World's best practice in Lamb Survival

In particular the first three days of life.

A report for

by Matthew Ipsen

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Executive Summary

The decline in the Australian sheep flock over the last 30 years, along with the relatively high sheep and lamb prices compared to wool returns, has highlighted the issue of low reproductive efficiency of the Australian sheep flock, particularly with the Merino breed. With such wastage in sheep flocks attracting increased attention in recent years due to animal welfare and economic considerations, sheep producers are looking for viable options to improve lamb survival.

Poor lamb survival, particularly in the first three days of life, is a major contributor to inefficient Net Reproduction Rate (NRR) in Australian sheep. Survival of lambs from birth to marking can vary considerably, with rates rarely exceeding 90% in single born lambs and 80% in twin born lambs. The estimated cost of peri-natal lamb loss to the Australian sheep industry is $A56 million.

The benefits of increasing the number of lambs born is often negated by decreases in lamb survival associated with an increase in multiple births. Therefore, breeding strategies that aim to increase net reproductive rates should improve or at least maintain the proportion of lambs surviving.

The successful rearing of a lamb to weaning is the culmination of a sequence of often inter-related events including genetics, physiology, behaviour and nutrition, with the environment providing an overarching complication. These interacting factors affect the outcome of an individual pregnancy, while the success or failure of each individual pregnancy determines the overall reproductive success of the whole flock.

To improve reproductive efficiency, commercial sheep producers would best be advised to select replacement rams on Australian Sheep Breeding Values for total weaning weight. Although the heritability of lamb survival is generally low within flocks, survival can be

improved by selection. Selecting rams whose daughters will wean higher percentages of lambs, leads to improvements in lamb survival in future generations. Identifying and retaining the best performing ewes on the basis of NRR and removing the worst performers from the flock will improve lamb survival in the current generation.

Because behaviour of both the ewe and lamb is affected by environmental factors, appropriate management through pregnancy and parturition will enhance the expression of maternal behaviour and lamb vigour, and so contribute to improving lamb survival. Improving ewe nutrition pre-partum will increase birth weights of lambs, providing greater amounts of body reserves to metabolise post birth. It will also ensure the ewe has sufficient reserves to facilitate a short parturition, begin lactation with adequate quantity and quality of colostrum and increase the maternal-lamb bond.

The provision of housing and individually penning of strategic flocks will improve lamb survival as it increases the maternal bond, manages dystocia and starvation/exposure issues and negates the risk to predation and climatic conditions. It has been proven to be an economical option in both South Africa and New Zealand.

Further investigation is required to determine the optimal combination of indirect selection methods (proxy traits) that can further improve lamb survival and can be implemented under practical field conditions.

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Foreword

Since the downturn in the Australian wool industry in 1990, the size of the national sheep flock has been in steady decline. This has been exacerbated by poor seasonal conditions over the last fifteen years, modest wool prices and the relatively stable income from prime lamb production. The combination of these factors has resulted in a significant change in the structure of the national flock with ewes currently representing around three quarters of the total flock.

The Merino ewe plays a pivotal role in the Australian sheep flock. It is the main breed used in wool production but also influences prime lamb production, either directly when joined to terminal sires or indirectly through the breeding of first cross ewes. The genetics of the Merino ewe contribute an estimated 59% of the genetics to Australian sheep meat industries. Therefore, improving the reproductive performance of the Australian Merino is an important pathway to maintaining a sustainable and viable sheep industry that will also result in improvements in profitability for sheep enterprises.

Lamb survival is one of the major contributors to the inefficiencies of the reproductive performance of the Merino ewe. While lamb survival from birth to weaning varies considerably between flocks, it is commonly acknowledged that the industry average is often less than 80% of lambs born. The majority of these lamb losses occur within the first three days of post-natal life.

Recently, the “Lifetimewool” and “Wean More Lambs” projects were developed to demonstrate that when best practice guidelines for ewe nutrition are followed, the survival of lambs, in particular twin born lambs, have resulted in significant improvements. However, there is still considerable scope for the industry to adopt these practices and further improve lamb survival.

My background is as a Merino stud breeder and commercial wool and prime lamb producer. I also operate a business in sheep artificial insemination and ultrasound pregnancy scanning. Although we achieve weaning results (lambs weaned to ewes joined) of 130%, I am often frustrated at lambing time by the number of lambs that do not survive, even when following industry “best practice”.

Through my business I also work with industry organisations, scientists, consultants and leading producers looking at and discussing ways to improve lambing percentages and survival rates. I promote the use of management practices and technologies to reduce lamb losses and also consider the welfare of the animal.

A Nuffield scholarship investigating world’s best practice in lamb survival, particularly in the first three days of life, appeared a natural fit and I hope to improve profitability for my own farm, my business clients and the industry.

Acknowledgments

I would like to take this opportunity to thank the many people who have helped make my Nuffield Scholarship a memorable experience. It has allowed me to continue my own personal development and have a better understanding of agriculture around the world and the issues that affect price, policies and politics.

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To my sponsor, Australian Wool Innovation, thank you for your support of the Nuffield program. I truly believe that this investment will provide for future leaders in the industry as well as connecting people committed to pushing boundaries and creating success.

Thank you to all the people around the world regarded as “world’s best” in research and practicality for sharing your knowledge and time with me. To the many hosts around the world, thank you for your hospitality and conversations. Without your help this report would not have been possible.

My fellow Nuffield Scholars, I am still in awe of you and your achievements. I look forward to catching up whenever possible and being inspired to continue on my own journey. I truly hope this amazing experience was as fulfilling for you as it was for me.

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Lastly, I owe so much to my parents. A massive thank you for running the farming business and for your support and encouragement along this journey. I hope that you get some sense of pride from my achievements as they are just as much yours as they are mine.

Abbreviations

ASBV	Australian Sheep Breeding Value
CPY17	Cytochrome P450 17α-Hydroxylase/17,20-Layse
EBV	Estimated Breeding Value
MBS	Maternal Behaviour Score
ME	Metabolisable Energy
NLW	Number of Lambs Weaned
NRR	Net Reproductive Rate
TWW	Total Weaning Weight

Objectives

This report provides an investigation into improving lamb survival, particularly in the first three days of life. It aims to explain what research and management practices are being utilised in major sheep producing nations. It examines the area of physiology, genetics and gene technology, behaviour, nutrition and management and their effects on lamb survival and mortality. With this information, the potential exists for appropriate animal management programs to be formulated to improve lamb survival, reduce ewe mortality rates and increase animal welfare on sheep enterprises.

Introduction

Improving the reproductive efficiency of the Merino ewe is crucial to the future of the Australian sheep industry. The Merino ewe is the backbone of the wool industry and contributes around 59% of the genetics to the prime lamb industry (Hatcher *et al*, 2010a). Improving reproductive performance is one of the biggest contributors to increasing profitability of Australian sheep producers and determines profit and losses in the months and years ahead.

Flock sizes in Australia are generally large and are grazed under extensive grazing systems. They have minimal labour inputs and production occurs in a range of environments. Under these circumstances of low-input systems and the complexity of lamb survival, the national average of net reproductive rate (NRR) has remained unchanged for more than 20 years (Clark, 2012).

Lamb mortality remains a key economic and welfare issue for Australian sheep producers, with the majority of lamb mortalities occurring within the first three days of postnatal life. Nearly half of all pre-weaning deaths occur on the day of birth but this rate reduces significantly once the lamb is one week old (Dywer, pers comm, 2013). Worldwide lamb mortality rates average from 9 to 20% (Mousa-Balable, 2010). However, within Australia, survival rates from birth to weaning are often less than 80% of lambs born (Brien *et al*, 2010). This is based on the known reproductive performance from ultrasound scanning results and achieved marking percentages. This emphasises the importance of the period immediately after post-partum for lamb survival and represents an important economic loss for producers.

Estimates of lamb mortality in Australia are that more than 10 million lambs die post birth, costing the Australian sheep industry $56 million in potential lost revenue every year. (Brien *et al*, 2010). The main causes of lamb mortality are related to trauma experienced during the birthing process and failure of neonatal adaptation to postnatal life. The “Sentinel Project” conducted by the Department of Primary Industries and Environment concluded 52% of deaths occur due to starvation and exposure (Armstrong, pers comm, 2012). This is because of the lamb's inability to maintain body temperature, low lamb vigour or poor establishment of a maternal bond. Dystocia also accounted for 19% of all lamb deaths (Armstrong, pers comm, 2012). Dystocia commonly occurs due to foetal-pelvic disproportion or mal-presentation (Hatcher *et al*, 2010a).

Lamb birth weight, birth type, maternal nutrition, dam age and sex all impact on lamb survival (Hatcher *et al*, 2009). The single largest influence on the survival of lambs in the first few days of life is their birth weight. Everett-Hincks and Dodds (2008) and many other studies have shown 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. "Lifetimewool" estimates optimum birth weights should range between 3 and 5 kg. There is a curvilinear relationship between lamb birth weight and survival in Merinos, with mortality highest at both low and high birth weights. However, for those lambs that do survive birth, heavier birth weight is a definite advantage in surviving the early post-natal period.

The majority of lamb deaths from birth to weaning are most commonly from multiple-born lambs rather than individuals. Published reports estimate mortality rates of single born lambs range between 6 to 30%, with losses of twin lambs generally double that of singles in the same flock (Hatcher *et al*, 2009). There are numerous reasons for lower survival rates in multiple born lambs including the incidence of malpresentation, birthing difficulties, lower birth weights, larger surface area to lose body heat, smaller reserves of body fat and competition with its litter mate for colostrum and milk (Hatcher, 2010b). Reduced milk and colostrum intake can lead to greater mortality from infectious disease due to the reduction in immunoglobulins transferred.

Dam age also has an influence on lamb mortality. Many researchers have highlighted decreased lamb survival from different aged dams. Younger ewes tend to have lower birth weight lambs and fewer losses due to difficult labour than older ewes. They show impairments in the expression of maternal behaviour and when compared to older ewes, are slower to begin grooming their lambs after birth. Younger ewes show equivalent amounts of grooming behaviour over the first two hours after delivery and make a similar number of low-pitched bleats. Initial contact with her lamb allows the ewe to learn to respond appropriately, and she becomes less likely to prevent subsequent suckling attempts. (Dwyer, pers comm, 2013). Older ewes have a higher potential for udder damage which can negatively affect lamb survival (Hatcher 2010b). The sex of the lamb affects survival. Female lambs have survival odds 1.3 that of male lambs and take less time to stand and suckle.

The proper development of foetuses and newborn lambs requires the adequate transportation of nutrients across the placenta and mammary gland. Approximately two thirds of the birth weight of a developing foetus is gained in the last six weeks of gestation. Therefore, balanced nutrition during late gestation is crucial for foetal development and survival at birth. Pregnant ewes must be fed adequately to provide energy and protein to support embryonic and foetal growth, the maintenance of metabolic processes and mammary gland growth, which affects colostrum and milk yield. The adequate transportation of nutrients also affects foetal ovarian development, postnatal growth, reproductive performance and metabolism (Mahboub *et al*, 2013).

The success of rearing a lamb to weaning is the result of a series of complex events involving animal physiology, behaviour, genetics, nutrition and the prevailing environment during late pregnancy and lambing (Hatcher *et al*, 2010b). The information contained in this report intends to provide sheep producers with knowledge to formulate appropriate management programs to improve lamb survival rates. While not all the information is new and some producers will not agree with all the information, it is hoped to at least challenge producers to think about different strategies that will improve lamb survival rates into the future.

Discussion

The survival of lambs in extensive sheep production systems is a major contributing factor to the economic efficiency of these farms and is an indicator of good animal welfare. Estimates of lamb pre-weaning mortality vary considerably between 10 and 30% and most of these mortalities occur within the first three days of postnatal life.

Many research and extension programs have aimed to increase the reproductive efficiency of the sheep flock through management and breeding methods. The NRR (number of born lambs per ewe) is certainly an economically important trait in any commercial sheep enterprise and attention should be paid to the care of pregnant ewes and their lambs before, during and after birth. The neonatal period is decisive for lamb survival.

In Australia and New Zealand “Lifetimewool” and “The Lamb Survival Project” were developed, and have been successful in producing guidelines and toolkits to enable sheep producers to optimise ewe production and the lifetime performance of their progeny to increase farm profits. Lifetimewool commenced in 2006 and by the end of 2010, 221 producers had completed the program. Participants in this extension program increased their whole farm stocking rates by 14%, increased lamb marking percentages by 11-13% depending on enterprise type, and decreased ewe mortality by 43% (Trompf *et al*, 2011). However, the average reproductive performance of Australian specialist sheep producers was 76.9% lambs marked per 100 ewes joined between 1977-2009 with only marginal improvement occurring over the past 30 years (Hatcher *et al*, 2010b).

If the improved rates above could be achieved across 25% of the national flock, this would increase the number of lambs weaned by more than one million per annum (Trompf *et al*, 2011).

While productivity gains achieved through better understanding of pasture assessment, managing ewe conditions score, pregnancy scanning, improved feed allocation and measuring ewe performance need to be reinforced for optimum conception and lamb survival rates, the success of rearing a lamb through to weaning is determined by genetics, behaviour, physiology and the environment, including on-farm management.

Genetics

Improving lamb survival through breeding is very relevant for low input and extensively managed flocks. This is because it identifies individuals and families of sheep that differ in their inherent ability to lamb unaided, nurture and rear their young, as well as identifying offspring that are less viable at birth, vocalise less and potentially, those that have either very low or very high birth weights. Genetics offer a relatively low cost solution and the effects are permanent and cumulative over time. The potential to genetically improve lamb survival is challenging because of the large number of environmental factors influencing the trait. Improvement is also reliant on a combination of other factors including heritability, selection intensity and the amount of genetic variation.

Heritability

The very low heritabilities of lamb survival, that is 0.03 for direct (lamb viability) and 0.05 for maternal (ewe rearing ability) (Brien *et al*, 2010), has led some researchers around the world to suggest that genetically improving lamb and litter survival will be ineffective (Amer, pers comm, 2013; Keynon, pers comm., 2013; Hickford, pers comm., 2013).

Hatcher *et al* (2010a) concluded that although genetic gain from selection for lamb survival is unlikely to be significant, gains are possible. This is also evidenced by Cloete *et al* (2004) who demonstrated responses from a South African Merino flock divergently selected for multiple rearing ability. They indicated that genetic gains of more than 10% over 21 years are possible. In this flock, ewe and ram progeny of ewes rearing more than one lamb per joining were chosen as replacements.

Figure 1: Hugh Taylor, Romney Stud, Lincoln, South Island, New Zealand. (M Ipsen, 2013)

A Romney stud flock in New Zealand (Fig. 1) also reduced lamb mortality to just 7%. As with the South African flock, this improvement was a result of direct selection of both ewes and rams from ewes with high rearing ability (Hickford, pers comm, 2013). However, gains of this scale may not be achieved in commercial situations where replacement animals are selected on other traits in addition to NRR. It does, however, illustrate the level of potential improvement that can be achieved (Hatcher *et al*, 2010b).

When traits have low heritability or are expressed only in one sex, it is common practice to increase accuracy by using the records of relatives, particularly progeny. Estimated breeding values (EBV) are a way to improve the accuracy of selection for lamb survival because they include information from progeny testing of sires and other relatives in a genetic evaluation. Producers in Australia can use Australian Sheep Breeding Values (ASBVs) for number of lambs weaned (NLW), available through MERINOSELECT. Recent studies suggest this could be further improved genetically by basing selection on total weight of litter weaned per ewe rather than the number of lambs born or weaned (Amer, pers comm, 2013).

Dirkie Uys (pers comm, 2013), a South African Merino producer, stated that for every 1kg increase in total weight weaned (TWW) EBV, will result in a 4% increase in weaning percentages. Brien *et al*, (2010) concluded in a study looking at opportunities for genetic improvement of lamb survival that without NLW incorporated as part of a breeding strategy, lamb survival through to weaning would decline genetically at a rate of 0.25 lambs per 100 lambs born per year.

Finding proxy traits for lamb survival has been identified as a mechanism to accelerate genetic selection for improved lamb survival. Lamb vigour at birth, time to stand, birth coat score, lamb to bleat, rectal temperature of the neonate and crown-rump length have all been shown to substantially improve the accuracy of lamb survival, particularly when progeny records are included (Dwyer, pers comm, 2013). The problem for commercial sheep producers is that these traits require more active intervention by a shepherd, undertaking at least daily checks of lambing paddocks, and will not suit management systems on most commercial properties.

The heritability of lamb survival also decreases with the age of the lamb, meaning that directly selecting for lamb survival must occur within the first week of life (Hatcher *et al*, 2010b). Again, capturing this information in a commercial enterprise is difficult and the low heritability of lamb survival suggests that genetic solutions to lamb survival are unlikely to be significant (Amer, pers comm, 2013).

The best option for commercial sheep producers is to select replacement animals based on net reproduction rate (Hatcher *et al*, 2010b). Merino producers can use the TWW ASBV when making ram purchasing decisions, as rams with more positive TWW ASBVs will sire daughters that wean a higher percentage of lambs.

Variation

Within any population there is always a certain amount of genetic variation. In statistical terms this is called the 95% confidence level. When determining the contribution of genetic variation to lamb survival, it is necessary to consider the direct genetic effect due to the genes of the lamb and the maternal effect of the dam, which has genetic and environmental components.

“Some ewes can, others can’t. Some rams can, others can’t.” Dirkie Uys (pers comm, 2013) suggested that there is a 40% variation between the best and worst rams ewe progeny. As at October 2010, there was a 46% range in the NLW ASBV in the Sheep Genetics database (Hatcher *et al*, 2010b).

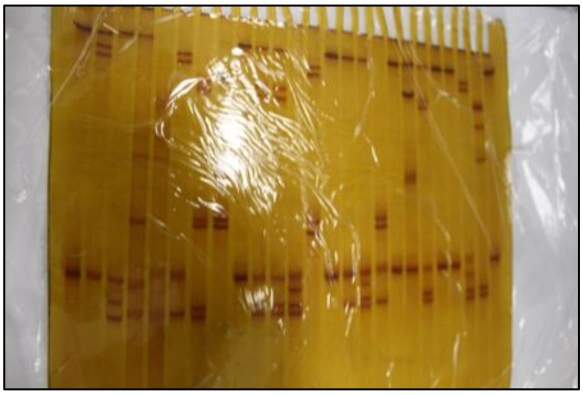

Figure 2: Gene Marker Smear, Lincoln University, Lincoln, New Zealand. (M Ipsen 2013)

Studies have also demonstrated genetic variation in cold survival through the establishment of lines of sheep with high and low cold tolerance (Hickford, pers comm, 2013). Unfortunately, in order to do this each sheep has to be subjected to a cold challenge in order to ascertain its level of cold tolerance, a practice not easily achieved on farm. This led researchers at Lincoln University in New Zealand to develop a cold tolerance gene-marker test (Fig. 2). The molecular research suggested that polymorphisms at the ovine β3-adrenergic receptor locus were associated with lamb mortality in New Zealand flocks (Hickford, pers comm, 2013). The research focused on the β3-adrenergic receptor gene, a key in the pathway that leads to heat generation in response to cold stress. They linked variation in this gene to the ability of newborn lambs to survive cold weather. Different forms (alleles) of the gene are associated with lambs having greater or lesser risk of dying from cold exposure. It should be noted that the effectiveness of the test in defining the percentage of lambs that will die from cold exposure from a single sire will vary depending on numerous factors, including the severity of the cold challenge and the genetics of the ewes that any given ram is mated to.

Exposure is a significant cause of death to lambs in Australia. The Commonwealth Scientific and Industrial Organisation (CSIRO) carried out work on birth coat and body reserves of energy as indicators of the ability of a lamb to resist cold. They found that sudden cold snaps might cause sharp increases in lamb mortality but lamb survival in Southern Australia is not related to weather chill index variables (Filmer and Adams, 2007).

For commercial producers, genetic variation allows for a number of breeding strategies to be employed. Sires that have poor progeny survival rates should be removed at the first practical opportunity, and consequently sires with good rates used. When selecting replacement ewes, ewes that have been sired by rams with good survival rates should be used to increase the rate at which genetic gain is made within the flock.

Selection intensity

Maternal rearing ability has a repeatability of at least 0.10 (Hatcher *et al*, 2010b). This suggests that multiple records on the rearing ability of a ewe over its lifetime can improve lamb survival in the current generation by identifying and culling ewes with poor rearing ability from the flock.

Lee *et al.* (2009) categorised ewes into quartiles based on their lifetime reproductive performance and found that the top 25% of ewes annually weaned one more lamb than the bottom 25%, which on average lambed only every second year, and, when they did lamb, reared only half of their lambs. Furthermore, the ewes in the top 25% were able to rear 90% of the lambs born despite having significantly more multiple births (Hatcher *et* al, 2010b). From this research they identified three opportunities that could improve NRR. The first is to increase the influence of highly productive ewes by retaining them beyond the normal culling age. The top 25% of ewes produced 41% of the lambs weaned (Lee *et al*, 2009). The second strategy is to remove ewes with low reproduction rates from the breeding flock as soon as can be identified, given that the bottom 25% of ewes produced just 8% of the lambs weaned (Lee *et al*, 2009).

“In a New Zealand Romney saleable meat yield trial, the number of lambs hitting the ground as a result of directly culling, against ewes and her progeny which failed to rear their lamb/s, had gone from 162% to 195% in the last three years of the trial. In 2008, 12.7% of lambs died before weaning but in 2010, only 5.1% were lost.” (Hickford, pers comm, 2013).

The third opportunity is to target management interventions to those parts of the flock most likely to produce the largest economic responses. The greatest example of this is ultrasound pregnancy scanning ewes for multiple foetuses and managing them according to nutritional requirements. Identifying ewes which are dry at two and three years of age rear only half as many lambs as ewes of the same age that have reared lambs. In additions, ewes that rear twins are 30% more likely to have twins again the following year (Sewell, pers comm, 2013).

Physiology

Physiological processes play a role in coordinating the physical aspects of birth, for example uterine contractions and milk letdown, and in stimulating maternal behaviour. In sheep, evidence suggests that oxytocin plays a significant role in post-partum stimulation of maternal responses. It is important for the formation of olfactory (sense of smell) memory and the selective behaviour of the ewe for her own lamb.

Prior to birth, ewes show indifference or hostility toward neonatal lambs, however, the birth process brings about a complete reversal in behaviour of the ewe. In the first hour after giving birth, 80% of the ewe’s behaviour is characterised by licking or grooming the lamb (Dwyer, pers comm, 2013). Licking or grooming the lamb serves to dry the lamb, to clear placental membranes from the nose and mouth, and to stimulate activity and respiration. This behaviour promotes the formation of the olfactory memory of the lamb, allows the ewe to express nurturing behaviour to facilitate the successful transition of her lambs from pre to postnatal life and creates an exclusive selective attachment for her own lambs.

During the immediate postpartum period, the lamb also performs a series of behaviours directed toward standing, locating the udder, and sucking. Initial movements are raising and shaking the head, followed by rolling onto the sternum, bleating, pushing up onto the knees, and then attempting to stand. These behaviours can proceed rapidly, with some lambs standing within a few minutes of birth, and most lambs standing within 30 minutes of delivery (Dwyer, 2003). The successful accomplishment of these behaviour patterns is vital for the formation of a strong attachment between ewe and lamb and for lamb survival.

Physiological differences exist between breeds in some aspects of the neuroendocrine processes that underlie maternal behaviour. In a series of studies comparing two British breeds of sheep, the Scottish Blackface and Suffolk ewes, Scottish researchers showed these breeds had significant and repeatable differences in all aspects of maternal behaviour (Dwyer, pers comm, 2013). Suffolk ewes were slower to begin grooming their lambs after birth; groomed their lambs in a series of short bouts, so spent less time licking lambs; made fewer low-pitched bleats to their lambs; and accepted a lower proportion of the suckling attempts of their lambs than did Blackface ewes. Suffolk ewes were also more likely to express fearful, aggressive or rejection behaviours towards the lambs particularly in maiden ewes. When offered a choice between their own lamb or a similar alien lamb in a y-maze, Suffolk ewes took longer to approach their own lamb than Blackface ewes (Dwyer, pers comm, 2013).

Merinos in Australia are generally regarded as being poorer mothers than other breeds. They spend less time at the birth site and have a much higher incidence of both permanent and temporary desertions of their lambs than other breeds (Dwyer, 2008). The results of the Scottish study demonstrate that significant variations in maternal care exist between breeds in behaviours important to the survival of the lamb, and this results in differences between breeds in lamb mortality when managed under identical conditions.

Within-breed studies have also indicated differences in ewe maternal behaviour. Merino ewes selected for superfine wool were less maternally responsive and had higher lamb mortality than broader wool Merinos. Cloete and Scholtz (1998) demonstrated where improved maternal ability was the aim, lamb survival was greater for Merino ewes selected for fertility and success in rearing multiple offspring, than for unselected or divergently selected lines. In this study, the selection criteria decreased desertion of lambs, although the main effect appeared to be an improvement in parturition, such as ease and speed of delivery (Cloete, pers comm, 2013).

Selection on the basis of maternal behaviour is difficult and relies on proxy measurements that may be only partly related to maternal care. The opportunity of developing gene marker tests that predict maternal behaviour exist due to the significant breed differences in these measurements and the correlation of behavioural traits with some aspects of maternal physiology (Hickford, pers comm 2013). There is also some evidence to suggest that lamb behaviour can be influenced by genetics, and hence the selection for lamb vigour would improve lamb survival (Dywer, 2008).

Nutrition

The survival of newborn lambs in the first hours following birth is significantly influenced by dam nutrition. Adequate transportation of nutrients across the placenta and mammary gland is required for the proper development of the foetus.

Suboptimal nutrition during pregnancy can negatively affect birth weight and early postnatal growth. The retardation of the growth of the mammary tissue will affect the lactation period, leading to reduced colostrum and milk production for the newborn lamb. This in turn affects growth and lamb survival. Failure to adequately manage ewe nutrition can also increase the duration and decrease the ease of parturition and negatively impact on the bond between the ewe and lamb.

Birth weight is perhaps the most important factor contributing to lamb survival. As evidenced in “Lifetimewool”, it is generally accepted that there is a curvilinear relationship between birth weight and survival to weaning. Lamb mortality is greatest at both the high and low birth weights and survival is optimised between 3 and 5 kg (Trompf *et al*, 2011). This suggests that manipulating ewe nutrition during pregnancy to increase birth weight, particularly among multiples, will improve lamb survival. It must be remembered however, that any increase in the average birth weight of single born lambs is likely to increase the chance of difficult birth and dystocia and therefore decrease survival.

Difficult births in single born lambs are commonly associated with higher birth weights but are also particularly prevalent in lighter lambs within highly fecund flocks, possibly resulting from prolonged parturition (Everett-Hincks *et* al, 2007). Lambs that endure difficult births have trouble maintaining body temperature and have inhibited behaviours in teat searching and suckling (Dwyer, 2003). This can increase the chance of death when the lamb is subjected to cold stress or undernutrition.

Mal-presented births have been shown to be more frequent in single and triplet born lambs than twin born lambs (Dwyer, 2003). While lamb birth weight is a well-recognised risk factor for explaining the difficulty of a singleton birth, the reason for difficulties in triplet-born lambs is less clear. It was suggested by Dwyer (2003) that in single and triplet bearing ewes there is less space in the uterine horn and therefore less room for the foetus to move freely. This may result in the foetus being expelled in an incorrect position.

Lamb birth weight is also strongly linked to placental development. Insufficient nutrition during gestation can reduce cotyledon numbers and development, thus inhibiting the adequate supply of nutrients and oxygen to the foetus. Placental insufficient lambs are often identified by light birth weight, greater plasma lactate concentration and packed cell volume, which all indicate signs of prolonged hypoxemia (Kerslake, 2010). Because the nutrient and oxygen transfer capacity of the placenta is reliant on the surface area of the placenta, which in turn is affected by the number of placentomes and utero-placental blood flow, multiple born lambs are at greater risk of placental insufficiency when compared to single born lambs (Kerslake, 2010). In a study by Dywer *et al*. (2005), they demonstrated that multiple born lambs had fewer cotyledons per foetus, they were slower at standing and suckling and had lower rectal temperatures. They also have a reduced ability to produce heat. All of these factors have a negative impact on the survival capacity of the newborn lamb after birth.

If ewes lose approximately 5 kg in the first 90 days of pregnancy, placental development and multiple lamb birth weights will be reduced. Ewes losing more than 12% of their mating live weight up to day 90 of pregnancy may have up to 10% lower lamb birth weights, regardless of late pregnancy nutrition (Kenyon, pers comm, 2013). Lambs with a lighter birth weight have a greater surface-area-to-birth-weight ratio than lambs of a heavier birth weight. They also have less energy reserves and are slower at standing and suckling after birth (Dwyer, pers comm, 2013). By having a greater surface-area-to-birth-weight ratio, the lighter lamb will lose more heat to the environment than the heavier lamb, making it more susceptible to excessive heat loss. Excessive heat loss occurs when exposure to cold weather conditions cause the lamb to lose more heat than it is able to produce (Dwyer, pers comm, 2013). Such an event generally occurs directly after birth, where wind, rain and birth fluid on the coat can cause rapid heat loss to the environment.

If a light weight lamb is able to produce enough heat to counter the heat being lost, it is still at a disadvantage. This is because, compared to a heavier lamb, a lighter lamb has a greater lower critical temperature below which it must generate heat to maintain a homoeothermic status (Kerslake, 2010). This need to generate heat earlier than a heavier lamb places greater demand on the energy reserves of a lighter lamb. A lighter lamb will therefore exhaust its energy reserves faster than a heavier lamb during a cold stress event. Failure to produce enough heat to counteract heat loss will result in hypothermia. The lighter birth weight of lambs offers some explanation as to why starvation/exposure syndrome is more commonly reported in litters of two or more (Kerslake, 2010).

The inadequate udder seeking behaviour of light birth weight lambs affects the amount of colostrum they are able to ingest. This results in an inability of the lamb to replace utilised energy reserves and to sustain heat production, and the onset of hypoglycaemia (Nowak, pers comm, 2013). An insufficient intake of colostrum can also result in inadequate immunoglobulin transfer from mother to young increasing the risk to infection after birth (Nowak, pers comm, 2013). French scientists concluded that because energy reserves available for heat production are finite, and because immunoglobulin absorption in the newborn intestine ceases at 24 to 36 hours of life, an early intake of colostrum is vital for provisions of extra energy reserves for thermoregulation and immunity to fight infections. Failure to consume colostrum will increase the risk of the newborn succumbing to hypothermia or infection after birth (Nowak and Poindron, 2006). Increasing the birth weight of twins and triplet born lambs is advantageous, as lambs of heavier birth weights are better equipped to survive conditions predisposing them to exposure and starvation. They have more energy stored as brown fat reserves and maintain their suckling drive for a greater duration than lighter lambs (Kenyon, pers comm, 2013).

Maternal undernutrition during pregnancy can result in poor maternal behaviour. Dwyer *et al*. (2003) demonstrated that a moderated reduction in maternal nutrition during late pregnancy resulted in a measureable reduction in the expression of maternal behaviours, in particular maternal behaviour score (MBS). MBS gives an indication of the strength of the ewe-lamb attachment when separated. Dam MBS has a significant effect on lamb death risk to starvation/exposure and dystocia where ewes with lower scores had higher lamb mortality rates (Dwyer *et al.*, 2003).

Ewes that are underfed during pregnancy have differing physiological profiles during the gestation period compared to ewes that are adequately fed. Low nutrition is associated with higher plasma progesterone in late gestation and a lower ratio of oestradiol to progesterone at birth. High plasma progesterone is negatively related to colostrum and milk yield and therefore threatens the survival of newborn lambs. In addition, progesterone and oestradiol are involved in the onset of maternal behaviour, and high ratios of oestradiol to progesterone are correlated with maternal grooming behaviour (Mousa-Balabel, 2010). Therefore, nutrition of ewes during the gestation period and at parturition can also influence ewes' maternal behaviour. Gestationally undernourished ewes display impairments that will affect the quality of their maternal relationship with their lambs. They will take longer to interact with their lambs, display more aggression, spend less time grooming and more time eating after birth and are more likely to desert their lambs.

One of the major determinants of lamb survival is nutrition of the ewes as reflected in body condition score at parturition. For Merino ewes, peri-natal lamb mortalities are likely to be over 50% if twin bearing ewes approach lambing in body condition score below 2. Although pre-partum condition scores appear to account for much of the lamb losses, there is a range of reported mortalities between 10 and 30%, even when ewes have higher than condition score 2. Holst *et al*. (2002) suggested that spinal and cranial meningeal lesions may be the reason for variable mortalities in ewes that are in adequate condition. Meningeal lesions are considered to be due to low feed intake immediately after pre-partum and the consequent slow clearance of progesterone resulting in dysfunctional parturition (Rowe, 2003).

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 pre-lamb feeding in ewes carrying more that one lamb. Scales *et al.* (1986) reported that a 10 kg increase in liveweight during the last six weeks of pregnancy resulted in an increase in birth weight of 0.46 kg for singles and 0.52 kg for twins. In a 2002 study with Romney ewes, 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 triplets increased litter weight at birth by 2 kg and improved litter survival to tagging by 4% (Everett-Hincks *et al.*, 2005).

Improving ewe nutrition pre- and post-gestation will lead to improvements in birth weight, energy reserve accumulation, efficient utilisation of energy reserves, and the intake of colostrum for sustainable heat production. This may help the ability of newborn lambs to increase and/or sustain heat production during a cold stress event.

Management

Within Australia, opinion is divided on the benefits of supervision at lambing time on ewe and lamb survival in extensive systems. Generally it is agreed that the ideal is for the ewe to give birth unaided and for ewe and lamb bonding to occur without human intervention. However, intervention decisions must be made whilst the ewe is in labour in order to determine whether a ewe or lamb will survive if left alone. Thus it can be difficult to know whether these interventions are genuinely helpful.

Fear, stress and disturbance are known to cause involuntary suppression of uterine contractions in mammals in labour, presumably to be able to deal with the presence of a predator or to escape from a stressor before giving birth (Dwyer, pers comm, 2013). For ewes unaccustomed to human presence, close supervision may act as a source of stress and unnecessarily delay or prolong parturition. A prolonged labour affects the expression of ewe maternal behavioural development and reduces lamb survival (Dywer, 2003). Thus a low stress environment for lambing ewes is likely to be associated with better welfare of the ewe, and improved lamb survival.

It is inevitable that with improvements in lambing percentages, adjustments to the overall management of the production system will need to be made. For example, very different management and production practices are required farming at 150 % lambing compared with 110%. At higher lambing percentages planning and management requires greater decision-making to closely match feed supply and animal demand. In addition to stock policy decisions, fertiliser application, selection of pasture varieties for improved feed production, provisions of stock shelter and adequate sub-division for effective feed planning will require consideration to support higher lambing percentages.

Pasture based grazing enterprises aim to achieve a balance between the demands of the grazing animals and the relatively unpredictable fluctuations in herbage supply. In Australia and New Zealand, pasture grazing guidelines for late pregnancy have been developed for single and multiple-bearing ewes. In New Zealand, these guidelines suggest using high quality pastures, mainly ryegrass (*Lolium perenne*) and White clover (*Trifolium repens*), to match the high production levels of pregnant ewes. However, a recent study showed that the dry matter intake of a triplet-bearing ewe is maximal on a ryegrass and clover sward of 4 cm or higher (Morris and Kenyon, 2004). From this study, the calculated energy intakes of triplet-bearing ewes grazing a sward height of 4 cm or higher suggest that they were unable to consume enough herbage to meet their theoretical energy requirements of their foetuses. In the same study, triplet-bearing ewes mobilised a greater amount of body reserves than twin-bearing ewes. This provides further evidence that triplet-bearing ewes were not consuming enough pasture to meet the energy requirements of their foetuses (Kenyon, pers comm, 2013).

From this research, it is becoming more evident that traditional ryegrass-white clover sward mixes are not suitable for many high production sheep systems. The International Sheep Research Centre at Massey University, New Zealand has developed a 'herb mix' that includes chicory (*Cichorium intybus*), plantain (*Plantago lanceolata*), Red (*Trifolium pretense*) and White clover based on agronomic properties and through animal preference studies. Studies show this mix can improve weaned lamb growth rate and the lactational performance of multiple bearing ewes (Fig. 3) (Kenyon, pers comm, 2013). It is hypothesised that pasture species currently used in Australia cannot support the nutritional requirements of multiple-bearing ewes.

Figure 3: Plantain, ryegrass, lucerne and Red clover pasture, Fraser Avery, New Zealand. (M Ipsen, 2013)

Because herbage intake can be limited by physical constraint (bulk and high water content) and rate of forage removal from the rumen (fibre), it can be difficult for high producing animals to consume enough herbage to meet their nutrient requirements (Forbes, 1996). This is especially true for multiple-bearing ewes whose ability to consume pasture may be restricted due to the limited space in the abdomen or limited capacity to ingest dry matter at the end of pregnancy. Offering energy and protein concentrates to grazing ewes has the potential to alter the metabolisable energy (ME) supply, the utilisation of ME, the amount of microbial protein synthesised, and the amount of dietary protein that escapes the rumen (Kerslake, 2010). Adding concentrations to hay, or pasture diets have been shown to increase total ME intake of single, twin, and triplet-bearing ewes during late pregnancy. Offering concentrates to pasture fed ewes may therefore be a management option to improve total energy intake of the ewe and to improve the growth and development of the foetus (Kenyon, pers comm, 2013).

Inclement weather in late pregnancy has been shown to have as much or more effect on lamb survival than inclement weather during lambing (Everett-Hincks and Dodds, 2008). In the last four to six weeks of pregnancy, intake often declines and the ewe, particularly those carrying multiples, will mobilise body reserves to meet both their own energy demands and those of their lambs. Any energy imbalance at this time will be exacerbated by inclement weather, thus decreasing lamb viability and subsequent survival (Everett-Hincks and Dodds, 2008).

Inclement weather can lead to high mortality rates during and shortly after a bad weather event. These deaths are largely due to hypoglycaemia (decrease of blood level sugars) due to depletion of body reserves of fat, which in turn produces hypothermia and death (Hatcher *et al*, 2010b). The provision of shelter in inclement weather has been reported to reduce lamb mortality on average by 10% (in single lambs by 3-13% and by 13-37% for multiple births) (Hatcher *et al*, 2010b).

In many countries, housing pregnant ewes to lamb has been used to improve lamb survival. Lamb mortality in housed flocks tends to be lower than outdoor flocks. Mortality rates of approximately 9% are given for mainly housed flocks (Dywer, 2008). Housing and intensive shepherding at lambing have reduced the incidence of stillbirths because ewes with dystocia can readily be identified and lambing assistance given. In addition, lambs that are protected from hypothermia and predation, disease, or ill health can be treated promptly and the practice of individually housing parturient ewes and their newborn lambs in small pens reduces lamb abandonment (Dwyer, pers comm, 2013). Housing triplet bearing-ewes in the United Kingdom allows for one of the triplet lambs to be fostered onto a singleton-bearing ewe.

Muir and Thompson (2009) conducted an on-farm research project for Meat and Wool New Zealand, and concluded that there is an opportunity to transfer a problem mob (the scanned triplet ewes) from outdoors to more intensive systems for lambing. The Poukawa Elite Flock historically has lamb survival rates of singles (90%), twins (88%) and declining to 79% in triplets. Muir and Thompson (2009) found transferring scanned triplet ewes from an extensive system to an intensive system for lambing significantly increased lamb survival (extensively 171% lambing vs intensive 222% lambing). It also reduced ewe mortality (9% vs 4%) and ewes under intensive management weaned 58.2 kg lamb/ewe whereas the triplet ewe left on the extensive property weaned to 47.4 kg lamb/ewe.

However, there is an increased risk of mortality because of infectious disease during housed lambing. Housing pregnant ewes, as observed in the United Kingdom- and in French-designed systems, at a relatively high stocking density, disrupts the behavioral patterns of the parturient ewe, which is motivated to seek isolation or seclusion. Preventing this behavioural response brings parturient ewes into close contact with one another and increases the frequency of mismothering and attempted lamb stealing. In addition, disruption after birth can affect the development of the ewe-lamb bond and may cause the ewe to leave the birth site early. Nowak (1996) observed a considerable improvement in twin lamb bonding with their dam and twin lamb survival when the mother remained at the birth site for a minimum of 6 hours. If paddock pasture quality and feed levels are good and the paddock has adequate shelter, then the ewe will stay at the birth site with her lamb for a greater period.

Although labour has been identified as an important factor in good sheep welfare, the extra labour costs associated with housing ewes has a detrimental financial impact on farm profitability. While in the United Kingdom lower input systems are becoming increasingly attractive as subsidy payments and farm incomes decline, in New Zealand two farm technology initiated programs have improved profitability by increasing survival rates of housed triplet born lambs (Kenyon, pers comm, 2013).

Wynand du Toit, a South African Dohne stud breeder, demonstrated lamb weaning percentages of 201%, which were achieved by individually penning 4200 ewes (Fig. 4). With 70% of ewes pregnancy scanned as multiple-bearing ewes, multiple born lamb survival rate was improved by 57% when compared to lambing outdoors. Lamb survival also increased to 92%. Under a costing analysis, the extra expense incurred for erecting the facility and all associated costs of lambing pens and labour, could repay the investment in two years and three months, if the profit went into repaying the investment only (du Toit, pers comm, 2013).

Figure 4: Wynand du Toit, Indoor lambing shed, Bredasdorp, South Africa. (M Ipsen, 2013)

Potential gains from management include monitoring and managing the body condition of ewes during pregnancy via improving the quality and quantity of pasture, and supplementation when required, to increase the birth weight of neonates and increase colostrum and milk production. Housing and individual penning of strategic flocks will increase the maternal bond, manage dystocia and starvation/exposure and the risk to climatic conditions.

Conclusion

The extensive Merino production systems in Australia and complexities of lamb survival result in major sheep reproduction inefficiencies, where lamb mortalities are estimated to be more than 30%. Such reproductive wastage has an economical impact but also is an animal welfare concern, adding further incentive to develop strategies to improve lamb survival.

Selecting sheep with a genetic propensity for lamb survival is a very beneficial and desirable option. Failure to include it as a trait in breeding objectives could result in a genetic decline over time. However, despite very low heritability estimates for lamb survival, and some researchers around the world suggesting genetic improvement will be ineffective, modest genetic gains appear to be possible.

Commercial producers would be best advised to select replacement animals on TWW ASBVs. Buying rams with positive TWW will sire daughters that wean a higher percentage of lambs. It must be taken into consideration that while gains will be slow, when combined with other lamb survival traits, the effects will be cumulative.

Selection intensity on maternal rearing ability will also have benefits for producers, as fertility at an early age is indicative of fertility and lamb rearing ability in later life. Removing the bottom 25% of the flock, based on maternal rearing ability, and retaining the top 25% for an extra year can substantially improve the average reproductive performance of the flock. The use of ultrasound pregnancy scanning and classifying ewes as “wet” or “dry” at weaning will identify those ewes that have successfully reared at least one lamb. The use of radio frequency identification discs and “Pedigree Matchmaker” software will further improve the accuracy of identifying ewes that rear all of their lambs.

Events occurring in the early postnatal period are critical for lamb survival because most lamb deaths occur during this time. The key recommendation from this report is to improve dam nutrition. Improving ewe nutrition pre-partum will increase birth weight, which is the most important factor contributing to lamb survival and ensure the ewe will have sufficient body reserves at parturition to facilitate a quick delivery, begin lactation with an adequate quantity of colostrum and provide satisfactory maternal care to her lamb. The lamb will benefit by having a greater amount of body reserves, particularly brown adipose fat, to metabolise post birth. Merino producers can facilitate this by ensuring the nutritional requirements of breeding ewes, particularly multiple-bearing ewes, are met during the later stages of pregnancy.

Ensuring the nutritional demands of ewes in each stage of pregnancy and the key to achieving higher production in the most cost effective manner is best accomplished from pastures wherever possible. Pastures that are of a high quality and have some legume content will safeguard ewes' body condition for lambing. Similarly, provision of a suitable lambing environment that encourages the ewe to choose a sensible birth site and remain there for at least six hours is likely to improve the chance of individual lambs surviving their first week of life.

The method of housing pregnant ewes, as used in many other sheep producing countries, could decrease lamb mortalities to rates of approximately 9%. The high cost of infrastructure and labour will lead many producers to disregard the concept. However, both in South Africa and New Zealand it has been proven to be an economically viable option, particularly when targeting specific mobs (light weight twin-bearing ewes or triplet-bearing ewes).

While the use of proxy traits for lamb survival, (lamb vigour at birth, birth coat score, lamb to bleat, rectal temperature and crown-rump length) have been identified as accelerating genetic selection, they do not immediately appeal as easy, cheap and quick to measure indicator traits in commercial breeding programs. Although rectal temperature and skeletal measures of lambs at birth are less time consuming to measure and well genetically correlated with lamb survival, especially to three days of age, they also require further investigation to determine their commercial usefulness. Current research underway in Australia is investigating the difficulties of collecting some of these proxy traits to improve lamb survival. The CSIRO-led collaboration with the University of New England is researching the use of SmartTag technology to measure ewe and lamb behaviour during and immediately after birth in a commercial situation. The results will help improve field-based measures for assessing lamb vigour. The researchers are looking specifically at the duration of labour and the time it takes the newborn lamb to bleat. The ewes are fitted with SmartTags that contain sensors that record each ewe's movements and both the ewe and lamb's vocalisations. The resulting information has the potential to increase lamb survival as studies around the world have shown consistently high genetic correlations between timed lamb behaviour and lamb survival to three days of age.

Other areas of investigation are in gene marker technologies. Scottish researchers have suggested the possibility of developing gene marker tests, which may identify young ewes that will show different qualities of maternal care. South African researchers recently investigated the use of the CYP17 gene marker, a genotype which has previously been linked to the ability of Angora goats to cope with external stress. They investigated whether the observed divergence in fitness (as reflected by number of lambs weaned) observed in a Merino selection experiment can be related to the genotypic composition of ovine CYP17. However, the difference in stress responses was not attributed to CYP17 genotype but suggests other factors along the DNA axis could be implicated in the stress response difference observed.

While a silver bullet for improving lamb survival, particularly in the first three days of life was not found, these are the key research and management practices from around the world which will help Australian sheep producers improve reproductive performance through increased lamb survival and reduced ewe mortality, improve farm profitability and mitigate consumer concerns for welfare standards.

Recommendations

The key research and management practices from around the world are:

- Ultrasound pregnancy scan for multiples with EID technology including Pedigree Match Maker or DNA Parentage.
- Select replacement rams on Australian Sheep Breeding Values for total weaning weight.
- Select replacement ewes on maternal rearing ability as fertility at an early age is an indicator of rearing ability in later life.
- Use the method of housing pregnant ewes, targeting specific mobs like lightweight twin bearing or triplet ewes.
- Improve ewe nutrition. Improving ewe nutrition pre-partum will increase birth weights of lambs providing greater amounts of body reserves to metabolise post birth and ensure the ewe has sufficient reserves to facilitate a short parturition, begin lactation with adequate quantity and quality of colostrum and increase the maternal-lamb bond.

Further investigation is required to determine the optimal combination of indirect selection methods (proxy traits) that can further improve lamb survival and can be implemented under practical field conditions.

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Plain English Compendium Summary

Project Title:	World's Best Practice in Lamb Survival
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Scholar:	Matthew Ipsen
Organisation:	Ewe Wish
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Objectives	This report provides an investigation into improving lamb survival, particularly in the first three days of life. It aims to explain what research and management practices are being utilised in major sheep producing nations.
Background	Poor lamb survival is recognized in Australia as a major contributor to reproduction inefficiency in the national flock. Improving lambing percentage is the biggest contributor to farm profitability and has breeders selecting for improved fecundity. However, improving the number of lambs born is often negated by decreases in lamb survival. This is associated with the increase in multiple births.
Research	Research was conducted in Scotland, France, South Africa, Argentina, Uruguay and New Zealand. Meetings were conducted with researchers, consultants and leading farmers in the field.
Outcomes	• Ultrasound pregnancy scan for multiples with EID technology • Select replacement rams on Australian Sheep Breeding Values for total weaning weight. • Select replacement ewes on maternal rearing ability. • Use the method of housing pregnant ewes, targeting specific mobs like lightweight twin bearing or triplet ewes. • Improve ewe nutrition pre-partum. Further investigation is required to determine the optimal combination of indirect selection methods (proxy traits) that can further improve lamb survival and can be implemented under practical field conditions.
Implications	The information in this report intends to provide sheep producers with information to formulate appropriate management programs to improve lamb survival rates.
Publications	