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Management of maternal-offspring behavior to improve lamb survival in easy care sheep systems

J. M. Everett-Hincks and K. G. Dodds

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ABSTRACT: This paper examines the environmental and management factors affecting lamb survival on high-performing sheep farms in New Zealand. Improved lambing percentage is the biggest contributor to higher profits on New Zealand sheep farms. Many sheep breeders have selected and bred ewes for increased fecundity over the last 4 decades. The increased proportion of ewes having triplets is of concern to farmers and to industry because neonatal lamb mortality is highest in triplets. The majority of lamb deaths occur in the first 3 d after birth and range from 5 to 30% for individual sheep flocks. The ability of a lamb to survive to weaning is determined by genetics, behavior, physiology, and the environment, including on-farm management practices. We investigated the effects of dam body condition in pregnancy, weather during lambing, lamb birth weight, and maternal behavior on single, twin, and triplet lamb viability at birth, lamb death risks from dystocia, and starvation exposure and survival through to weaning for 20 industry flocks from 2003 to 2004 (15,821 lambs). Ewes with higher body condition scores in mid pregnancy had heavier lambs at birth ($P < 0.01$). Lambs weighing 5.5 to 6 kg at birth ($P < 0.01$) were more likely to be viable at birth and survive to weaning than heavier or lighter lambs. Weather conditions during late pregnancy ($P < 0.05$) proved more important than conditions during lambing ($P < 0.05$) in determining lamb viability and survival through to weaning. Older ewes and ewes with triplets require considerably more attention for farmers to realize their production potential. This information can help formulate appropriate management programs to improve lamb survival rates under easy care farming systems.

Key words: birth weight, body condition score, dystocia, heat loss, lamb survival, starvation exposure

INTRODUCTION

Improved lambing percentage is the biggest contributor to higher profits on New Zealand sheep farms. Many sheep breeders have selected and bred ewes for increased fecundity over the last 4 decades. Lamb survival is an important issue in highly fecund sheep flocks. The national mean lambing percentage from 2004 to 2006 was 125%, compared with 100% from 15 yr earlier (1990 to 1993; Anonymous, 2006). Davis et al. (1983) reported that as mean litter size increases above 1.7, the decline in single-bearing ewes is offset by an increase in triplet-bearing ewes. The increased proportion of ewes having triplets is of concern to farmers and to industry because lamb mortality is greatest in triplets (Everett-Hincks et al., 2005a,b; Kerslake et al., 2005) and twin- and triplet-born lambs have greater mortality rates than singles (Johnson et al., 1982; Hinch et al., 1983; Scales et al., 1986; Hall et al., 1988). Many studies report lower survival to weaning in lambs weighing less than 3 kg at birth (Hight and Jury, 1970; Dalton et al., 1980; Johnson et al., 1982; Nowak and Lindsay, 1992), but overall, the relationship between lambing rate and lamb survival in highly fecund ewes is poorly understood.

This paper provides an investigation into the environmental and management effects on lamb survival and mortality on high performing sheep farms in New Zealand. With this information appropriate animal management programs can be formulated to reduce lamb mortality rates.
Lamb survival to weaning LSWWT Lamb survival to weaning (approximately 100 d of age) based on a record for

...localized moderate to severe (study by Kerslake et al. (2005) characterized primary

...in the gastrointestinal tract), and other exposure (no brown adipose tissue on heart and kidneys...moderate to severe localized subcutaneous edema, organ ruptures, or hemorrhages) were given a score of 1. Lambs dying from risk factors other than a difficult birth were also given a score of 0, except that lambs with a death risk factor of starvation exposure were assigned as missing.

Starvation and exposure death risk factor LDSE All surviving lambs to 3 d of age were given a score of 0, whereas those that died between birth and 3 d of age from the starvation exposure complex (diagnosed based on the degree of brown adipose tissue depletion and lack of food in the gastrointestinal tract) were given a score of 1. Lambs dying from risk factors other than starvation and exposure complex were also given a score of 0.

Lamb survival to 3 d post birth LS3day Lamb survival to 3 d post birth based on days survived between date of birth and date of death. Lambs that survived to 3 d of age were given a score of 1, whereas those that did not were given a score of 0.

Lamb survival to weaning LSWWT Lamb survival to weaning (approximately 100 d of age) based on a record for weaning weight for the lamb; then the lamb was assumed to be alive and given a score of 0.

Table 1. Lamb traits recorded between birth and 3 d of age

<table>
<thead>
<tr>
<th>Lamb trait</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb birth weight</td>
<td>LBW</td>
<td>Recorded after birth and measured to the nearest 0.1 kg.</td>
</tr>
<tr>
<td>Lamb viability at birth</td>
<td>LVB</td>
<td>Lambs with no lung aeration at postmortem were given a score of 0, whereas lambs with partial or full lung aeration were given a score of 1. All lambs alive at birth were also given a score of 1.</td>
</tr>
<tr>
<td>Dystocia death risk factor</td>
<td>LDD</td>
<td>All surviving lambs to 3 d of age were given a score of 0, whereas those that died between birth and 3 d of age from difficult births (using evidence of moderate to severe localized subcutaneous edema, organ ruptures, or hemorrhages) were given a score of 1. Lambs dying from risk factors other than a difficult birth were also given a score of 0, except that lambs with a death risk factor of starvation exposure were assigned as missing.</td>
</tr>
<tr>
<td>Starvation and exposure death risk factor</td>
<td>LDSE</td>
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</tr>
<tr>
<td>Lamb survival to 3 d post birth</td>
<td>LS3day</td>
<td>Lamb survival to 3 d post birth based on days survived between date of birth and date of death. Lambs that survived to 3 d of age were given a score of 1, whereas those that did not were given a score of 0.</td>
</tr>
<tr>
<td>Lamb survival to weaning</td>
<td>LSWWT</td>
<td>Lamb survival to weaning (approximately 100 d of age) based on a record for weaning weight for the lamb; then the lamb was assumed to be alive and given a score of 0.</td>
</tr>
</tbody>
</table>

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the data were obtained from an existing database.

Animal performance records were obtained from the AgResearch Lamb Survival Database and from the national sheep recording database, Sheep Improvement Limited, for 20 flocks (15,821 lambs), from 2 yr of lambing data (2003 to 2004) and including many breeds and breed compositions (predominantly Romney, Coopworth, and Texel) to investigate management and environmental effects for the lamb traits in Table 1.

The flocks are in the Otago Southland regions of New Zealand and were performance recorded. All lambs that died between birth and 3 d of age were collected, tagged, weighed, and autopsied to determine the cause of death. The autopsy procedure was modified from that described by McFarlane (1965), in consultation with veterinary practitioners. The autopsy procedure first diagnosed lamb viability at birth based on the presence of lung aeration and then assigned a primary cause of death, which included dystocia (organ rupture, hemorrhage, moderate to severe localized subcutaneous edema on head, neck, brisket, or rib cage), starvation exposure (no brown adipose tissue on heart and kidneys and no food in the gastrointestinal tract), and other causes (infection, congenital abnormality, other). The study by Kerslake et al. (2005) characterized primary dystocia as localized moderate to severe (>3-mm thickness) subcutaneous edema on the lamb’s body at postmortem.

Data were edited to remove missing records and low subclass numbers. Ewes 2 to 6 yr of age were included, and ewes older than 6 yr were grouped into age group 6. Lambs from litters greater than 3 were removed from the data set. Lambs were also removed from the data set if they were fostered, hand-reared, aborted, resulted from embryo transfer, or where their dam was assisted by the shepherd with lambing.

Weather conditions were tested in the survival analyses in the form of a sheep heat loss (HL) calculation described by Coronato (1999), which incorporates temperature, wind speed, and precipitation data collected from the nearest weather station. In this study, sheep HL values ranged from a minimum of 10 W·m⁻² to a maximum of 108 W·m⁻², with a mean of 45 W·m⁻². Heat loss variables, calculated for each flock according to date of birth, were average HL 2 wk before birth (HL₂₉₈b), average HL 1 wk before birth (HL₁₉₈b), average HL on the day of birth (HL₉₀₈b), and average HL over the 3 d after birth (HL₃₉₈d).

All ewes were scored for body condition (1 = emaciated to 5 = grossly fat, at 0.5 intervals) at mid pregnancy and again 2 wk before lambing (Jeffries, 1961). Ewe body condition score in mid pregnancy (BCSm), and 2 wk before lambing, and the change in body condition from mid to late pregnancy were tested as covariates and fixed effects in the models. A maternal behavior score (MBS), similar to that described by O’Connor et al. (1985), was recorded on dams from 5,691 lambs and 8 flocks and fitted as a class effect for lamb death risk to dystocia (LDD), lamb death risk to starvation exposure (LDSE), lamb survival to 3 d of age (LS₃₉₈d), and lamb survival to weaning (LSWWT). The MBS was scored on a 5-point scale based on the distance that a ewe retreats from her lambs when the shepherd is tagging them (Table 2).
A pedigree file containing the parents and grandparents of each lamb was used to form a relationship matrix. Random effects included a direct additive genetic effect and a maternal genetic effect. Analyses were performed using ASREML (Gilmour, 2006). Fixed effects and covariates were tested and retained in the model if statistically significant at $P < 0.05$, with the objective of accounting for most of the variation in the trait. Date of birth, lamb sex, and age of dam effects, as well as year of birth by litter size and by flock interactions and birth weight within litter size and dam age interactions, were fitted regardless of significance.

The final model for lamb birth weight ($n = 15,821$) included the fixed effects of flock ($P < 0.01$), year of birth ($P < 0.01$), litter size at birth ($P < 0.01$), date of birth ($P < 0.01$), birth weight within age of dam ($P < 0.01$), and lamb sex ($P < 0.01$). Date of birth ($P < 0.01$) and date of birth within flock $\times$ year of birth ($P < 0.01$), birth weight deviation within litter size ($P < 0.01$), age of dam ($P < 0.01$), and lamb sex ($P < 0.01$). Date of birth ($P > 0.05$) and date of birth within flock $\times$ year of birth ($P < 0.01$), birth weight deviation within litter size ($P < 0.01$), birth weight within age of dam ($P < 0.05$), and average HL ($HL_{2wb}$; $P < 0.01$), and HL3day ($P < 0.01$) were fitted as covariates.

The final model for LS3day ($n = 15,821$) included the fixed effects of flock ($P < 0.01$), year of birth ($P < 0.01$), litter size at birth ($P < 0.01$), flock $\times$ year of birth ($P < 0.01$), flock $\times$ litter size ($P < 0.01$), year of birth $\times$ litter size ($P > 0.05$), flock $\times$ year of birth $\times$ litter size ($P < 0.01$), age of dam ($P < 0.01$), and lamb sex ($P > 0.05$). Date of birth ($P < 0.01$), flock $\times$ year of birth ($P < 0.01$), birth weight deviation within litter size ($P < 0.01$), birth weight within age of dam ($P < 0.05$), and average HL ($HL_{1wb}$; $P < 0.01$) and HL3day ($P < 0.01$) were fitted as covariates.

The final model for LSWWT ($n = 15,821$) included the fixed effects of flock ($P < 0.01$), year of birth ($P < 0.01$), litter size at birth ($P < 0.01$), flock $\times$ year of birth ($P < 0.01$), flock $\times$ litter size ($P < 0.01$), year of birth $\times$ litter size ($P > 0.05$), flock $\times$ year of birth $\times$ litter size ($P < 0.01$), age of dam ($P < 0.01$), and lamb sex ($P < 0.05$). Date of birth ($P < 0.01$), flock $\times$ year of birth ($P < 0.01$), birth weight within litter size ($P < 0.01$), birth weight within age of dam ($P < 0.05$), dam BCSm ($P < 0.05$), and average HL ($HL_{1wb}$; $P < 0.01$) and HL3day ($P < 0.05$) were fitted as covariates.

**RESULTS**

Table 3 provides a summary of the effects of litter size at birth, lamb sex, and dam age on the lamb traits recorded between birth and 3 d of age and for lamb survival to weaning age.

**Lamb Birth Weight**

Lamb birth weight was lowest for triplet-born lambs, ewe lambs, and lambs born to 2-yr-old dams (Table 3). Twin-born lambs were on average 0.70 kg heavier than triplet-born lambs, and single-born lambs were 1.69 kg heavier than triplet-born lambs. Ram lambs were 0.37 kg heavier than ewe lambs (Table 3). Dam BCSm had a significant effect on lamb birth weight where greater body condition score ewes had heavier lambs at birth ($\beta = 0.11 \pm 0.021$ kg of birth weight/BCSm; $P < 0.01$).

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**Table 2. The maternal behavior scores (MBS) recorded for dams at lamb tagging**

<table>
<thead>
<tr>
<th>Description of MBS¹</th>
<th>MBS¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ewe flees at the approach of the shepherd, shows no interest in the lambs, and does not return</td>
<td>1</td>
</tr>
<tr>
<td>Ewe retreats further than 10 m but comes back to her lambs as the shepherd leaves them</td>
<td>2</td>
</tr>
<tr>
<td>Ewe retreats to such a distance that tag identification is difficult (5 to 10 m)</td>
<td>3</td>
</tr>
<tr>
<td>Ewe retreats but stays within 5 m</td>
<td>4</td>
</tr>
<tr>
<td>Ewe stays close to the shepherd during handling of her lambs</td>
<td>5</td>
</tr>
</tbody>
</table>

¹O’Connor et al. (1985).
Lamb viability was lowest for triplets (Table 3). Twin LBW was 7% greater than for triplets and single LBW was 5% greater than for triplets (Table 3). Dam BCSm had a significant effect on LBV where ewes of greater BCSm had less viable lambs than ewes with lower BCSm ($\beta = -0.02 \pm 0.005$ units of LBV/BCSm; $P < 0.05$). Lamb birth weight had a significant effect on LBV, where heavier and lighter lambs were less viable at birth than the optimum birth weight of 0.5 kg above the mean ($P < 0.01$; Figure 1). The HL2wb significantly affected LBV where greater heat loss over this period led to lower lamb viability ($\beta = -0.001 \pm 0.0007$ units of LBV/W·m^-2; $P < 0.05$).

### Lamb Survival to 3 Days of Age

Lamb survival from birth to 3 d of age was lowest for triplet lambs and lambs born to 5-yr-old dams (Table 3). Twin LS3day was 8% greater than for triplets and single lambs (Table 3). The optimum birth weight for survival to 3 d of age (Figure 3) was 2 kg lighter than the mean (Figure 4; where heavier than the mean) and greatest for lambs born 2 kg lighter than the mean (Figure 4; $P < 0.01$). Mean HL 3 d from birth (HL3day) significantly affected lamb death risk to starvation exposure for single lambs ($\beta = -0.001 \pm 0.0005$ units of LDSE/W·m^-2), twin ($\beta = 0.0003 \pm 0.0002$ units of LDSE/W·m^-2), and triplet lambs ($\beta = 0.00003 \pm 0.0004$ units of LDSE/W·m^-2) to differing degrees ($P < 0.05$). Lamb death risk to starvation exposure increased for twin lambs as HL increased 3 d from birth, whereas the reverse relationship was true for single lambs; that is, as HL increased, LDSE decreased for single-born lambs.

### Lamb Death Risk to Starvation Exposure

Starvation exposure rates were lowest in single lambs and lambs born to 2-yr-old dams (Table 3). Triplet LDSE was 1% greater than single and twin lambs (Table 3). Lamb death risk to starvation exposure was lowest for lambs born of optimum birth weight (1 kg heavier than the mean) and greatest for lambs born 2 kg lighter than the mean (Figure 4; $P < 0.01$).

### Lamb Viability at Birth

Lamb viability was lowest for triplets (Table 3). Twin LBW was 7% greater than for triplets and single LBW was 5% greater than for triplets (Table 3). Dam BCSm had a significant effect on LBV where ewes of greater BCSm had less viable lambs than ewes with lower BCSm ($\beta = -0.02 \pm 0.005$ units of LBV/BCSm; $P < 0.05$). Lamb birth weight had a significant effect on LBV, where heavier and lighter lambs were less viable at birth than the optimum birth weight of 0.5 kg above the mean ($P < 0.01$; Figure 1). The HL2wb significantly affected LBV where greater heat loss over this period led to lower lamb viability ($\beta = -0.001 \pm 0.0007$ units of LBV/W·m^-2; $P < 0.05$).

### Lamb Death Risk to Dystocia

Dystocia rates were greatest in triplets, ram lambs, and lambs born to 3-yr-old dams (Table 3). Triplet LDD was 9% greater than for twins (Table 3). Lambs of optimum birth weight, that is 0.5 to 1 kg above the overall mean (regardless of litter size), had less death risk to dystocia. Death risk to dystocia was greatest in triplet lambs 2 kg lighter than the mean (Figure 2; $P < 0.01$). Mean HL during the 2 wk before birth (HL2wb, $\beta = 0.005 \pm 0.0008$ units of LDD/W·m^-2; $P < 0.01$) and 3 d from birth (HL3day, $\beta = 0.001 \pm 0.0003$ units of LDD/W·m^-2; $P < 0.01$) increased lamb death risk to dystocia, with HL leading up to birth having the greater impact of the two. Unfavorable dam MBS increased lamb death risk to dystocia ($P < 0.01$) with greater values for triplet lambs with dams having a MBS lower than 3. Single born lambs were not affected by the MBS of their dam (Figure 3).
Figure 1. Quadratic regression of lamb viability at birth (LVB) on lamb birth weight deviation from the mean (LBWdev; ± SE): LVB = −0.009LBWdev² + 0.0072LBWdev + 0.0503. Mean lamb birth weight = 4.8 kg.

Figure 2. Quadratic regression of lamb death risk to dystocia (LDD) on lamb birth weight deviation from the mean (LBWdev) for single, twin, and triplet lambs, respectively (± SE): LDD = 0.0122LBWdev² − 0.0288LBWdev + 0.0394; LDD = 0.0243LBWdev² − 0.0376LBWdev + 0.0135; and LDD = 0.0202LBWdev² − 0.0435LBWdev + 0.099. Mean lamb birth weight = 4.8 kg.
Figure 3. Least squares means (± SE) of lamb death risk to dystocia (LDD) by dam maternal behavior score (MBS) for single, twin, and triplet lambs.

Figure 4. Quadratic regression of lamb death risk to starvation exposure (LDSE) on lamb birth weight deviation from the mean (LBWdev; ± SE): LDSE = 0.0141LBWdev^2 + 0.0308LBWdev + 0.0168). Mean lamb birth weight = 4.8 kg.
Management to improve lamb survival

Figure 5. Least squares means (± SE) of lamb death risk to starvation exposure × dam maternal behavior score for single, twin, and triplet lambs.

Lamb survival to 3 d of age was lowest for triplet lambs born 2 kg lighter than the mean. Mean HL 1 wk before birth (HL1wb; $\beta = -0.003 \pm 0.0005$ units of LD3day/W·m$^{-2}$; $P < 0.01$) had a highly significant effect on survival rates and HL1wb had a greater impact on survival than HL0day ($\beta = -0.002 \pm 0.0005$ units of LS3day/W·m$^{-2}$; $P < 0.01$).

Mean HL 1 wk before birth (HL1wb; $\beta = -0.003 \pm 0.0005$ units of LD3day/W·m$^{-2}$; $P < 0.01$) had a highly significant effect on LS3day, where greater HL led to lower survival rates and HL1wb had a greater impact on survival than HL3day ($\beta = -0.002 \pm 0.0005$ units of LS3day/W·m$^{-2}$; $P < 0.01$).

Lamb survival to weaning age was lowest for triplets, ram lambs, and lambs born to 2-yr-old dams (Table 3). Twin LSWWT was 11% greater than for triplets (Table 3). Lamb survival to weaning age was greatest for lambs born to dams of greater BCSm ($\beta = 0.001 \pm 0.009$ units of LSWWT/BCSm; $P < 0.05$).

Lambs born of optimum birth weight (1 kg above the mean) had the greatest survival rates to weaning (Figure 8; $P < 0.01$). Lamb survival to weaning was lowest for triplet lambs born 2 kg lighter than the mean.

DISCUSSION

The majority of lamb deaths from birth to weaning occur in the first 3 d after birth and range from 5 to 30% for individual sheep flocks (Kerslake et al., 2005). Previous research has shown that under New Zealand conditions starvation/exposure accounts for approximately 30% of newborn lamb losses (McCutcheon et al., 1981). Dalton et al. (1980) reported dystocia rates of 27% in dead single lambs and 17% in dead multiple lambs. A recent study by Kerslake et al. (2005) showed that the predominant cause of death from birth to 3 d of age was dystocia, accounting for 57% of single and 47% of multiple lamb deaths. Haughey (1983) suggested that between 20 to 60% of neonatal lamb deaths pathologically categorized as starvation or exposure are actually consequences of birth stress. Differing results between studies may be due to differences in clinico-pathological diagnoses.

It has long been recognized by New Zealand sheep farmers who farm outdoors all year round that weather conditions have the largest influence on lamb survival. Alexander (1984) has also reported the importance of weather on newborn lamb survival.

Maternal care can minimize the impact of detrimental environmental factors on lamb losses (Poindron et
Figure 6. Quadratic regression of lamb survival to 3 d of age (LS3<sub>day</sub>) on lamb birth weight deviation from mean (LBWdev) for single, twin, and triplet lambs, respectively (± SE): LS3<sub>day</sub> = −0.016LBWdev<sup>2</sup> + 0.0598LBWdev + 0.369; LS3<sub>day</sub> = −0.0386LBWdev<sup>2</sup> + 0.077LBWdev + 0.3792; and LS3<sub>day</sub> = −0.0376LBWdev<sup>2</sup> + 0.0763LBWdev + 0.303. Mean lamb birth weight = 4.8 kg.

Figure 7. Least squares means (± SE) of lamb survival to 3 d of age × dam maternal behavior score for single, twin, and triplet lambs.
Figure 8. Quadratic regression of lamb survival to weaning age (LSWWT) on lamb birth weight deviation from the mean (LBWdev) for single, twin, and triplet lambs, respectively (± SE): LSWWT = −0.0238LBWdev^2 + 0.0881LBWdev + 0.4936; LSWWT = −0.047LBWdev^2 + 0.0893LBWdev + 0.4743; and LSWWT = −0.0397LBWdev^2 + 0.1011LBWdev + 0.3609. Mean lamb birth weight = 4.8 kg.

Figure 9. Least squares means (± SE) of lamb survival to weaning age × dam maternal behavior.
al., 1984). However, the proper expression of adequate maternal behavior is made more difficult by modern livestock systems, which increase fecundity and thus increase demands upon the mothering ability of ewes (Chenoweth and Landeta-Hernandez, 1998). Therefore, a better understanding of environmental and management conditions throughout pregnancy and at lambing may allow a reduction in lamb losses seen in highly fecund ewes.

Lamb survival is predominantly controlled by the environment (Lopez-Villalobos and Garrick, 1999; Morris et al., 2000; Everett-Hincks et al., 2002, 2005b). This study has shown that weather conditions, measured in the form of sheep HL (Coronato, 1999), have a highly significant effect on newborn lamb survival. Heat loss leading up to lambing had a greater impact on lamb survival than HL recorded on the day of birth or after birth. This finding is in agreement with Coronato (1999) who also suggested that bioclimatic conditions during late pregnancy are at least as important as conditions during lambing in determining the survival of lambs.

It is likely that weather conditions in late pregnancy are influencing the energy balance of the ewe when her nutritional requirements are greatest, particularly for ewes with twins (Holmes, 1975) and triplets (Everett-Hincks et al., 2005a). The energy cost during pregnancy in the ewe is largely met by increased feed intake, except in very late pregnancy when intake may decline. It is likely that ewes with multiples will mobilize maternal tissues to support their energy demands and those of their growing fetuses (Jelbart and Dawe, 1984). However, under severe HL the energy cost is likely not to be met for ewes with larger litters even if there is sufficient feed. Therefore, it is likely that an energy imbalance at this time, exacerbated by environmental HL, is significantly affecting LVB and subsequent lamb survival.

The last 4 to 6 wk before lambing are critical, and Scales et al. (1986) showed that when multiple-bearing ewes were offered additional feed in late pregnancy, lamb mortality was reduced, indicating merit in improved prelamb feeding for ewes carrying more than 1 lamb. Scales and coworkers reported that a 10-kg increase in ewe liveweight during the last 6 wk of pregnancy resulted in an increased birth weight of 0.46 kg for singles and 0.52 kg for twins. In a 2002 study with Romney ewes conducted by Everett-Hincks et al. (2005a), twin litter weight at birth was similar for ewes grazing 2-, 4-, and 6-cm sward heights; however, increasing pasture allowance from just 2 to 4 cm for ewes with triplet litters increased litter weight at birth by 2 kg and improved litter survival to tagging by 4%.

Birth weight, fitted as a quadratic effect in this study, emphasizes the importance of an optimum birth weight for survival traits where lesser and greater birth weights are not favorable for these traits. The optimum birth weight where lamb death risk to starvation exposure and dystocia were lowest and lamb viability and survival were highest was 0.5 to 1 kg above the mean. An optimum birth weight of around 5.5 kg for all lamb traits in this study is significantly heavier than the optimum birth weight of 3 kg reported nearly 3 decades earlier by Dalton et al. (1980). Increased birth weight is an advantage to the survival of twin and triplet lambs, indicating that selection for multiple births should be accompanied by selection for increased birth weight. Hight and Jury (1970) reported that lambs of heavier birth weights are better equipped to survive conditions predisposing them to exposure and starvation because they have more energy stored as brown fat reserves and maintain their suckling drive for a greater duration than lighter lambs.

Lamb birth weight has been reported as the predominant factor leading to dystocia in single lambs (Fogarty, 1992). However, birth weight is unlikely to be the only reason for high dystocia rates in larger litters. This study showed that lighter lambs had higher dystocia rates. Dystocia can be a consequence of lamb birth weight, sire breed, dam pelvic conformation (Fogarty and Thompson, 1974), malpresentation, maternal overfeeding, or prolonged parturition (Sargison, 1997; Everett-Hincks et al., 2007). In addition, lambs that endure difficult births have trouble maintaining body temperature and have inhibited behaviors in teat searching and suckling (Eales et al., 1982). This can increase the chances of death when subjected to cold stress or undernutrition. The high rate of deaths from dystocia in triplet lambs was unexpected. It may indicate that dystocia as a primary cause of lamb death is underestimated within highly fecund sheep flocks and is particularly prevalent in lighter lambs possibly resulting from prolonged parturition (Everett-Hincks et al., 2007).

Inadequate feeding of ewes can result in poor maternal behavior, and poor ewe behavior is an important cause of lamb death (Nowak, 1996; Everett-Hincks et al., 2005a). Dwyer et al. (2003) demonstrated that a moderate reduction in maternal nutrition during late pregnancy resulted in a measurable reduction in the expression of maternal behaviors, in particular MBS at parturition, under intensive conditions indoors. The same authors did not observe a change in neonatal lamb behavior from the effect of maternal undernutrition and concluded that neonatal progress was affected by birth weight.

Dam maternal behavior score had a significant effect on lamb death risk to starvation exposure and dystocia where ewes with lower scores had higher lamb mortality rates. Maternal behavior score gives an indication of the strength of ewe-lamb attachment when separated (Everett-Hincks et al., 2005b). Nowak (1996) observed a considerable improvement in twin lamb bonding with their dam and twin lamb survival when the mother remained on the birth site for a minimum of 6 h. If paddock pasture quality and feeding levels are good and the paddock has adequate shelter, then the ewe will stay at the birth site with her lambs for a greater period (Pitu et al., 1988; Pollard and Littlejohn, 1999).
Studies have attempted to define suitable husbandry practices for larger litter sizes and to encourage ewe-lamb attachment and subsequently survival immediately after birth. In a New Zealand survey of farmer practices at lambing, Aspin (1997) identified that when selecting paddocks for lambing, priority considerations were pasture cover, shelter, stocking rate, and topography; however, these factors were not defined. Pollard and Littlejohn (1999) investigated sheltering behavior of lambing ewes under extensive conditions and found that types of shelter did not affect lamb productivity in the 1 yr of study, where weather was moderate. They did, however, observe that the least used artificial shelters were near roadways and human activity, reinforcing the ewe’s need to seek isolation. However, for New Zealand conditions the effect of weather on lamb survival is an important source of variability, which could be alleviated by carefully selecting more sheltered north-facing paddocks for ewes in the late stages of pregnancy, not just at lambing and to reconsider pre-lamb shearing.

Ideally, ewes with triplets should be identified as early as possible, separated, and preferentially fed (Geenty, 1997). Ewes with higher BCS at pregnancy scanning had heavier lambs at birth; therefore, it is important to manage ewes to ensure they are a BCS 3 at mid-pregnancy and body condition is maintained throughout the remainder of pregnancy. Ewe BCS will likely act as an energy buffer in times of environmental and nutritional stress. Beilharz and Luxford (1984) discussed the limiting effect of the environment on reproductive progress. They proposed that larger litter sizes could only be utilized successfully if the environment was improved. They maintained that even relatively small increases in litter size would need improvement in the environment if deleterious side effects were to be avoided. Our study has confirmed the importance of the maternal environment for the growth and survival of larger litters and that further research is needed to better understand the biochemical mechanisms in the latter stages of gestation.

LITERATURE CITED


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