher T4 concentrations than all other groups. In the late pregnancy period (P90-134) thyroidectomised ewe groups (Groups 2, 3 and 4) had similar T4 and T3 hormone profiles.

*Gestation length and lamb size*

Dam treatment had no effect on either gestation length or lamb birthweight (Table 5.4). At docking (L47) lambs born to Group 2 ewes were lighter (by 3.0 kg, $P<0.05$) than lambs born to Group 3 ewes but, by weaning (L122), dam treatment had no effect on lamb liveweight. Dam treatment had no effect on newborn lamb CRL (Table 5.5). The girths of lambs born to Group 2 ewes were 3.5 cm greater ($P<0.05$) than the girth of lambs born to Group 4 ewes (Table 5.5).



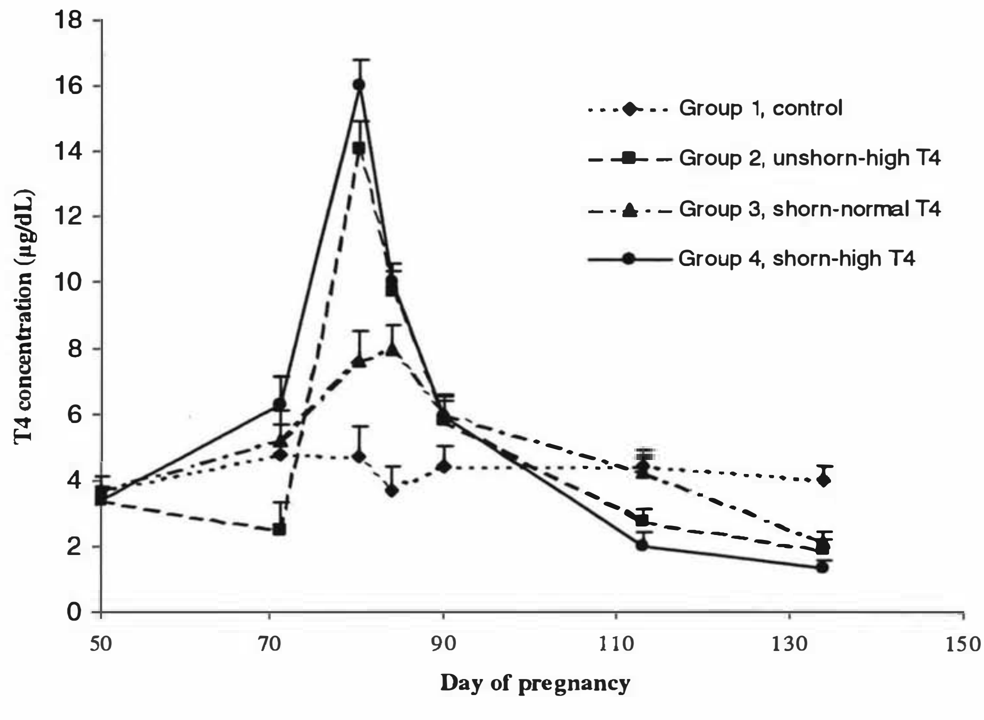




**Figure 5.1.** Effect of dam treatment on maternal T3 (ng/dL) (upper graph) and T4 (µg/dL) (lower graph) concentrations during mid- to late-pregnancy. In the T3 graph 'Morris' indicates T3 elevation reported by Morris *et al.* (2000). The vertical bars indicate standard errors of the means.

**Table 5.4.** The effect of dam treatment on the gestation length (days) and liveweights (kg) at birth (L1), L47 and L122 of twin lambs (Mean ±SE). Means within columns having different superscripts are different (P<0.05).

| | Gestation length | | Lamb liveweight | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | L1 | | L47 | | L122 | |
| | (n) | | (n) | | (n) | | (n) | |
| Dam treatment | | | | | | | | |
| 1. Unshorn control T4 | 18 | 148.6 ±0.4 | 18 | 4.71 ±0.14 | 15 | $15.4^{ab}$ ±0.7 | 15 | 32.0 ±1.1 |
| 2. Unshorn elevated T4 | 24 | 148.2 ±0.3 | 24 | 4.70 ±0.13 | 20 | $13.4^{a}$ ±0.6 | 20 | 28.9 ±0.9 |
| 3. Shorn control T4 | 20 | 148.4 ±0.4 | 20 | 4.42 ±0.12 | 14 | $16.4^{b}$ ±0.7 | 14 | 30.6 ±1.1 |
| 4. Shorn elevated T4 | 22 | 148.8 ±0.3 | 22 | 4.57 ±0.12 | 20 | $14.1^{ab}$ ±0.6 | 20 | 29.5 ±0.9 |

**Table 5.5.** The effect of dam treatment on the crown rump length (CRL) (cm) and Girth (cm) of twin lambs (Mean ±SE). Means within columns having different superscripts are different (P<0.05).

| | (n) | CRL | Girth |
|---|---|---|---|
| Dam treatment | | | |
| 1. Unshorn control T4 | 18 | 49.3 ±2.1 | $39.9^{ab}$ ±1.0 |
| 2. Unshorn elevated T4 | 24 | 52.4 ±1.9 | $42.3^{b}$ ±0.9 |
| 3. Shorn control T4 | 20 | 56.4 ±2.0 | $39.3^{ab}$ ±0.9 |
| 4. Shorn elevated T4 | 22 | 52.8 ±1.9 | $38.8^{a}$ ±0.9 |

*Summit metabolism*

Dam treatment had no effect on either the proportion of twin-born lambs reaching summit metabolism (Table 5.6) or actual summit metabolic rate (Table 5.6).

**Table 5.6.** The effect of dam treatment on the proportion of lambs (%) that reached summit metabolism and the summit metabolic rate (W/kg) of twin lambs (Mean ±SE).

| | (n) | Proportion of lambs that reached summit metabolism | (n) | Summit metabolic rate |
|---|---|---|---|---|
| Dam treatment | | | | |
| 1. Unshorn control T4 | 12 | (100)[2] | 12 | 16.18 ± 1.07 |
| 2. Unshorn elevated T4 | 16 | 1.94 ± 0.76[1](88) | 14 | 16.40 ± 0.99 |
| 3. Shorn control T4 | 10 | 1.38 ± 0.79 (80) | 8 | 18.94 ± 1.31 |
| 4. Shorn elevated T4 | 16 | 0.78 ± 0.54 (69) | 11 | 15.36 ± 1.11 |

[1] Logit transformed.

[2] Back transformed (%).

## Discussion

In both Chapters 2 and 3, it was concluded that the lamb birthweight response to mid-pregnancy shearing was not due to either an increase in dam intake or gestation length, although the actual mechanism was not identified. Morris *et al.* (2000) observed elevated T3 concentrations after shearing ewes in mid-pregnancy and subsequently observed a birthweight effect in singletons. This, together with known effects of thyroid hormones on foetal growth and development (Spencer and Robinson 1993, Symonds 1995), suggests that elevated maternal thyroid hormone concentrations could be the mechanism responsible for heavier lamb birthweights. To test this hypothesis, twin-bearing ewes in the present study were either; left unshorn or shorn during mid-pregnancy and either had T3/T4 concentrations similar to those of the pregnant unshorn ewe or were subjected to elevated T3/T4 concentrations in the short to medium post mid-pregnancy shearing period (as observed by Morris *et al.* (2000)). The hypotheses developed in Chapter 3 to explain the variable results achieved in pregnancy shearing studies states, that first: the dam must have the potential to respond (i.e. be destined to give birth to lambs of low birthweight), and; secondly, the dam must have the means to respond (i.e. an adequate level of condition and/or nutrition). Therefore in this study twin-bearing ewes were utilised, as birthweights are more likely to be below potential in multiple-born lambs. Additionally, ewes were offered a level of nutrition equal to expected foetal growth (i.e. so that conceptus free liveweight did not change, which had been observed to result in a birthweight response in Chapter 3). In the present study, dam treatment had no effect on either ewe liveweight or condition score. Hence any differences among the four ewe groups could be attributed solely to shearing and T4 treatments.

This study was designed to allow separate tests of the effects of shearing and thyroid hormone manipulation on lamb birthweight. If elevated maternal thyroid hormone (T3/T4) concentrations are the mechanism responsible for the higher birthweights observed from mid-pregnancy shearing, it would be expected that lambs born to Groups 2 and 4 ewes (in which dams had elevated T3/T4 concentrations in mid-pregnancy) would be heavier than those born to Groups 1 and 3. However, if the shearing effect operated via other mechanisms, one would expect lambs born to

Groups 3 and 4 (mid-pregnancy shorn dams) to be heavier than lambs born to Groups 1 and 2 (unshorn dams).

In the present study elevated maternal T3/T4 concentrations in mid-pregnancy did not increase lamb birthweight. This lack of a response was not due to ineffective manipulation of thyroid hormone concentration. The T4 implants inserted in thyroidectomised ewes (Groups 2, 3 and 4) maintained maternal T4 and T3 concentrations at a level similar to that observed in the unshorn pregnant ewe (Group 1, sham operated) although, in late pregnancy, both the T3 and T4 concentrations of thyroidectomised ewes were lower than those found in Group 1. T3 concentrations in all ewe groups (including Group 1) in the present study were above those reported by Morris *et al.* (2000). This difference could have been due to yearly variation, type of sheep or variation due to radioimmunoassay procedures. Daily T4 injections from P71 to P81 successfully elevated both T3 and T4 concentrations for at least 10 to 14 days above those observed in Groups 1 and 3. Morris *et al.* (2000) reported mid-pregnancy shearing elevated T3 concentrations for at least 20 days. Interestingly, T3 and T4 concentrations of Group 2 ewes appeared to remain higher than those observed directly pre-treatment in this group for at least 20 days. However, this was not observed in Group 4. Peak T3 concentrations reached by Group 2 and 4 ewes were greater than those reported by Morris *et al.* (2000) (by approximately 60 to 90 ng/dL) although, the relative elevation above levels observed in unshorn ewes between studies was similar. It is possible the lower T3/T4 concentrations of thyroidectomised ewes (Groups 2, 3 and 4) in comparison to Group 1 ewes in late pregnancy may have negated any positive effects of elevated concentrations in mid-pregnancy. However, there was no difference in the birthweights of lambs born to Group 3 and 4 ewes, which had differing concentrations of T3/T4 in mid-pregnancy but similar concentrations in late pregnancy.

The lack of a birthweight response from mid-pregnancy shearing in the present study (i.e. birthweights of lambs born to Group 1 and 2 ewes (unshorn) did not differ from those born to Group 3 and 4 ewes (shorn)) contrasts with the findings of Morris and McCutcheon (1997), Morris *et al.* (2000) and Revell *et al.* (2002) and Chapters 2, 3 and 4. When the average birthweights of lambs born to unshorn ewes in the present study are plotted using the approach developed in Chapters 2 and 3 (Figure 5.2), we see that a birthweight response to mid-pregnancy shearing is not expected. Moreover, Morris *et al.* (2000) reported that despite elevated T3 concentrations in both single- and twin-bearing ewes, a birthweight response was only seen in singletons. Twin-lambs born to unshorn dams in that study weighed 4.5 kg (similar to weights reported in the present study) whereas singletons born to unshorn lambs weighed only 5.1 kg (0.7 kg lighter than their counterparts born to shorn dams). Due to the relatively high twin birthweights found in all groups (including the controls) in the present study, and the possibility that t he T3/T4 elevation period may have been insufficient, the hypothesis that mid-pregnancy shearing is due to elevated maternal T3/T4 concentrations cannot be successfully tested. To successfully test whether elevated T3/T4 concentrations are the mechanism responsible for increased lamb birthweights, conditions must be present that would otherwise result in a birthweight response to mid-pregnancy shearing. Nutritional management of ewes in the present study was designed to be similar to that of Group M ewes in Chapter 3 (which displayed a birthweight response) and to avoid placing additional extra stress on thyroidectomised ewes. Therefore to successfully determine if elevated maternal T3/T4 concentrations are responsible for the birthweight response, ewes in good condition should be offered a level of nutrition below maintenance (i.e. below that required to permit expected foetal growth). However, this restriction should not be as severe as that given to Group L ewes in Chapter 3 (especially if ewes are in poor condition) in which a birthweight response was also not observed.

In both Chapter 2 and 3, dam shearing treatment had no effect on either the proportion of lambs reaching summit metabolism or summit metabolic rate (SMR) (W/kg). In contrast, Revell *et al.* (2002) reported that twin lambs born to shorn dams had higher SMR than their counterparts born to unshorn dams, although they found the opposite relationship in singletons. Thyroid hormones are involved with the maturation of BAT (which is a ready source of energy for heat production in the newborn lamb) in late pregnancy and, therefore, maternal T3/T4 concentrations in pregnancy might have an important role in lamb survival. Summit metabolic rate is independent of body weight so it is possible to examine the effects of dam treatment on the metabolic responses in the lamb, without a birthweight response necessarily being observed. If elevated T3/T4 concentrations in mid-pregnancy do result in increased thermoregulatory capacity in newborn lambs, higher SMR in lambs born to Group 2 and 4 ewes compared to lambs born to Group 1 and 3 ewes would be expected. In the present study dam treatment had no effect on SMR. It is possible that the elevation in T3/T4 in mid-pregnancy is too early to affect BAT, as BAT is laid down in late pregnancy. However, lambs born to Group 1 ewes, which displayed the highest T3/T4 concentrations in late pregnancy, did not display higher SMR to Groups 2, 3 and 4. The lack of an effect of dam treatment on SMR in the present study also indicates that shearing treatment had no effect on SMR, which supports the findings of both Chapters 2 and 3.

**Conclusion**

Manipulating maternal thyroid hormone concentrations around mid-pregnancy in the present study had no effect on lamb birthweight. The magnitude of T3/T4 elevation of thyroidectomised ewes was similar to that previously reported in pregnancy-shorn ewes, although the duration of the elevation appeared to be shorter. Consequently it is possible that the lack of a birthweight response in the present study was due to an insufficient period of elevated thyroid hormone concentration. However, when the birthweights of the twin-born lambs in this study are compared to those in previous mid-pregnancy shearing studies, it becomes apparent that a birthweight response to mid-pregnancy shearing is not expected. Therefore, to successfully determine whether elevated maternal T3/T4 concentrations are responsible for the increases in lamb birthweight from mid-pregnancy shearing, conditions must be present that would otherwise result in lamb birthweight response to mid-pregnancy shearing. Under these conditions the effect of elevated maternal T3/T4 concentrations on lamb birthweight can be evaluated (therefore determining if it is the mechanism for the birthweight response to mid-pregnancy shearing). In support of previous mid-pregnancy shearing studies, dam treatment had no effect on SMR. Finally, while it is not possible to determine, in this study, the role of thyroid hormones, the protocol developed here could be applied to future studies of this type, as it produced the desired changes in maternal T3 and T4 concentrations.

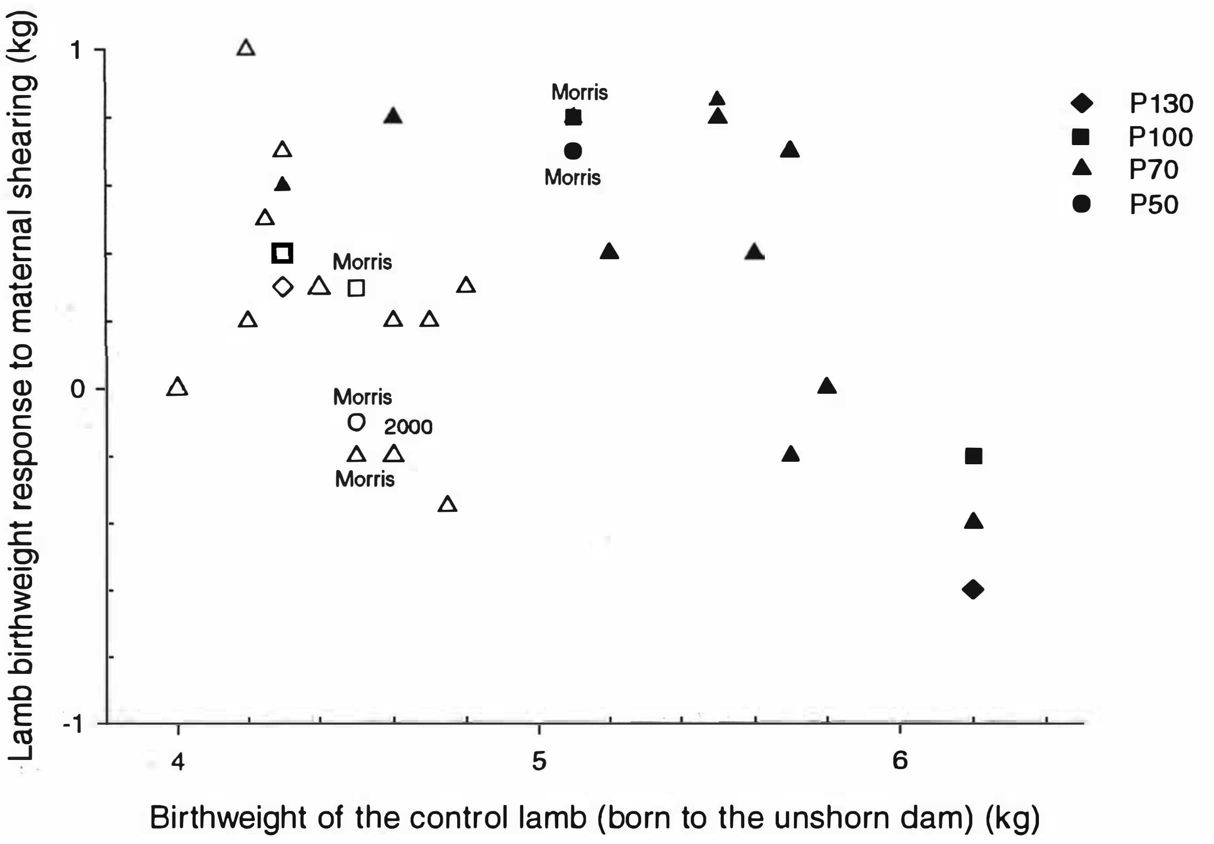



**Figure 5.2.** Birthweight responses to mid- to late-pregnancy shearing (singles- closed symbols, twins- open symbols) as a function of the birthweights of control lambs born to unshorn dams (each point represents a separate trial or treatment [shearing date] within a trial (Morris and McCutcheon 1997, Morris *et al.* 2000, Revell *et al.* 2000, Revell *et al.* 2002 and Chapter 2 and 3)). The present study is indicated by '2000'. The results of Morris *et al.* (2000) within each birthrank for each of the shearing dates are indicated by 'Morris'.

# Chapter six - General discussion

## Introduction

Lambing percentages in New Zealand have increased over the past decade from an average 100 to 115% (MWES 2000a) and will probably continue to rise while prices for lamb remain at an all-time high (MWES 2000b). Any increase in lambing percentage will result in an increase in the proportion of multiple-born lambs. It is known that a 10% increase in ovulation rate results in a 6.9% increase in the number of lambs born per ewe (Geenty 1997). Multiple-born lambs are lighter than their singleton counterparts and have lower survival rates to weaning (Geenty 1997). The biggest killer of multiple-born lambs is starvation-exposure (Dalton *et al.* 1980; Fogarty *et al.* 1992). Lighter born lambs have a greater surface area to body mass ratio and have a lower level of body reserves than their heavier born counterparts. Management techniques that can increase birthweights of otherwise lightweight lambs should reduce losses due to starvation-exposure and increase survival rates to weaning. Previous New Zealand mid-pregnancy shearing studies have been shown that this technique can increase lamb birthweights but the results have been inconsistent in both magnitude and the birthrank specificity.

The aim of this thesis was to address the variation observed in the lamb birthweight response to mid-pregnancy shearing, first, by evaluating the relationship between dam herbage allowance post mid-pregnancy shearing and the lamb birthweight response and second, by determining if the birthweight response was due to an increase in dam intake. Additionally; the effect of mid-pregnancy shearing on the newborn lamb's thermo-regulatory capability and survival rates to weaning (under commercial conditions) and lastly, a possible metabolic mechanism for the birthweight response were also examined. In this Chapter progress in achieving these objectives is discussed, together with the significance of the results, and areas requiring further study are identified.

**Achievement of ewe liveweight targets**

Under pastoral grazing systems, where individual herbage allowances cannot be controlled, it is extremely difficult to accurately manipulate ewe liveweights over an extended period. In Chapters 2, 3 and 5 daily herbage allowances were controlled via daily allocation of new pasture using electric fencing (i.e. via break fencing) or though rotational grazing. Additionally, ewes were regularly weighed to help monitor progress. Consequently, in all studies, ewe groups achieved their liveweight targets.

Based on the findings of Chapter 2 and those of previous mid-pregnancy shearing studies it was hypothesised in Chapter 2 that the birthweight response to pregnancy shearing is greatest in conditions in which the unshorn dam gives birth to a lamb(s) of low birthweight. Therefore Chapter 3 was designed to produce lambs born to unshorn ewes of either low or 'normal' birthweight and to determine if the birthweight response to mid-pregnancy shearing was greater in the low birthweight group. To achieve this ewe liveweights and herbage allowances were manipulated (Group M ewes were 63 kg at mid-pregnancy shearing and fed to permit total ewe liveweight to increase with expected foetal growth while, Group L ewes were 54kg at mid-pregnancy shearing and fed to permit total liveweight gain to increase at half the expected foetal growth) in an attempt to influence lamb birthweights. Ewes in both groups met their liveweight targets. This manipulation was successful, with lambs born to Group M ewes being heavier than those born to Group L, allowing the hypothesis to be tested.

**Evaluation of measurement techniques**

*Ewe intake*

The literature is inconclusive as to whether the birthweight response to mid-pregnancy shearing is due to an increase in dam intake post-shearing. If mid-pregnancy shearing was found to increase dam intake and consequently the birthweight response was found to be dependent on an increase in dam intake, this technique may be unattractive to farmers, as both pasture availability and growth are minimal during winter when mid-pregnancy shearing is undertaken. Therefore, the aim of the intake measurements was to determine if mid-pregnancy increased dam intake (and therefore caused the birthweight effect) and not to determine the differences in intake between the nutritional treatments used. The nutritional treatments used in Chapter 2 were designed to determine if differences in dam herbage allowances post mid-pregnancy shearing were responsible for the variable birthweight responses observed, as dam herbage allowances post shearing differ in the literature.

In Chapter 2, when ewe intakes were initially calculated it became apparent that the DMD, OMD and DOMD values of the herbage samples collected by the OF sheep were incorrect (when these values were used to calculate intakes, results produced were well below what the ewes must have eaten based on daily feed allowances and changes in ewe liveweight). Therefore DMD, OMD and DOMD values reported by Parker *et al.* (1991) under similar conditions were used to calculate an intake value comparable to the allowances given. The use of the Parker *et al.* (1991) data did not affect the relative differences between shearing treatments. A clear explanation of the erroneous DMD, OMD and DOMD values from the OF sheep is unknown. One possible explanation is that the OF sheep used, selected different herbage from that of the ewes used in the study. However, the OF technique is a validated technique, and these animals were offered the same pasture as the ewes. Collection and analysis of the OF herbage samples was as described by Morris *et al.* (1993). Subsequently, in Chapter 3, procedures used for the collection and analysis of herbage samples from OF sheep were the same as that used by Morris *et al.* (1993) and that in Chapter 2 but, no problems were encountered.

*Ewe rectal temperatures*

Shearing ewes in the winter period can incur the risk of ewe losses. It has also been suggested that the birthweight response from pregnancy shearing is triggered by cold stressing the dam. Consequently in both Chapters 2 and 3 rectal temperatures were used as an indicator of possible cold stress. However, on most measurement days no difference in the rectal temperature between shorn and unshorn ewes was observed (when differences did occur they were relatively minor with a maximum of 0.2°C). This indicates that under the conditions found in these studies, mid-pregnancy had little to no effect on ewe body temperature and is unlikely to have caused cold stress. Additionally, a point specific rectal temperature may not be a good indicator of what is occurring on a 24 h basis in an uninterrupted grazing situation. In both studies rectal temperatures were recorded under relatively mild environmental conditions (maximum of 17.2°C and minimum of –1.2°C). Furthermore, shearing ewes with a cover comb (leaving 5-9 mm stubble) rather than the conventional standard comb (3 – 4 mm) improves ewe insulation (Dabiri 1995a). In Chapter 3, rectal temperatures were not taken until late pregnancy (50 –70 days post shearing), by which time additional wool growth would have further increased insulation. Gregory (1995) reported that the lower critical temperature (LCT) of a 40 kg ewe, fed at maintenance, with 1 cm of stubble was 17°C. Once that stubble increased to 3 cm, the LCT lowered to 5°C. Wool length growth of Romney type sheep is approximately 0.4 mm/day during the winter period (Sherlock *et al.* 2001) and thus by late pregnancy we would expect approximately 3 cm of stubble. A more accurate determination of the effect of shearing treatment on thermoregulatory control of the ewe may have been achieved by placing ewes in a calorimetry chamber (as used by Dabiri *et al.* 1995a) and measuring heat production under controlled environmental conditions. However in both Chapters 2 and 3 this was not practical, as rectal temperatures were taken when faecal samples to measure intake were collected. Placing ewes indoors to determine heat production would have reduced the numbers for intake measurements.

Air temperature and wind run data are used in Chapter 2 to calculate a wind chill factor, when determining the effect of dam shearing treatment on newborn lamb rectal temperature. However, little use is made of the air temperature data for describing the possible effect this has (in addition to wind and/or rain) on the lamb birthweight response to mid-pregnancy shearing. Since it is assumed that cold stress is inducing the birthweight response, in the future comprehensive air, wind and rain data should be collected in the period following shearing. This data could be used as a covariate in the analysis and may help account for some of the differences observed in the birthweight response to mid-pregnancy shearing between studies.

*Condition scores*

In all studies, ewe CS were recorded. The two aims of this measurement were to, firstly; determine if mid-pregnancy shearing had any effect on dam condition during either mid- to late-pregnancy or in lactation, and secondly; to determine if the variation in the birthweight response could explained by variation in dam condition at mid-pregnancy shearing. Ewe CS were measured on a 0 to 5 scale in 0.5 units. Any changes in dam CS may have indicated a change in ewe metabolism (i.e. an increase in adipose tissue mobilisation). However, only minor differences (if any), were observed (up to maximum of 0.2 units) in the present studies. The CS system is not very sensitive to small changes in the relative amounts of soft tissue. Dabiri *et al.* (1996) found no effect of shearing treatment on CS but observed lower backfat depths in shorn ewes in comparison to unshorn ewes 24 days after shearing using an ultrasound scanner. Similarly, using computer topography (CT), Jopson and Davies (2000) reported that shorn ewes mobilised more body fat than unshorn ewes. In the present studies, the use of a ultrasound scanner may have improved the sensitivity of the results.

*Measurement of newborn lamb thermoregulatory capability*

Studies in the UK indicate that lambs born to pregnancy-shorn dams have enhanced thermoregulatory capability. Revell *et al.* (2002) under pastoral conditions reported contradictory results, such that mid-pregnancy shearing enhanced the twin-born lamb summit metabolic rate (SMR) but had the opposite effect in singletons. Lamb rectal temperatures (during the immediate 48 hr post birth period, Chapter 2), rate of change in heat production (Chapter 2) and SMR (Chapters 2, 3 and 5) were used as, possible indicators of a mid-pregnancy shearing effect on the new-born lambs thermoregulatory capability.

In Chapter 2, fewer than 50% of the lambs tested, via closed circuit calorimetry, reached summit metabolism. This relatively low success rate, limited the ability of that study alone, to determine if mid-pregnancy shearing of the dam had any effect on newborn lamb's thermo-regulatory capability. To improve the usefulness of this test, in Chapter 3, wool from the back and the sides of all newborn lambs weighing more than 4 kg was clipped to a residual stubble depth of 2 mm. This resulted in 90

% of the newborn lambs reaching summit metabolism, which improved the efficacy of the test.

*Large scale commercial field studies*

In support of the literature, mid-pregnancy shearing was found to increase lamb birthweight in both Chapters 2 and 3. However, to determine if this increase in birthweight has any effect on lamb survival rates to weaning large numbers of lambs are required. Therefore, on each of two commercially managed farms, more than 1000 ewes were either shorn during mid-pregnancy or left unshorn and lamb birthweights and survival rates to weaning were recorded (Chapter 5).

On each of the two farms, unshorn and shorn ewes were inadvertently separated for a short period (but offered similar herbage allowances), even though, farm staff were explicitly told not to do so. This relatively short separation period is unlikely to have had any effect on the results achieved. However, this separation highlights the risk of conducting experiments under commercial conditions on farms some distance away from the university, when stock cannot be directly monitored on a day to day basis. Farm staff on both properties believed that this separation was the correct management decision based on normal farm management practice. They believed that there was inadequate shelter for both unshorn and shorn ewes in the short-term post mid-pregnancy shearing. Providing ewes with shelter after mid-pregnancy shearing is advocated to reduce the chance of ewe losses.

Another issue encountered when conducting the large-scale commercial studies which was not found in the smaller more intensely managed studies was the numbers of ewes that went unaccounted for, or were removed from the study (due to ewes either going missing, losing tags, or not being identified as having lambed). Staff were instructed to record all ewe deaths. However, in large paddocks, with uneven topography and in areas of scrub some ewes and lambs can go unnoticed. A possible way to reduce the numbers of ewes that lost tags would have been to double tag all ewes. Tag losses in sheep have been recorded to be as high as 5%, depending on type of tag used (Verkaik 2001), *Maternal T3/ T4 manipulation*

Mid-pregnancy shearing was found in Chapters 2 and 3 to not be due to either an increase in dam intake or gestation length. Therefore, the mechanism responsible for the birthweight effect had not been identified. Morris *et al.* (2000) reported elevated maternal thyroid hormone concentrations in the period post pregnancy shearing. They stated that this could be the signalling mechanism by which mid-pregnancy shearing affects foetal growth. Others have demonstrated an association between maternal thyroid status and foetal growth (Bell *et al.* 1989, Spencer and Robinson 1993). Consequently an attempt was made to manipulate maternal thyroid hormone concentrations in pregnant ewes to determine if this elevation was responsible for the birthweight effect observed from mid-pregnancy shearing. Ewes were either thyroidectomised or had their thyroids left intact, and had either elevated thyroid hormone concentrations (similar to that observed in shorn ewes) or had thyroid hormone concentrations at a level seen in the unshorn ewe.

T4 implants were used to maintain maternal T3/T4 concentrations at a level seen in the unshorn ewe. These implants successfully maintained maternal T3 and T4 concentrations above basal levels for at least 10 weeks post insertion. However, after 8 weeks, the concentration fell below those observed in the sham operated (non-thyroidectomised) ewes. This indicates that it would have been more appropriate to insert replacement implants after 8 weeks instead of 10 weeks used. Yet in the preliminary studies (see Appendix I for results), the implants appeared to be effective for at least a 10-week period.

Daily injections of T4 for 10 days (in addition to the T4 implants), were used to induce a short term elevation in maternal T3 and T4 concentrations in an attempt to mirror those observed in the pregnancy shorn ewe. The T4 injection regimen used, increased maternal T4 and T3 concentrations for 10 to 14 days which was slightly less than the 20 days aimed for. Thus, it may have been more appropriate to inject ewes for at least 15 days to induce a 20-day elevation.

*Statistical analysis*

Analysis of data in the thesis was generally undertaken using generalized linear models to examine the relationship between specific components (i.e. ewe nutrition, pregnancy-rank etc) and the birthweight effect due to mid-pregnancy shearing. Ewes were randomly allocated within the treatments (and therefore did not differ in liveweight and condition etc) and they were all subjected to the same environmental conditions within each study. Therefore, the use multivariate analysis under this situation is unwarranted. Multivariate analysis could have been used to determine the relative importance of a range of parameters affecting the birthweight response based on the results of previous pregnancy shearing studies. This may have identified further parameters that needed to be investigated. However, between studies there are differences in the type of data (i.e. liveweights, condition scores, wether data etc) that are presented, which may make it difficult to undertake a multivariate analysis

Ewe intakes and rectal temperatures were analysed as individual points rather than via repeated measures. This limited the ability of Chapter 2 and 3 studies to make reference to the whole time period in which intakes and rectal temperature were measured. Therefore the results for both intakes and rectal temperatures were limited to examining the relationship at singular points of time. This also meant that inferences could not be made between individual measurement points. In hindsight intake and rectal temperature measurements should have been analysed as repeated measures.

**The effect of mid-pregnancy shearing on lamb birthweight**

Early studies under New Zealand pastoral conditions indicated that pregnancy shearing could be used as a technique to increase lamb birthweights. However, in the literature there is a lack of consistency in both the magnitude and birth-rank specificity of the response. It was concluded in Chapter 3 that there are two criterion the dam must meet if a birthweight response to mid-pregnancy is to occur, first; the dam must have the potential to respond (i.e. be otherwise destined to give birth to a lamb(s) of low birthweight) and secondly; the dam must have the means to respond (i.e. an adequate level of condition and/or nutrition). This hypothesis was somewhat verified by the results achieved in the large scale commercial studies, by retrospectively examining the relationship dam shearing treatment and both ewe liveweight and condition score at mid-pregnancy shearing and their effect on twin lamb birthweight. These data show that at a practical level, to achieve a birthweight response, lambs born to unshorn dams need to be destined to be born below approximately 5.8 kg and 4.6 kg for singletons and twin-born lambs respectively (based on Figure 3.1). Furthermore, a birthweight response will not be achieved (even when there is the potential to respond) if the ewe is in either poor condition (twin-bearing ewes with a CS of 2 or below, or weighing less than 50 kg at mid-pregnancy shearing) and/or when the ewe is offered a low level of nutrition during mid- to late-pregnancy (e.g. Group L in Chapter 3, in which ewes were fed at half their pregnancy nutritional requirement). In addition, a birthweight response will not occur when ewes are in very good condition at mid-pregnancy (e.g. twin-bearing ewes with a CS of 3.5 or higher) as these ewes are already destined to give birth to lambs of high birthweight.

Although the relative conditions in which a birthweight response occurs has been identified, the exact conditions have yet to be quantified. In Chapter 3, a birthweight response to mid-pregnancy shearing was achieved in lambs born to Group M ewes but not those born to Group L. In hindsight, if a third intermediary group had been utilised, the point at which a birthweight response does or does not occur may have been more accurately defined.

Ewes in the thyroid study (Chapter 5) were of similar liveweight at mid-pregnancy and were offered a similar herbage allowance during the mid- to late-pregnancy period as Group M ewes in Chapter 3. However, dam treatment had no effect on birthweight. The average lamb birthweight observed in that study (i.e. 4.6 kg) was within the birthweight range in which a birthweight response to mid-pregnancy shearing is not expected (based on Figure 3.1). Consequently, the hypothesis being tested in the thyroid manipulation study (that the birthweight response to mid-pregnancy shearing is due to an elevation in maternal thyroid hormone concentrations) could not be supported or rejected. The level of allowance used (a level of nutrition that enabled the dam to maintain conceptus-free liveweight) was selected as it had resulted in the birthweight response in Chapter 3 (in Group M) and additionally, placed no extra stress on pregnant ewes, who had had their thyroids removed. This study shows that to manipulate ewes with an average liveweight of 60kg at mid-pregnancy to ensure a birthweight response to mid-pregnancy shearing, ewes need to be offered a level of allowance between that given to Groups L and M ewes in Chapter 3. Under most commercial situations ewe allowances do not result in total ewe liveweight increasing by the expected foetal growth during pregnancy. On the other hand, allowances are also not designed to result in the dam losing substantial conceptus-free liveweight. Therefore we would expect to observe a birthweight response to mid-pregnancy shearing in most commercial conditions.

**Does a birthweight response always mean an increase in lamb survival rates to weaning?**

International literature has indicated that lambs born to shorn ewes display enhanced thermoregulatory capability independent of a birthweight effect, suggesting a survival advantage under adverse weather conditions. In contrast, in Chapters 2, 3 and 5 of this thesis, dam shearing treatment had no effect on the newborn lamb's thermoregulatory capability. However an increase in birthweight of an otherwise lightweight lamb should increase survival rates to weaning. In both the large-scale commercial studies, a birthweight response was observed, but no significant effect on overall lamb survival rates to weaning was found. Although mid-pregnancy shearing did tend to increase the survival rates of multiple-born lambs but tended to have the opposite effect in singletons.

This lack of a statistically significant birthweight effect on survival rates can be explained by use of the lamb survival data collected by Dalton *et al.* (1980) involving more than 10,000 lambs. In Tables 6.1, 6.2, 6.3 and 6.4 lamb survival rates, stratified within birthweight ranges (as reported by Dalton *et al.* 1980) have been used to calculate a 'predicted' survival rate (by multipling the survival rates calculated by Dalton *et al.* (1980) and the actual number of lambs born within each of these birthweight ranges at both Riverside and Tuapaka). These 'predicted' survival rates can then be compared to actual lamb survival rates found at both commercial research locations (Riverside and Tuapaka, Table 4.11).

At Tuapaka, mid-pregnancy shearing increased twin lamb birthweights by only 0.1 kg. Predicted twin lamb survival rates to weaning at Taupaka (Table 6.1) do not differ between shearing treatments (83.1% and 83.3% for unshorn and shorn lambs respectively). In support of this calculation, actual survival rates did not significantly differ (78.6% and 82.6% for unshorn and shorn lambs respectively). The lack of a birthweight effect on lamb survival in this situation is due to the relatively small increase in birthweight not substantially increasing the numbers of twin-born lambs in the higher survival rate ranges.

**Table 6.1.** The effect of dam shearing treatment on predicted twin lamb survival rates (based on survival data presented by Dalton *et al.* (1980)) to weaning at Tuapaka.

| | | Dam shearing treatment | | | |
|---|---|---|---|---|---|
| | | Unshorn | | Shorn | |
| Birthweight range | Dalton's survival % | Actual numbers born | Predicted survival | Actual numbers born | Predicted survival |
| < 2.0 | 22.4 | 2 | 0.4 | 3 | 0.7 |
| 2.0 - 2.5 | 53.1 | 2 | 1.1 | 0 | 0 |
| 2.5 - 3.0 | 71.4 | 7 | 5.0 | 2 | 1.43 |
| 3.0 - 3.5 | 78.0 | 22 | 17.2 | 9 | 7.0 |
| 3.5 - 4.0 | 81.8 | 61 | 49.9 | 41 | 33.5 |
| 4.0 - 4.5 | 85.7 | 113 | 96.8 | 87 | 74.6 |
| 4.5 - 5.0 | 82.5 | 144 | 118.8 | 146 | 120.5 |
| 5.0 > | 84.2 | 225 | 189.5 | 245 | 206.3 |
| Total | | 576 | 479 | 536 | 444 |
| Predicted survival rate (%) | | | 83.1 | | 83.3 |
| Actual survival rate (%) | | | 78.6 | | 82.6 |

At Tuapaka mid-pregnancy shearing was also found to increase singleton birthweight by 0.2 kg (non significantly). Predicted survival rates are substantially higher in singleton lambs (Table 6.2) born to unshorn dams (85.8%) than shorn dams (78.4%) and this supports the negative effect of mid-pregnancy shearing found at Tuapaka (91.7% and 80.0% survival rates for unshorn and shorn lambs respectively). Although the average difference in birthweight was only 0.2 kg, the average birthweight of lambs born to unshorn ewes was approximately 5.5 kg (which is above the highest singleton survival rate ranges of 4.0 to 5.0 kg). Therefore, any increase in birthweight under these conditions (relatively heavy lamb birthweights) will result in a decrease in survival rates.

**Table 6.2.** The effect of dam shearing treatment on predicted singleton lamb survival rates (based on survival data presented by Dalton *et al.* (1980)) to weaning at Tuapaka.

| | | Dam shearing treatment | | | |
|---|---|---|---|---|---|
| | | Unshorn | | Shorn | |
| Birthweight range | Dalton's survival % | Actual numbers born | Predicted survival | Actual numbers born | Predicted survival |
| < 2.0 | 16.3 | 0 | 0 | 0 | 0 |
| 2.0 - 2.5 | 50.7 | 0 | 0 | 1 | 0.5 |
| 2.5 - 3.0 | 66.6 | 0 | 0 | 1 | 0.6 |
| 3.0 - 3.5 | 77.0 | 1 | 0.8 | 0 | 0 |
| 3.5 - 4.0 | 82.9 | 6 | 4.9 | 1 | 0.8 |
| 4.0 - 4.5 | 87.7 | 10 | 8.8 | 7 | 6.1 |
| 4.5 - 5.0 | 87.4 | 17 | 14.9 | 13 | 11.4 |
| 5.0 - 5.5 | 86.0 | 20 | 17.2 | 27 | 23.2 |
| 5.5 - 6.0 | 83.5 | 21 | 17.5 | 19 | 15.8 |
| 6.0 - 6.5 | 76.6 | 25 | 19.2 | 22 | 16.9 |
| 6.5 > | 62.0 | 20 | 12.4 | 24 | 14.9 |
| Total | | 120 | 103 | 115 | 90 |
| Predicted survival rate (%) | | | 85.8 | | 78.4 |
| Actual survival rate (%) | | | 91.7 | | 80.0 |

At Riverside, predicted twin lamb survival rates to weaning (Table 6.3) did not differ substantially between shearing treatments (84.7% and 85.0% for lambs born to unshorn and shorn dams respectively) even though a 0.4 kg increase in birthweight was observed. In support of this prediction, there was a non-significant 3% difference in actual lamb survival rates (78.8% vs 81.8% for unshorn and shorn lambs respectively). The question therefore to be asked is why does this 0.4 kg increase in birthweight fail to increase survival rates? The majority of twin lambs born to unshorn dams at Riverside were already in the higher birthweight survival ranges (4.0 kg or heavier) and therefore any increase in birthweight does not substantially increase numbers of lambs within these ranges. However, if relatively more of these lambs had have been in the lighter birthweight ranges (i.e. if the average birthweight of lambs born to unshorn dams had have been lower), the increase in birthweight would have most likely increased overall survival rates.

At Riverside, in support of the findings at Tuapaka, predicted survival rates of singletons born to shorn dams were slightly lower than those born to unshorn dams (74% vs 76.1% respectively). Accordingly, actual survival rates were found to be lower in lambs born to shorn ewes than their counterparts born to unshorn ewes (79.2% vs 85.1% respectively, but not significantly so). This again shows the negative effect of an increase in birthweight when lamb birthweights are already destined to be relatively heavy (i.e. average above 6.0 kg for lambs born to unshorn dams).

**Table 6.3.** The effect of dam shearing treatment on predicted twin born lamb survival rates (based on survival data presented by Dalton *et al.* (1980)) to weaning at Riverside.

| | | Dam shearing treatment | | | |
|---|---|---|---|---|---|
| | | Unshorn | | Shorn | |
| Birthweight range | Dalton's survival % | Actual numbers born | Predicted survival | Actual numbers born | Predicted survival |
| < 2.0 | 22.4 | 2 | 0 | 0 | 0 |
| 2.0 - 2.5 | 53.1 | 2 | 1 | 2 | 1 |
| 2.5 - 3.0 | 71.4 | 8 | 5.3 | 1 | 0.6 |
| 3.0 - 3.5 | 78.0 | 24 | 18.2 | 8 | 6.1 |
| 3.5 - 4.0 | 81.8 | 73 | 60.5 | 25 | 20.7 |
| 4.0 - 4.5 | 85.7 | 121 | 106.1 | 71 | 62.3 |
| 4.5 - 5.0 | 82.5 | 184 | 160.8 | 149 | 130.2 |
| 5.0 > | 84.2 | 262 | 220.6 | 410 | 345.2 |
| Total | | 676 | 572.5 | 666 | 566.1 |
| | | | | | |
| Predicted survival rate (%) | | | 84.7 | | 85.0 |
| Actual survival rate (%) | | | 78.8 | | 81.8 |

It is of interest to note that while mid-pregnancy shearing tended to increase survival rates in twin lambs (but not significantly)(Tables 6.1 and 6.3) the actual increase in survival rates observed, were greater than those predicted. This may indicate that there is some other factor(s), which may act independently of birthweight and improve the survival rates of lambs born to shorn dams. In Chapters 2, 3 and 5 it was shown that the lamb's thermo-regulatory capability was not affected. Other possible mechanisms reported include; changes in lamb fleece characteristics (e.g. the greater wet fleece depth of lambs born to shorn dams in comparison to their counterparts born to unshorn dams, found in Chapter 2), a change in dam behaviour (e.g. the seeking of shelter), easier lambing, increased ease for lamb finding the teat, increased dam awareness of the lamb, and fewer ewes being lost to casting with consequent loss of their lambs (Wodzicka-Tomaszewska 1963a; Frengley 1964; Rutter *et al.* 1971; Alexander and Lynch 1976; Lynch and Alexander 1976; Black and Chestnutt 1990).

**Table 6.4.** The effect of dam shearing treatment on predicted singleton lamb survival rates (based on survival data presented by Dalton *et al.* (1980)) to weaning at Riverside.

| | | Dam shearing treatment | | | |
|---|---|---|---|---|---|
| | | Unshorn | | Shorn | |
| Birthweight range | Dalton's survival % | Actual numbers born | Predicted survival | Actual numbers born | Predicted survival |
| < 2.0 | 16.3 | - | - | - | - |
| 2.0 - 2.5 | 50.7 | - | - | - | - |
| 2.5 - 3.0 | 66.6 | - | - | - | - |
| 3.0 - 3.5 | 77.0 | 3 | 2.3 | 0 | 0 |
| 3.5 - 4.0 | 82.9 | 1 | 0.8 | 0 | 0 |
| 4.0 - 4.5 | 87.7 | 6 | 5.3 | 4 | 3.5 |
| 4.5 - 5.0 | 87.4 | 16 | 13.9 | 5 | 4.4 |
| 5.0 - 5.5 | 86.0 | 42 | 36.1 | 19 | 16.3 |
| 5.5 - 6.0 | 83.5 | 21 | 17.5 | 17 | 14.2 |
| 6.0 - 6.5 | 76.6 | 34 | 26.0 | 35 | 26.8 |
| 6.5 > | 62.0 | 58 | 35.9 | 50 | 31 |
| **Total** | | 181 | 137.9 | 130 | 96.2 |
| | | | | | |
| Predicted survival rate (%) | | | 76.1 | | 74.0 |
| Actual survival rate (%) | | | 85.1 | | 79.2 |

Based on the calculated predicted survival rates and actual survival rates found on both farms, it becomes apparent that there are two factors, which control a lamb survival response from an increase in birthweight (independently of any other effect) and additionally, whether that response is a positive or negative one. First; for a positive survival response, the average birthweight of lambs born to the unshorn dams needs to be within a survival range below optimum, and secondly; the birthweight response needs to be large enough to move at least a significant proportion of these otherwise lightweight lambs into a higher survival rate range. This is supported by Morris *et al.* (1999) who illustrated (Table 6.5) that a 0.5 kg increase in birthweight in a twin-bearing flock with an average birthweight of approximately 3.7 kg will increase survival rates by 4 % (77.4 to 81.5 %).

On the other hand a substantial increase in lamb birthweight (i.e. 0.5 kg), of lambs otherwise destined to be born of relatively high birthweight (i.e. above 5.0 kg) can actually result in a decrease in lamb survival rates. However, Figure 3.1 illustrates that under conditions in which lambs born to unshorn ewes are destined to be of high birthweight, mid-pregnancy shearing will either not increase lamb birthweight or have a minimal effect and therefore should not have a large effect on survival rates to weaning.

**Table 6.5.** Actual survival of multiple-born lambs by birthweight range and predicted survival rate if birthweights are increased by 0.5 kg due to pregnancy shearing (adapted from Morris *et al.* 1999).

| Actual BW range (kg) | No. born | Survival (%) | Actual survival | New distribution if a 0.5kg increase | Predicted survival |
|---|---|---|---|---|---|
| <2.0 | 49 | 22.4 | 11 | - | - |
| 2.0-2.5 | 162 | 53.1 | 86 | 49 | 26 |
| 2.5-3.0 | 325 | 71.4 | 232 | 162 | 116 |
| 3.0-3.5 | 674 | 78.0 | 526 | 325 | 253 |
| 3.5-4.0 | 709 | 81.8 | 580 | 674 | 551 |
| 4.0-4.5 | 460 | 85.7 | 394 | 709 | 608 |
| 4.5-5.0 | 194 | 82.5 | 160 | 460 | 379 |
| ≥5.0 | 57 | 84.2 | 48 | 251 | 211 |
| Totals | 2630 | | 2037 | 2630 | 2144 |
| Survival (%) | | | 77.4 | | 81.5 |

**The possible impact of using the mid-pregnancy shearing on New Zealand sheep farms**

If New Zealand sheep farmers are to employ mid-pregnancy shearing as a technique to increase lamb birthweights and possibly survival rates to weaning, there are some additional consequences and implications, which need to be considered. In contrast to popular perception, mid-pregnancy shearing does not necessarily result in an increase in feed intake. Additionally, any increase in dam intake that does occur, is not responsible for the enhanced birthweights observed. Any policy that substantially increases feed demand during that period of year in which pasture growth is at its minimum (winter) can have detrimental effects on feed availability and therefore, reduces the viability of that technique. On those occasions in which an increase in dam intake has been found it has been relatively intermittent and minor (up to a maximum of 12 %) indicating that the mid-pregnancy shearing should not significantly affect feed demand (especially when a cover comb is used).

Mid-pregnancy shearing of Romney ewes was found to increase annual dam wool production (by 0.2 kg) in the large-scale commercial studies when a twice-yearly shearing policy was used. However, this relationship was not observed in either Chapter 2, 3 or 5 although, others have reported that twice yearly shearing increases annual fleece weight in comparison to a once yearly policy (Livingston and Parker 1984). Utilisation of the mid-pregnancy shearing technique would require a twice-yearly shearing policy on most New Zealand crossbred farms (i.e. Romney, Perendale and Coopworth breed types) due to relatively longer staple lengths over the summer period (if ewes are not shorn twice yearly) resulting in poorer wool colour (i.e. an increase in yellowing), increased levels of cotting and higher rates of fly strike. Any increase in wool production from a twice yearl y shearing should reduce some of the additional costs. Furthermore, twice yearly shearing improves both wool colour and fibre soundness, both of which should increase wool value on a per kilo basis (as long as staple lengths are not below 80mm). However there are some breeds (e.g. down types and Merino) in which a twice yearly shearing would result in a very short staple length (below 70 mm). For these wool types a once yearly shearing policy is advocated. Similarly, in southern parts of New Zealand where humidity is not a problem, a once yearly shearing policy could be used in some crossbred flocks. On these properties changing the timing of shearing to mid-pregnancy (rather than post weaning) should increase returns from wool without increasing shearing costs (Parker and Gray 1989; Parker 1992; Parker *et al.* 1995).

It was observed at Riverside, that twin lambs born to shorn ewes were heavier at weaning than their counterparts born to unshorn ewes. In contrast, this relationship was not observed at either Tuapaka, or in Chapters 2, 3 and 5. However, Morris *et al.* (1999) reported a heavier average weaning weight, in twin lambs born to pregnancy-shorn ewes. Any increase in lamb weaning weights should improve farmer returns for lambs either sold either directly for slaughter or store. Heavier weaning weights should also improve the weights of replacement animals and thus their performance. At Riverside, herbage masses, ewe liveweights and condition were all greater than those observed at Tuapaka. This may indicate that a mid-pregnancy shearing effect on lamb weaning weight will only occur under favourable conditions.

**What is the financial effect?**

If farmers are to adopt a new management technique it must have the potential to either increase farm profitability, save labour or meet some other personal aspiration. The potential financial effect of a mid-pregnancy shearing policy on a per 1000 ewe basis, can be calculated for both the Riverside and Tuapaka farms.

Assumptions:

1. Use of the mid-pregnancy shearing technique will require a twice yearly shearing policy
2. Shearing at mid-pregnancy reduces the need to crutch pre-lambing
3. Wool quality is not affected (colour, strength or length)
4. Mid-pregnancy shearing has no effect on ewe death rates (either losses post shearing or through reduced castings)

<u>Scenario one:</u> Riverside

At Riverside lambs born to mid-pregnancy shorn ewes had a 2% higher survival rate (although not significant) with an overall weaning percentage of approximately

135%. Lambs were on average 1.2 kg heavier at weaning (with a store value of $1.80/kg liveweight (which was the actual price paid for these lambs)). Mid-pregnancy shorn ewes produced an extra 0.2 kg fleece weight (at $3.11/kg, MWES 2000b). It costs $2.00 to shear a ewe and $0.60 for a full crutch pre-lambing (Burtt 2000).

| | |
|---|---|
| Costs: | |
| 1000 ewes @ $2.00 (an additional shearing) | -$2,000 |
| Returns: | |
| 1000 ewes @ $0.60 (as there is no need for a pre-lamb crutch) | + $600 |
| 1000 ewes @ 200 g extra wool @ $3.11/kg | + $622 |
| 1350 lambs @ 1.2 kg @ $1.80/kg | +$2916 |
| 28 lambs (2% higher survival) extra lambs @ 29 kg @ $1.80/kg | +$1462 |
| Margin | +$3600 |

Scenario two: Tuapaka

At Tuapaka there was no lamb survival response and no weaning weight effect. Shorn ewes produced an extra 0.2 kg fleece.

| | |
|---|---|
| Costs: | |
| 1000 ewes @ $2.00 (an additional shearing) | -$2,000 |
| Returns: | |
| 1000 ewes @ $0.60 (as there is no need for a pre-lamb crutch) | + $ 600 |
| 1000 ewes @ 200 g extra wool @ $3.11 | + $ 622 |
| Margin | - $ 778 |

These two scenarios show that when lamb survival rates to weaning are not affected (i.e. Tuapaka) by mid-pregnancy shearing (a worst case scenario) this technique will cost the sheep farmer approximately $0.78 per ewe. However, even a relatively small increase in lamb survival (i.e. 2%), in addition to an increase in lamb weaning weights from mid-pregnancy can result in a profitable return to the farmer ($ 3.60 per ewe). If at Riverside, a weaning weight response had not occurred and there was only a 2% survival response, there would still have been a positive $0.68 per ewe margin from mid-pregnancy shearing. Furthermore in situations where a once yearly shearing policy is utilised (resulting in no additional costs) a failure to achieve a survival response will not incur an additional cost to the farmer. It should also be remembered that farmers do not choose shearing policies for profit reasons only. Other reasons include: cash flow, pattern of pasture growth, climatic considerations, labour requirements and wool quality (Livingston and Parker 1984).

**Should New Zealand farmers routinely use mid-pregnancy shearing?**

The present studies demonstrate that not all ewes will respond to the mid-pregnancy shearing technique. Additionally, any increase in lamb survival rates to weaning based solely on an increase in lamb birthweight, will only occur if lambs are otherwise destined to be born in a birthweight range below optimum, and if the magnitude of the birthweight response is large enough to move a significant proportion of these lambs into a higher survival rate range. Therefore the question that needs to be asked is, should all New Zealand farmers routinely use the mid-pregnancy shearing technique? On those farms in which a winter, once yearly shearing policy is currently used a change to the mid-pregnancy shearing technique is advocated (e.g. for Merinos and for crossbred farms were humidity is not a problem over the summer period). Changing the timing of the current shearing policy to match the mid-pregnancy period (rather than the often-used late pregnancy period) has the possible advantage of increasing both lamb birthweight and survival rates without the disadvantage of incurring additional costs.

Shearing twice yearly would result in one of two management options, firstly, shearing pre-wean/pre-tup or secondly, post-wean/post tup (Livingston and Parker 1984). Shearing post-weaning and post-tupping best matches the mid-pregnancy shearing policy. On farms in which a twice-yearly shearing policy is required if mid-pregnancy shearing is to be utilised, returns need to be greater than additional costs incurred. Therefore the chance of achieving a positive response (in terms of lamb survival) needs to be greater than the likelihood of getting a nil response (which still incurs a cost). Multiple bearing ewes are more likely to give birth to lambs of relatively low birthweight than single bearing ewes. Additionally, multiple-born lambs are more likely to be born in a birthweight range below their optimal survival rate, than their singleton-born counterparts. Consequently, an increase in birthweight is more likely to increase survival rates in multiple-born lambs than singletons. As a result the chance of a mid-pregnancy shearing policy having a positive effect on lamb birthweight and survival is greater in multiple-born lambs. Therefore, the mid-pregnancy shearing policy is advocated for use in high fecundity flocks, but not for flocks with low lambing percentages (e.g. near or below 100%). However, this does not preclude a proportion of ewes within a relatively low lambing percentage flock from being mid-pregnancy shorn (i.e. multiple-bearing ewes). Utilisation of pregnancy scanning can enable multiple bearing ewes to be identified and mid-pregnancy shorn, while single bearing ewes are left unshorn (thus reducing costs). However, if a once yearly mid-pregnancy shearing policy is to be utilised all ewes can be shorn regardless of pregnancy rank without increasing costs. Once yearly pre-lamb shearing in comparison to shearing with lambs at foot or post lambing decreases shearing costs and should increase wool returns (Parker and Gray 1989; Parker 1992; Parker *et al.* 1995). Therefore, achievement of a positive financial return is not dependent on a lamb survival response to mid-pregnancy shearing.

**How should the mid-pregnancy shearing technique be managed on New Zealand sheep farms?**

The mating period does not need to be altered by utilising a mid-pregnancy shearing policy. The eighteenth day after ram introduction should be nominally called day 1 (P1). Approximately 70 days (P70) after P1 ewes should be mid-pregnancy shorn using a cover comb and provided with shelter and an adequate level of nutrition (and if required they may need to be held overnight in the woolshed if adverse weather conditions occur). If it is assumed that a 2 cycle mating period is used, foetuses will range in age from 53 to 87 days at P70. If the mating period is greater than 2 cycles (e.g. 2.5 cycles) then the foetuses will range in age from 44 to 87 days at P70. A birthweight response to mid-pregnancy shearing has been observed in the P50 to P100-day range. In situations in which only twin-bearing ewes are to be mid-pregnancy shorn, pregnancy scanning needs to be undertaken prior to mid-pregnancy shearing. However, scanning can only accurately detect foetuses older than 45 days, thus mid-pregnancy shearing may need to occur slightly later if scanning is to be undertaken. Shearing later than P100 may increase the risk of ewe losses due to pregnancy toxaemia and may reduce any potential birthweight response.

**Areas requiring further study**

A series of studies have now been undertaken to evaluate the mid-pregnancy shearing technique. The results of the present studies combined with those of previous studies indicate the conditions in which a birthweight response will or will not occur, and whether any increase in birthweight is likely to increase lamb survival rates to weaning. Other possible production responses have also been identified. Therefore further research on similar lines is not required. In southern, and more exposed parts of New Zealand shearing ewes during the winter period requires the use of either blade shears or the lifter comb. Pregnancy shearing studies have shown that a birthweight response can occur with either the standard or cover comb under North Island winter conditions. However, no studies have evaluated the response when either the blade shears or lifter combs are used. Even though these ewes would have more insulation (in comparison to those shorn with cover comb), they are exposed to cooler conditions than those in the North Island. Therefore it is unclear whether a birthweight response will be observed. Shearing ewes in these southern parts of New Zealand with either the standard or the cover comb may possibly result in large ewe losses.

It was hypothesised that an elevation in maternal thyroid hormone concentrations post shearing was the mechanism responsible for the birthweight response. However, manipulation of maternal thyroid hormone status, failed to produce a birthweight response. When the birthweights of lambs born in that study were examined, it became apparent that a birth weight response to mid-pregnancy shearing would not be expected. Therefore to successfully determine whether elevation in maternal thyroid hormone concentrations are responsible for the birthweight effect, conditions must be present that would otherwise result in a birthweight response to mid-pregnancy shearing. Consequently, this study needs to be repeated under conditions in which a birthweight response is expected (using ewes in either slightly poorer condition and/or ewes offered a level of nutrition slightly below optimal) and with a longer period of T4 elevation. This would allow the hypothesis developed to be successfully tested.

**Conclusion**

Mid-pregnancy shearing has been shown to be a technique that can increase lamb birthweights. The birthweight response from mid-pregnancy shearing has been found not to be due to either an increase in dam intake or gestation length. However, it has not been successfully concluded whether the mechanism responsible for the birthweight effect is an elevation in maternal thyroid hormone concentration post mid-pregnancy shearing. To achieve a birthweight response from mid-pregnancy shearing the ewe must meet two criterion, first; she must have the potential to respond (i.e. be destined to give birth to an otherwise lightweight lamb(s)) and secondly; she must have the means to respond (i.e. an adequate level of nutrition and/or condition). Mid-pregnancy shearing has not been found to have any effect on the newborn lamb's thermoregulatory capability. In the large-scale studies mid-pregnancy shearing failed to have any statistically significant effect on the overall lamb survival rates to weaning. For a birthweight response to positively affect survival rates (and thus returns), lambs must be otherwise destined to be born within a birthweight range in which survival rates are below optimal and any increase in birthweight observed, must be large enough to move a large proportion of these lambs to a higher survival rate range. The mid-pregnancy shearing technique is best suited for highly fecund flocks or in lower fecundity flocks where single and multiple bearing ewes can be managed separately.

# References

Adalsteinsson S (1972) Experiments on winter shearing of sheep in Iceland. *Acta Agriculturae Scandinavica* **22**, 93 – 96.

Alexander G, Lynch JJ (1976) Phalaris windbreaks for shorn and fleeced lambing ewes. *Proceedings of the Australian Society of Animal Production* **11**, 161 – 164.

Alexander G, Lynch JJ, Mottershead BE, Donnelly JB (1980) Reduction in lamb mortality by means of grass wind breaks: Results of a five year study. *Proceedings of the Australian Society of Animal Production* **13**, 329 – 323.

Alexander G, McCance I (1958) Temperature regulation in the new-born lamb. I: Changes in rectal temperature within the first six hours of life. *Australian Journal of Agricultural Research* **9**, 339 – 347.

Alexander G, Williams D (1971) Heat stress and development of the conceptus in domestic sheep. *Journal of Agricultural Science* **76**, 53 - 72.

Anderson GM, Barrell GK (1998) Effects of thyroidectomy and thyroxine replacement on seasonal reproduction in the red deer hind. *Journal of Reproduction and Fertility* **113**, 239 – 250.

Aulie A, Astrup HN, Nedkvitine JJ, Velle W (1971) Serum Non-esterfied fatty acids and plasma glycerol as indicators of fat mobilisation in pregnant sheep subjected to cold stress. *Acta Veterinarina. Scandinavica* **12**, 496 – 503.

Austin AR, Young NE (1977) The effects of shearing pregnant ewes on lamb birth weights. *Veterinary Record* **100**, 527 – 529.

Bell AW, McBride BW, Slepetis R, Early RJ, Currie WB (1989) Chronic heat stress and pernatal development in sheep: I. Conceptus growth and maternal plasma hormones and metabolites. *Journal of Animal Science* **67**, 3289 – 3299.

Black HJ, Chestnutt DMB (1990) Influence of shearing and grass silage quality on the performance of pregnant sheep. *Animal Production* **51**, 573 – 582.

Brown DE, Harrison PC, Hinds FC, Lewis JA, Wallace MH (1977) Heat stress on foetal development during late gestation in the ewe. *Journal of Animal Science* **44(3)**, 442 – 446.

Burtt ES (Ed) (2000) Lincoln University financial budget manual. (Farm management group. Lincoln University, New Zealand).

Cabello G, Levieux D (1981) Hormonal status in the newborn lamb (Cortisol, T3,T4). Relationships to birthweight and length of gestation: Effect of litter size. *Biology of the Neonate* **39**, 208 – 216.

Cartwright GA, Thwaites CJ (1976) Foetal stunting in sheep. I: The influence of maternal nutrition and high ambient temperature on the growth and proportions of merino foetuses. *Journal of Agricultural Science* **86**, 573 – 580.

Champion SC, Robards GE (1995) The relationship between wool production, liveweight and liveweight change in four specialty carpet wool breeds, Romneys and Merinos. *Proceedings of the New Zealand Society of Animal Production* **55**, 137 – 140.

Clarke L, Darby CJ, Lomax MA, Symonds ME (1994) Effects of ambient temperature during 1st day of life on thermoregulation in lambs delivered by cesarean section. *Journal of Applied Physiology* **76(4)**, 1481 – 1488.

Cloete SWP, van Niekerk FE, van der Merwe GD (1994) The effect of shearing pregnant ewes prior to a winter lambing season on ewe and lamb performance in the southern cape. *South African Journal of Animal Science* **24** (4), 140 – 142.

Cooper K, Morris ST, McCutcheon SN (1998) Effect of maternal nutrition during early and mid-gestation on fetal growth. *Proceedings of the New Zealand Society of Animal Production* **58**, 175-177.

Dabiri N, Holmes C, McCutcheon SN, Parker W, Morris ST (1995a) Resistance to cold stress in sheep shorn by cover comb or standard comb. *Animal Science* **60**, 451 – 456.

Dabiri N, Morris ST, Parker WJ, McCutcheon SN, Wickham GA (1995b) Productivity and cold resistance in ewes pre-lamb shorn by standard or cover comb. *Australian Journal of Agricultural Research* **46**, 721 – 732.

Dabiri N, Morris ST, Vallentine M, Parker WJ, McCutcheon SN, Wickham GA (1996) Effects of pre-lamb shearing on feed intake and associated productivity of May- and August-lambing ewes. *New Zealand Journal of Agricultural Research* **39**, 53 – 62.

Dabiri N, Parker WJ, Morris ST, McCutcheon SN (1994) Effects of pre-lamb and conventional full-wool shearing on the productivity of ewes. *Proceedings of the New Zealand Society of Animal Production* **54**, 223 – 226.

Dalton DC, Knight TW, Johnson DL (1980) Lamb survival in sheep breeds on New Zealand hill country. *New Zealand Journal of Agricultural Research* **23**, 167 – 173.

Dick JL, Sumner RMW (1997) Seasonal changes in fibre and follicle characteristics related to wool bulk in Perendale ewes. *Proceedings of the New Zealand Society of Animal Production* **57**, 61 – 64.

Duff XJ (1981) An investigation of perinatal lamb mortality in a flock of Romney ewes in the Wairarapa district of New Zealand. Riverside Farm, Publication No 4, Massey University. Pp 67.

Eales FA, Gilmour JS, Barlow RM, Small J (1982) Causes of hypothermia in 89 lambs. *Veterinary Record* **110**, 118 – 120.

Egan EO, Notman AB, Hill J (1997) Effect of partial replacement of barely with molassed sugar beet feed in concentrate given and winter shearing on the performance of pregnant ewes and survival of new-born lambs. *Proceedings of the British Society of Animal Science.* 181.

Elvidge DG, Coop IE (1974) Effect of shearing on feed requirements of sheep. *New Zealand Journal of Experimental Agriculture* **2**, 397 – 402.

Everitt GC (1961) Research findings. *Proceedings of the Ruakura Farmers Conference,* 57 – 63.

Frengley GAG (1964) Out of season shearing with reference to farm management. *Proceedings of the 14th Lincoln collage farmers Conference.* 50 – 56.

Fogarty NM, Hall DG, Holst PJ (1992) The effect of nutrition in mid-pregnancy and ewe live weight change on birth weight and management for lamb survival in highly fecund ewes. *Australian Journal of Experimental Agriculture* **32**, 1 – 10.

Forbes JM (1968) The physical relationships of the abdominal organs in the pregnant ewe. *Journal of Agricultural Science* **70**, 171 – 177.

Geenty KG (Ed) (1997) 'A guide to improved lambing percentage.' (Dinniss and Associates: Waikanae, New Zealand)

Genuth, SM (1993) The thyroid gland. In 'Physiology, 3rd Edition'. (Eds Berne RM, Levy MN) pp 932 - 966. (Mosby Year Book, Inc: U.S.A)

Geytenbeek PE (1962) A survey of post-shearing losses. *Proceedings of the Australian Society of Animal Production* **4**, 185 – 186.

Greco D, Stabenfeldt GH (1997) Endocrine glands and their function. In 'Textbook of Veterinary Physiology, 2nd Edition'. Cunningham JG (Ed). (W.B. Sauders Company: U.S.A.) pp 385 – 417.

Glanville JRD, Phillips CJC (1986) The effect of winter shearing welsh mountain ewes in the hill environment. *Animal Production* **42**, 455.

Gregory NG (1995) The role of shelterbelts in protecting livestock: A review. *New Zealand Journal of Agricultural Research* **38**, 423 – 450.

Guyton AC (Ed) (1991) 'Textbook of Medical Physiology, 8th Edition' (W. B. Saunders Company: Philadelphia, USA)

Hawker H, LittleJohn RP (1989) Relationships between staple strength and other wool characteristics of Romney ewes. *New Zealand Journal of Agricultural Research* **32**, 305 – 310.

Herdt T (1997) Gastrointestinal physiology and metabolism In 'Textbook of Veterinary Physiology, 2nd Edition'. Cunningham JG (Ed). (W.B. Sauders Company: U.S.A.). pp 263 – 384.

Hight GK, Jury KE (1970) Hill country sheep production. II: Lamb mortality and birth weights in Romney and Border Leicester X Romney flocks. *New Zealand Journal of Agricultural Research* **13**, 735 – 752.

Hopkins PS, Nolan CJ, Pepper PM (1980) The effects of heat stress on the development of the foetal lamb. *Australian Journal of Agricultural Research* **31**, 763 – 771.

Hopkins PS, Thorburn GD (1972) The effects of feotal thyroidectomy on the development of the ovine foetus. *Journal of Endocrinology* **54**, 55 – 66.

Husain M, Morris ST, McCutcheon SN, Parker WJ (1997) Pasture management to minimise the detrimental effects of pre-lamb shearing. *New Zealand Journal of Agricultural Research* **40**, 489 – 496.

Jefferies BC (1961) Body Condition Scoring and its use in Management. *Tasmanian Journal of Agriculture* **32**, 19-21.

Jopson NB, Davis GH (2000) Nutrition and lamb survival. Final report for WoolPro, Palmerston, North New Zealand (97AR37).

Kaneko JJ (1997) Thyroid function. In 'Clinical Biochemistry of Domestic Animals 5th Edition'. (Eds Kaneko JJ, Harvey JW, Bruss M) pp 571 – 588. (Academic Press, USA)

Kirk JA, Cooper RA, Chapman A (1984) Effect of shearing housed pregnant ewes on their plasma levels, lamb birth weight and lamb growth rate to 56 days. *Animal Production* **38**, 524.

Kneale WA, Bastiman B (1977) In wintering of ewes: Part V. The effect of shearing at housing. *Experimental Husbandry* **32**, 70 – 74.

Knight TW, Lynch PR, Hall DRH, Hockey HUP (1988) Identification of factors contributing to the improved lamb survival in Marshall Romney sheep. *New Zealand Journal of Agricultural Research* **31**, 259 – 271.

Livingston PJ, Parker WJ (1984) Comparing shearing policies. *Riverside farm publication No 10,* Massey University, New Zealand.

Lodge GA, Heaney DP (1975) Influence of feed allowance during pregnancy on reproductive performance of ewes and growth of suckled and artificially reared lambs. *Canadian Journal of Animal Science* **55**, 533 – 544.

Lynch JJ, Alexander G (1976) The effects of gramineous windbreaks on behaviour and lamb mortality among shorn and unshorn Merino sheep during lambing. *Applied Animal Ethology* **2**, 305 – 325.

McCorkindale AB (1999) CF2000 – a new way of looking at the same information. *Proceedings of the New Zealand Society of Animal Production* **59**, 79 – 81.

McCutcheon SN, Holmes CW, McDonald MF (1981) The starvation-exposure syndrome and neonatal lamb mortality: A review. *Proceedings of the New Zealand Society of Animal Production* **41**, 209 – 217.

McCutcheon SN, Holmes CW, McDonald MF, Rae AL (1983) Resistance to cold stress in the new-born lamb. 1: Responses of Romney, Drysdale x Romney, and Merino lambs to components of the thermal environment. *New Zealand Journal of Agricultural Research* **26**, 169 – 174.

McCutcheon SN, McDonald MF, Wickham GA (Eds) (1986) 'Sheep production: Volume two - Feeding, Growth and Health.' p 94. (New Zealand Institute of Agricultural Science, Wellington).

Maund BA (1980) Shearing ewes at housing. *Animal Production* **30**, 481.

Mellor DJ (1983) Nutritional and placental determinants of foetal growth rate in sheep and consequences for the newborn lamb. *British Veterinary Journal* **139**, 307 – 324.

Minitab (1998) Minitab version 12.1. Minitab Inc.

Morgan H, Broadbent JS (1980) A study of the effects of shearing pregnant ewes at housing. *Animal Production* **30**, 476.

Morris ST, Kenyon PR, Burnham DL, McCutcheon SN (1999) The influence of pre-lamb shearing on lamb birthweight and survival. *Proceedings of the New Zealand Grasslands Associatio*n **61**, 95 – 98.

Morris ST, McCutcheon SN (1997) Selective enhancement of growth in twin foetuses by shearing ewes in early gestation. *Animal Science* **65**, 105 – 110.

Morris ST, McCutcheon SN, Revell DR (2000) Birth weight responses to shearing ewes in early to mid gestation. *Animal Science* **70**, 363-369.

Morris ST, Parker WJ, Blair HT, McCutcheon SN (1993) Effect of sward height during late pregnancy on the intake performance of continuously stocked June- and August- lambing ewes. *Australian Journal of Agricultural Research* **44**, 1635 – 1651.

Murry BF, Crosby TF (1986) Mid-term shearing, gestation and lamb performance. *University Collage, Dublin, Research Report:* 75 – 76.

MWES (2000a) Annual Review of the New Zealand Sheep and Beef industry 1999-2000. Meat and Wool Economic Service of New Zealand. Publication No **G2166**, 1 - 48.

MWES (2000b) Meat and Wool Sector – mid-season update 2000-01. Meat and Wool Economic Service of New Zealand. Publication No **G2177**, 1 - 54.

Nathanielsz PZ, Comline RS, Silver M, Thomas AL (1973) Thyroid function in the foetal lamb during the last third of gestation. *Journal of Endocrinology* **58(3)**, 535 – 546.

Nedkvitine JJ (1972) Effect of shearing before and after lambing. *Acta Agriculturae Scandinavia* **21**, 97 – 102.

Nedkvitine JJ, Astrup H, Velle W (1971) Unpublished.

Nicol AM (Ed) (1987) 'Livestock Feeding on Pasture.' Pp 40 – 44. (New Zealand Society of Animal Production: Hamilton, New Zealand)

Oliver JE, Fairbridge RW (Eds) (1987) The Encyclopedia of Climatology, Encyclopedia of Earth Sciences Series, Vol. 6. pp. 928 – 929. (van Nostrand Reinhold company: New York, USA)

Orleans-Pobee J, Beatson PR (1989) Effects of nutrition and shearing during pregnancy on birth weight in highly fecund Booroola-cross sheep. *Proceedings of the New Zealand Society of Animal production* **49**, 285 – 290.

Parker WJ (1992) Managing a pre-lamb shearing policy. *Proceedings of the Central Districts sheep and beef farmers conference*, 65 – 69.

Parker WJ, McCutcheon SN, Carr DH (1989) Effect of herbage type and level of intake on the release of chromic oxide from intraruminal controlled release capsules in sheep. *New Zealand Journal of Agricultural Research* **32**, 537-546.

Parker WJ, Gray DI (1989) The effect of alternative ewe shearing policies on sheep performance, cashflow and profit. *Wool* **12**, 16 – 19.

Parker WJ, Morris ST, McCutcheon SN (1991) Wool production and feed intake in unmated and mated Border Leicester X Romney crossbred ewes shorn in July or November. *New Zealand Journal of Agricultural Research* **34**, 427 – 437.

Parker WJ, Dabiri N, Morris ST, McCutcheon SN, Holmes CW (1994) Cover combs for winter – early spring shearing: a research update. *Proceedings of the Central Districts sheep and beef farmers conference*, 86 – 90.

Parker WJ, Dabiri N, Morris ST, McCutcheon SN, Holmes CW (1995) Cover combs improve the management of winter-early spring shearing of sheep. Massey University. 1 – 24.

Parkinson TJ (1997) Requirement for thyroid hormones in seasonal reproduction in sheep. Diploma for Fellowship of the Royal College of Veterinary Surgeons. United Kingdom (Thesis).

Phillips CJC, Fowler GB, Glanville JRD (1988) A note on the effects of winter shearing and pre and post natal environment on the performance of Welsh Mountain ewes. *Research and Development in Agriculture* **5**:2, 113 – 115.

Pierzchala K, Bobek S, Niezgada J, Ewy Z (1983) The effect of shearing on the concentration of coritsol and thyroid hormones in the blood plasma of sheep. *Zentralblatt Fur Veterinarmedizin Areihe A* **30**, 749 – 759.

Rattray PV, Garrett WN, East NE, Hinman N (1974) Growth, development and composition of the ovine conceptus and mammary gland during pregnancy. *Journal of Animal Science* **38**:3, 613 – 626.

Rattray PV, Trigg TE (1979) Minimal feeding of pregnant ewes. *Proceedings of the New Zealand Society of Animal production* **39**, 242 – 250.

Revell DK, Main SF, Brier BH, Cottam YH, Hennies H, McCutcheon SN (2000) Metabolic responses in sheep to mid-pregnancy shearing that are associated with a selective increase in the birth weight of twin lambs. *Domestic Animal Endocrinology* **18**, 409 – 422.

Revell DK, Morris ST, Cottam YH, Hanna JE, Thomas DG, Brown S, McCutcheon SN (2002). Shearing ewes at mid-pregnancy affects foetal growth and development. (*In press, Australian Journal of Agricultural Research Vol 53*).

Russel AJF, Armstrong RH, White IR (1985) Studies on the shearing of housed pregnant ewes. *Animal Production* **40**, 47 – 53.

Russel AJF, Doney JM, Reid RL (1967) The use of biochemical parameters in controlling nutritional state in pregnant ewes, and the effect of under-nourishment during pregnancy on lamb birth weight. *Journal of Agricultural Science* **68**, 351 – 358.

Rutter W, Laird TR, Broadbent PJ (1971) The effects of clipping pregnant ewes at housing and of feeding different basal roughages. *Animal Production* **13**, 329 – 336.

Rutter W, Laird TR, Broadbent PJ (1972) A note on the effects of clipping pregnant ewes at housing. *Animal Production* **14**, 127 – 130.

Salman AD, Owen E (1986) The effect of the time of winter shearing on the performance of pregnant ewes. Fourth Scientific Conference, Scientific Research Council, *Proceedings of Agricultural Research* **1,** 1746 – 1757.

SAS (1985) SAS Users Guide, Statistics, Version 5 edition. SAS Institute Inc. Cary, North Carolina, United States of America.

Scales GH, Burton RN, Moss RA (1986) Lamb mortality, birthweight and nutrition in late pregnancy. *New Zealand Journal of Agricultural Research* **29**, 75 – 82.

Sheath GW, Webby RW, Keeling P, Thompson RD, Page CR, Burton GT (1999) The results and success factors of nine group farm monitoring programmes. *Proceedings of the New Zealand Society of Animal Production* **59**, 87 – 90.

Shelton M (1964) Relationship of environmental temperature during gestation to birthweight and mortality of lambs. *Journal of Animal Science* **23**, 360 – 364.

Shelton M (1965) Effect of heat stress and thyroxine implants during gestation on lambing performance and wool production. *Journal of Animal Science* **24**, 288.

Shelton M, Huston JE (1968) Effects of high temperature stress during gestation on certain aspects of reproduction in the ewe. *Journal of Animal Science* **27**, 153 – 158.

Sherlock RG, Harris PM, Lee J, Wickham GA, Woods JL, McCutcheon SN (2001) Intake and long-term cysteine supplementation change wool characteristics of Romney sheep. *Australian Journal of Agricultural Research* **52**, 29 – 36.

Slator JS, Mellor DJ (1981) Within-day variations in the composition of maternal and fetal plasma from catheterised ewes fed once daily or at hourly intervals during late pregnancy. *Research in Veterinary Science* **31**, 224-230.

Smeaton DC, Webby RW, Tarbotton IS, Clayton JB (2000) The effects of shearing Finnish Landrace x Romney ewes in mid-pregnancy on lamb survival, birthweights and other weights. *Proceedings of the New Zealand Society of Animal production* **45**, 58 - 60.

Smith JF (1982) Principals of reproduction. 'In Sheep production: Volume one - Breeding and Reproduction'. (Eds Wickham GA, McDonald MF) p211 - 238 (New Zealand Institute of Agricultural Science: Wellington, New Zealand)

Spencer GSG, Robinson GM (1993) Stimulation of placental, fetal and neonatal growth by thyroxine administration to pregnant rats. *Journal of Endocrinology* **139**, 275-279.

Stott AW, Slee J (1985) The effect of environmental temperature during pregnancy on the thermoregulation in the newborn lamb. *Animal Production* **41**, 341 – 347.

Sumner RMW, Clarke JN, Pearson AJ, Speedy PM (1994) Repeatability of seasonal wool growth in Merino sheep. *Proceedings of the New Zealand Society of Animal Production* **54**, 163 – 165.

Sykes AR, Griffiths RG, Slee J (1976) Influence of breed, birthweight and weather on the body temperature of newborn lambs. *Animal Production* **22**, 395 – 402.

Symonds ME (1995) Pregnancy, parturition and neonatal development: interactions between nutrition and thyroid hormones. *Proceedings of the Nutrition Society* **54**, 329 – 343.

Symonds ME, Bird JA, Clarke L, Gate JJ, Lomax MA (1995) Nutrition, temperature and homeostasis during perinatal development: a review. *Experimental Physiology* **80**, 907 – 940.

Symonds ME, Bryant MJ, Clarke L, Darby CJ, Lomax MA (1992) Effect of maternal cold exposure on brown adipose tissue and thermogenesis of the newborn lamb. *Journal of Physiology* **455**, 487 – 502.

Symonds ME, Bryant MJ, Lomax MA (1986) The effect of shearing on the energy metabolism of the pregnant ewe. *British Journal of Nutrition* **56**, 635 – 643.

Symonds ME, Bryant MJ, Lomax MA (1989) Lipid metabolism in shorn and unshorn pregnant sheep. *British Journal of Nutrition* **62**, 35 – 49.

Symonds ME, Bryant MJ, Lomax MA (1990) Metabolic adaptation during lactation in winter-shorn sheep. *Journal of Agricultural Science* **114**, 201-205.

Thompson GE, Basset JM, Samson DE, Slee J (1982) The effects of cold exposure of pregnant sheep on foetal plasma nutrients, hormones and birth weight. *British Journal of Nutrition* **48**, 59 – 64.

Thompson GE, Goode JA (1981) Lactogenesis in ewes exposed to neutral and cold environmental temperatures during the last week of gestation. *Animal Production* **32**, 245 – 250.

Verkaik J (2001) Use of ear tags in sheep: a survey of properties and problems of use. *Praktijkonderzoek Veehouderij* **152**, 35pp.

Vipond JE, King ME, Inglis DM, Hunter EA (1987) The effect of winter shearing of housed pregnant ewes on food intake and animal performance. *Animal Production* **45**, 211 – 221.

Wodzicka-Tomaszewska M (1963a) The effect of shearing on sheep. *Proceedings of the Ruakura Farmers Conference,* 28 – 39.

Wodzicka-Tomaszewska M (1963b) The effect of shearing on the appetite of sheep. *New Zealand Journal of Agricultural Research* **6**, 440 – 447.

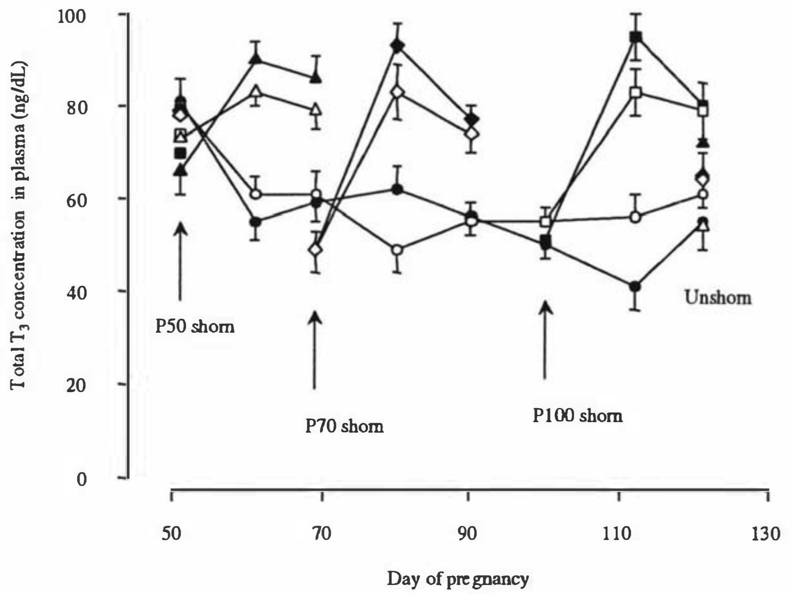
Yeates NTM (1958) Foetal dwarfism in sheep- an effect of high atmospheric temperature during gestation. *Journal of Agricultural Science* **51**, 84 – 89.

# Appendix

## Appendix 1: Artificial control of thyroid levels

*Introduction*

Morris *et al.* (2000) observed elevated maternal T3 concentrations for a period of at least 20 days after shearing ewes during pregnancy (Figure 1). Subsequently, singleton lambs born to these shorn ewes had greater birthweights than their counterparts born to unshorn ewes. The aim of Chapter 5, was to determine if elevated maternal thyroid hormone concentrations post pregnancy shearing were responsible for the birthweight response to mid-pregnancy shearing. Thus a technique was required to control thyroid hormone concentrations in the pregnant ewe. To achieve this, ewes had their thyroids removed (thyroidectomised) allowing for control of maternal thyroid hormone concentrations, via artificial means, without the possibility of a negative feedback effect.




**Appendix Figure 1**. From Morris *et al.* (2000). Effects of time of shearing (P50, triangels; P70, diamonds; P100 squares; and unshorn, circles) and pregnancy rank (single-bearing ewes, closed symbols; twin-bearing ewes, open symbols) on plasma triiodothyronine (T3) concentration.

Therefore, the aim of these preliminary studies was to develop techniques that could be used to firstly, maintain thyroid hormone concentrations at the levels found in the unshorn ewe and secondly, to produce the elevation in thyroid hormone concentrations observed in pregnancy shorn ewes for the short to medium term.

### *Study 1 - Development of a technique to control maternal thyroid hormone concentrations at a level seen in the unshorn ewe*

#### *Aim*

Morris *et al.* (2000) reported a fairly constant maternal T3 concentration in unshorn pregnant ewes. The aim of this study was to develop a procedure to maintain T3 and T4 concentrations in thyroidectomised ewes at a level seen in unshorn ewes.

A preliminary study looked at using 2ml minipumps (Alzet Osmotic Pumps, USA) (containing 50mg of T4) to control thyroid hormone concentrations in thyroidectomised ewes. However, these failed to raise T3 and T4 concentrations above basal levels in thyroidectomised ewes. A range of T4 implants (20, 25, 30 and 70mg, Glaxo, Middlesex, UK) used by Parkinson (1997) in sheep and by Anderson and Barrell (1998) in deer, were then sourced for testing.

#### *Method*

Three sham operated (non-thyroidectomised) ewes were used as controls. Additionally, 8 thyroidectomised ewes (see Chapter 5 for procedure) were randomly divided into four groups (n = 2) and implanted with differing T4 implants (Table 1), inserted subcutaneously under the skin of the right front leg. All groups were blood sampled weekly for differing periods of time (Table 1). Plasma was analysed for both T3 and T4 concentrations (see Chapter 5).

**Appendix Table 1.** Ewe treatment groups.

| | Thyroid status | T4 Implants | Blood sampling |
|---|---|---|---|
| Group | | | |
| 1 | Thyroidectomised | 20 mg | 9 weeks |
| 2 | Thyroidectomised | 30 mg | 12 weeks |
| 3 | Thyroidectomised | 70 mg | 12 weeks |
| 4 | Thyroidectomised | 2 X 25 mg | 6 weeks |
| 5 | Sham | None | 12 weeks |

*Data analysis*

The results shown are based on the averages from each ewe group. No standard errors are shown due to low numbers within each group.

*Results*

The average T4 concentrations of Group 5 (control ewes) ranged from 4 to 6 μg/dL during the 12-week period (Figure 2) and average T3 concentrations ranged from 100 to 180 ng/dL (Figure 2). The average T3 concentrations of Group 5 ewes (controls) were higher than that observed by Morris *et al.* (2000).

Average T4 concentrations of Group 3 (70 mg implant) were higher than those observed in Group 5 by 2 weeks after implant insertion and remained higher throughout the trial period (concentrations ranged from 4.8 to 12μg/dL). T3 concentrations of Group 3 rose after two weeks post implant insertion to be above that observed in Group 5 (145 ng/dL) by weeks 5 and 6 before falling over the next 5 weeks to concentrations similar to those observed pre-insertion (60ng/dL).

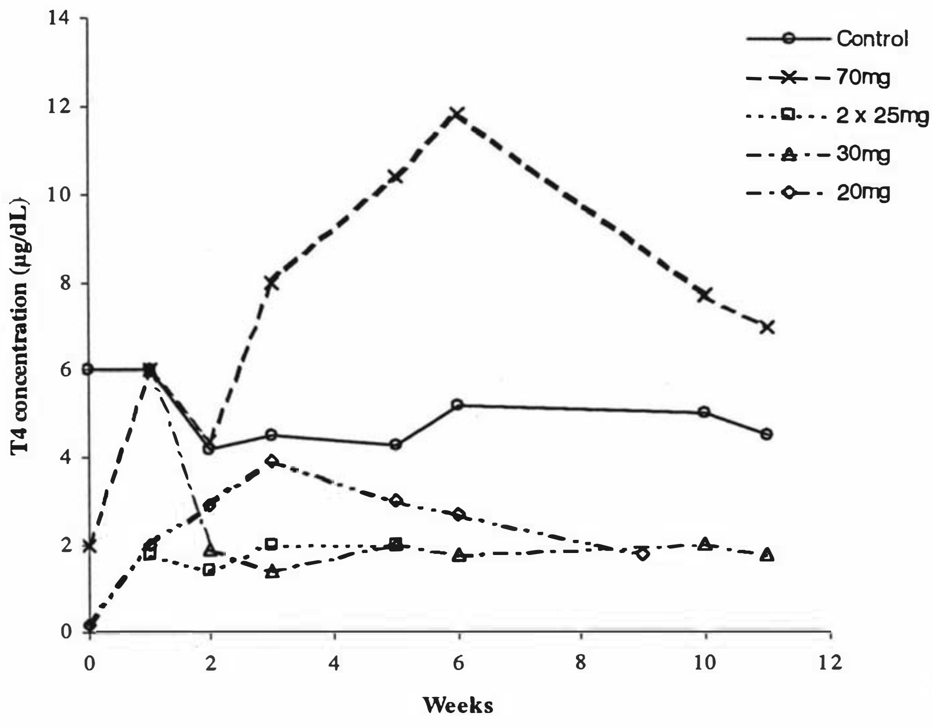
The T4 concentrations of both Group 1 (inserted with 20mg implant) and 2 (inserted with 30mg implant) remained lower than those recorded in Group 5 during the trial period (concentrations ranged from 1.4 to 4.0 μg/dL and 1.8 to 6 μg/dL respectively). Surprisingly, the T4 concentration of Group 1 ewes was often higher than that recorded in Group 2 ewes. T3 concentrations of both Groups 1 and 2 ranged from 35 to 70ng/dL and 70 to 80 ng/dL respectively during the measurement period.

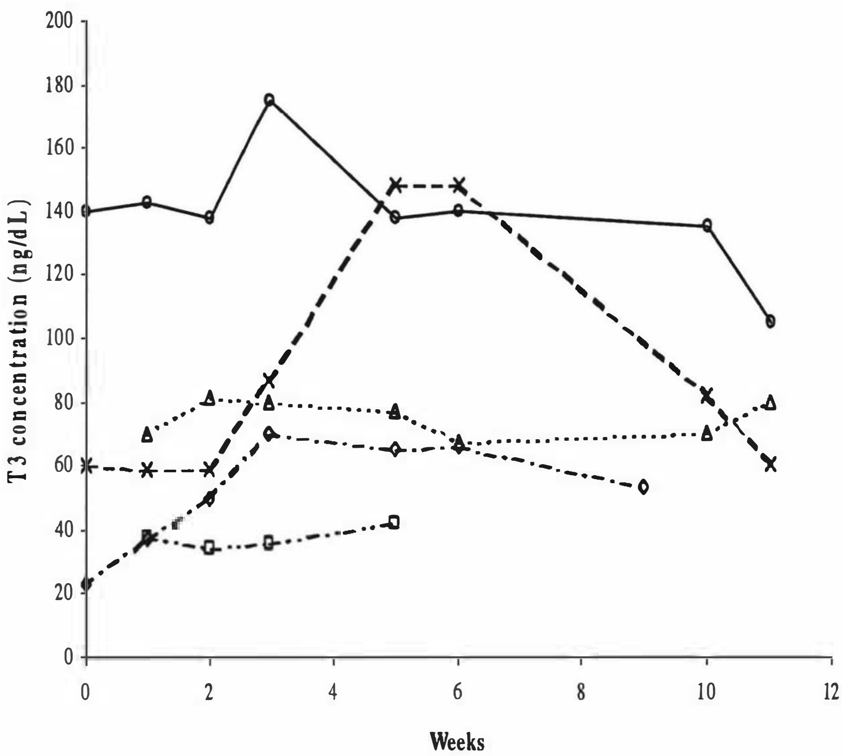
The average T4 concentration of Group 4 (inserted with two 25mg implants) remained lower than Group 5 and was often lower that that recorded in both Group 1 and 2 ewes. Similarly, T3 concentrations of Group 4 remained lower than all other groups (35-45 ng/dL) during the measurement period.

*Discussion/Conclusion*

The average T3 concentrations observed in Group 5 ewes (control) were higher that reported by Morris *et al.* (2000) in their unshorn ewes. The difference in T3 concentrations between Group 5 and Morris *et al.* (2000) ewes could be due to either; yearly variation, breed type differences or assay variation. Although our aim was to mirror the T3 profiles reported by Morris *et al.* (2000) it was decided to choose a T4 implant regimen that produced T3 and T4 concentrations similar to that seen in the control ewes (Group 5) of the present study which were from the same flock as those ewes to be used in Chapter 5.

Seventy-milligram implants (Group 3) gave T4 responses well above those observed in unshorn control ewes (Group 5) and were thus unsuitable. In contrast two 25mg implants (Group 4) resulted in T3 and T4 concentrations well below those observed in control ewes. Additionally, concentrations in this group were often below than seen in both Group 1 and 2 (20 and 30 mg each respectively). This may indicate that these implants were defective. T3 and T4 concentrations of both Group 1 and 2 ewes were approximately half that observed in control ewes. Based on this result it was decided to implant thyroidectomised ewes to be used in the Chapter 5 study with both a 20mg and a 30mg T4 implant to maintain thyroid hormone concentrations at a level observed in Group 5. Chapter 5 results show that this combination was successful.




**Appendix Figure 2.** The effect of differing T4 implants on maternal T4 (µg/dL) (upper graph) and T3 (ng/dL) (lower graph) concentrations.

*Study 2 - Development of a technique to elevate thyroid hormone concentrations in the short to medium time period*

*Aim*

Morris *et al.* (2000) (Figure 3) showed an elevation in maternal T3 concentration for at least 20 days post mid-pregnancy shearing. Therefore the aim was to develop a technique to elevate both T3 and T4 concentrations for at least 20 days in thyroidectomised ewes.

*Method*

To achieve this short-term elevation a series of injection regimens were tested on thyroidectomised ewes. Eight thyroidectomised ewes were randomly divided into 4 groups (n = 2) and given either 0.5 or 0.75mg injections of T4 daily or on every second day for up to 5 days (Table 2). All groups were blood sampled daily for differing periods of time (Table 2). Plasma was analysed for both T3 and T4 concentrations (see Chapter 5).

**Appendix Table 2**. Ewe treatment groups.

| | T4 dose (mg) | Injection days | Blood sampling days |
|---|---|---|---|
| Group | | | |
| 1 | 0.75 | 1 | 0,1,3,7 |
| 2 | 0.50 | 1,2,3 | 0,1,2,3,4,7 |
| 3 | 0.75 | 1,2,3,4,5 | 0,1,2,3,4,5,7,10,16 |
| 4 | 0.75 | 1,3,5 | 0,1,2,3,4,5,7,10,16 |

*Data analysis*

The results shown are based on the averages from each treatment.

*Results*

Group 1 (a single 0.75mg T4 injection) displayed elevated T4 concentrations (by 2-4 μg/dL, Figure 3.) above those observed pre-injection for at least 3 days. However, 7 days post injection, concentrations were similar to those found before injection.

Similarly T3 concentrations rose the day following injection (by 20 ng/dL) but fell to be similar to that found pre-injection by day 3 (Figure 3).

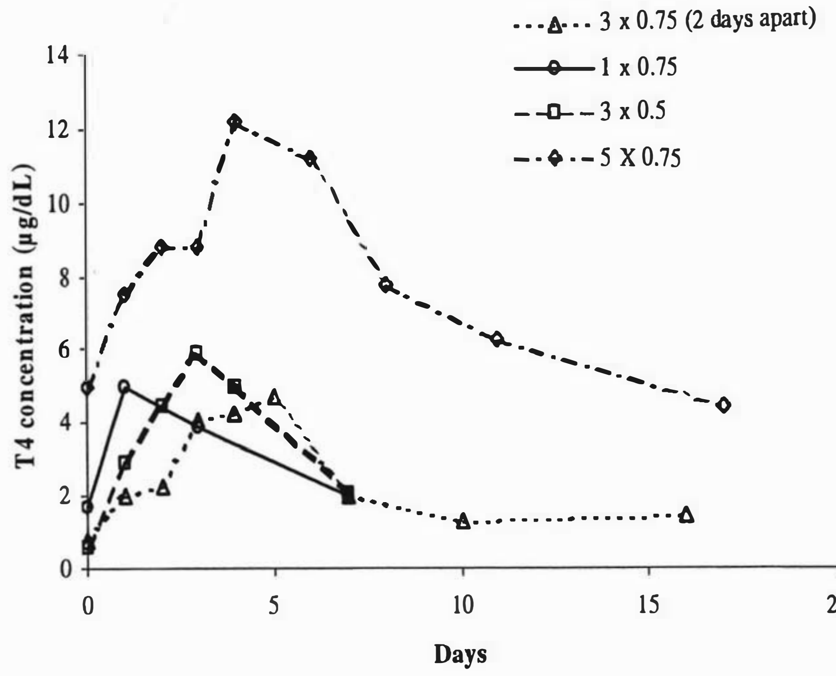
Group 2 (three 0.5mg T4 injections) had elevated T4 concentrations (by 5.0 μg/dL) at day 3. However, by day 7 these concentrations had dropped to be similar to that observed before the injection regimen. Similarly, T3 concentrations rose to be 20ng/dL higher by day 3, before declining.

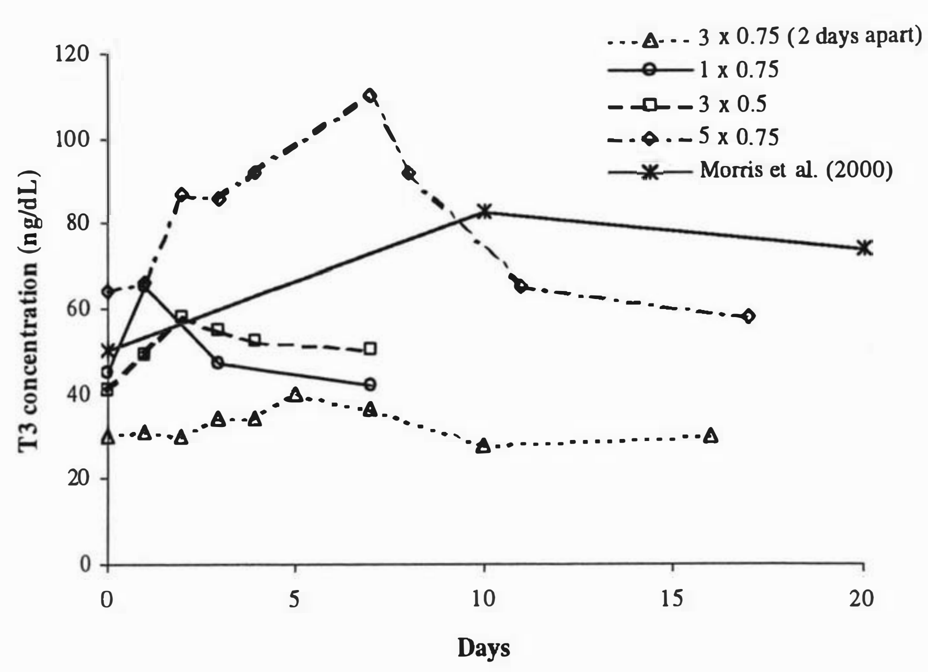
Group 3 (injected with 0.75mg of T4 daily over a five day period) T4 concentrations rose to a maximum of 7μg/dL higher than that recorded pre-treatment and remained higher for at least 5 after the last injection. Similarly, T3 concentrations rose by a maximum of 50ng/dL and remained higher for at least 2 days after the last injection.

Group 4 (injected every second day over a five-day period) displayed elevated T4 concentrations (by a maximum of 3μg/dL) for at least 5 days following the last injection. The T3 response in Group 4 was minimal (maximum increase of 10ng/dL) but concentrations did remain higher than pre-treatment concentrations for at least 2 days after the final injection.

*Discussion/Conclusion*

This study indicated that for a T4 injection regimen to be effective in increasing T3 concentrations by at least 40-50ng/dL (as reported by Morris *et al.* 2000), ewes must be injected daily over a period of at least 5 days with a dose rate of 0.75mg of T4. It was decided to inject thyroidectomised ewes in Chapter 5 daily with 0.75 mg of T4 for 10 days with the aim of achieving a 20-day elevation. The results of Chapter 5 show that this was successful in elevating both T3 and T4 concentrations for at least 10 to 14 days.




**Appendix Figure 3**. The effect of differing T4 injection regimens on maternal T4 (µg/dL) (upper graph) and T3 (ng/dL) (lower graph) concentrations. The results reported by Morris *et al.* (2000) are indicated by "Morris et al. 2000).

## Appendix 2: Autopsies of dead lambs at Tuapaka

### *Introduction*

Mid-pregnancy shearing was found to increase lamb birthweight in both Chapters 2 and 3. It was suggested that this increase in birthweight should improve lamb survivability. An increase in the birthweight of an otherwise lightweight lamb(s) should reduce losses due to starvation exposure. However, an increase in the birthweight an otherwise heavier lamb(s) may increase losses due to dystocia and negate any positive effects of reduced losses due to starvation exposure. Lambs found dead at Tuapaka in the Chapter 4 study were diagnosed as having died from starvation exposure, dystocia or other, based on the following autopsy sheet (Duff 1981). Autopsies were used in Chapter 4 to determine whether mid-pregnancy shearing reduces losses due to starvation-exposure and the effect of an increase in birthweight on losses due to dystocia.

### *Diagnosing cause of death*

Lambs considered to have died from 'dystocia' were those: which had not walked or had walked little; showed no evidence of umbilical thrombus; did not have fully inflated lungs; displayed oedema (fluid under skin) around head, neck and/or chest; had intact fat reserves around heart and kidneys; and/or showed bleeding from liver, brain and/or spinal cord.

Those considered to have died from 'starvation exposure' were those: which showed evidence of having walked; displayed the presence of an umbilical thrombus; had fully inflated lungs; showed moderate to marked depletion of fat reserves around heart and kidneys; and may have shown oedema in the skin of extremities (ears, legs and tail).

Lambs were diagnosed to have died from 'other' causes if they: displayed symptoms unrelated to those stated above (i.e. malformations, enteritis etc); did not clearly meet the criteria for being diagnosed as dying from either starvation exposure or dystocia; or if cause of death could not be determined.

*Autopsy sheet used at Tuapaka*

| | | | |
|---|---|---|---|
| **Farm Name:** | | **Date:** | |
| **Weight:** | | **Birth rank:** | |
| **Sex:** | | **Assisted Birth:** | |

**Please circle the appropriate box:**

| | | |
|---|---|---|
| **Feet** | Has not walked | Has walked |

**Oedema:**

| | | | |
|---|---|---|---|
| **Head** | None | Moderate | Severe |
| **Hind limbs** | None | Moderate | Severe |
| **Breech** | None | Moderate | Severe |

| | | | |
|---|---|---|---|
| **Forelimbs** | None | Moderate | Severe |
| **Tail** | None | Moderate | Severe |
| **Generalised** | None | Moderate | Severe |

| | | |
|---|---|---|
| **Umbilicus – Thrombus:** | Yes | No |
| **Abdominal cavity (B fat):** | Yes | No |

| | | |
|---|---|---|
| **Navel Infection:** | Yes | No |
| **Rib cage bruising:** | Yes | No |

**Liver:**

| | | |
|---|---|---|
| **Rupture and haemorrhage:** | Yes | No |

| | | |
|---|---|---|
| **Disease Foci** | Yes | No |

**State of Metabolic Fat depletion:**

| | | | |
|---|---|---|---|
| **Heart** | None | Moderate | Severe |

| | | | |
|---|---|---|---|
| **Kidneys** | None | Moderate | Severe |

| | | |
|---|---|---|
| **Enterotoxaemia** | Yes | No |

| | | | |
|---|---|---|---|
| **Lungs Inflation:** | Full | Partial | None |

**Gastrointestinal Tract Food:**

| | | |
|---|---|---|
| **Stomach** | Yes | No |
| **Meconium** | Yes | No |

| | | |
|---|---|---|
| **Small Intestine** | Yes | No |
| **Faeces:** | Yes | No |

**Diagnosis:**

| | | |
|---|---|---|
| **Dystocia** | **Starvation/Exposure** | **Other** |