

Lamb survival – balancing genetics, selection and management

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Abstract. The historically small size of the Australian sheep flock, 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 the Merino. The major obstacle to improving net reproduction rate (NRR, the number of lambs weaned per ewe joined) is lamb survival. The animal welfare issues relating to lamb survival are discussed along with the major causes of lamb loss and factors that impact on lamb survival. The successful rearing of a lamb to weaning is the culmination of a sequence of often interrelated events involving 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. Three options are available for commercial sheep producers to improve reproductive efficiency. Firstly, Australian Sheep Breeding Values (ASBVs) can be used to select rams whose daughters will wean a higher percentage of lambs leading to improvements in lamb survival in future generations. Secondly, a combination of 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. Thirdly, management options that involve monitoring and actively managing ewe nutrition during pregnancy and optimise the features of a lambing paddock will help boost lamb survival. Actively managing the body condition of the ewes during pregnancy to a target fat (or condition score) of 3 can significantly improve lamb survival, particularly that of twins. Minimising the impact of chill within the lambing paddock through reducing wind speed, increasing temperature and reducing dampness will enhance lamb survival. The benefits of each of these three options are cumulative, such that improvements in NRR of 14% within 10 years are possible. However, prior to the development of extension programs endorsing these three strategies to improve lamb survival, they must be demonstrated in commercial flocks across a range of production environments and proven to work over a number of seasons.

Keywords: Merino sheep, net reproduction rate, ASBVs, ewe selection, rearing ability.

Introduction

The Australian sheep flock is at its smallest since 1905, currently numbering approximately 72 million head (Australian Bureau of Statistics 2009). At this level, many industry commentators are questioning the long-term sustainability of the flock and its associated industries. Significant changes in the structure of the national flock have also occurred, with ewes now representing 73% of the national flock, 85% of these being pure Merino (Curtis 2009). Of sheep more than 12 months old, 80% were ewes and 89% of these were Merino. The Merino ewe now plays a pivotal role in the national flock, being the dominant wool producer and influencing prime lamb production directly through the use of terminal sires and indirectly though breeding first cross ewes for specialist prime lamb production. Merinos contribute an estimated 59% of the genetics to the Australian sheep meat (lamb and mutton) industries (Apps et al*.* 2003). It is in this context that improving the reproductive efficiency of the Merino ewe in particular is crucial to the future of the Australian sheep industry.

The average reproductive performance of Australian specialist sheep enterprises was 76.9% lambs marked per 100 ewes joined between 1977–2009 (ABARE 2010) with only marginal improvement occurring over the past 30 years (Figure 1). The major source of reproductive wastage is lamb loss (Kleemann and Walker 2005). Published reports of the magnitude of loss range from 4 to 72% of lambs born (Arnold and Morgan 1975; Smith 1962).

It is often difficult to accurately quantify the extent of lamb mortality as counts of observed lamb carcases are notoriously unreliable; however, losses are commonly accepted to range between 20 and 25%. Reported mortality rates of single born lambs range between 6 to 30% (Atkins 1980; Egan et al*.* 1972; Hatcher et al*.* 2009; Kelly 1992; Knight et al*.* 1975) with losses of twin lambs generally double that of singles in the same flock (Fowler 2007; Kelly 1992). However, significant variation occurs between flocks in lamb survival.

Current *Wean More Lambs* (Australian Wool Innovation and Meat & Livestock Australia 2008) lamb survival targets are 90 and 70% (i.e. 10 and 30% mortality) for single and twin-born lambs respectively. Pope and Atkins (2009) reported average survival rates of 80% for singles and 67% for twin lambs born between 1975 and 1983 at Trangie Agricultural Research Centre (TARC) in western NSW, which is a relatively benign lambing environment. While these figures are slightly lower than the industry targets, they indicate that lamb mortality is a significant contributor to lowered reproductive efficiency. It is also apparent that there is considerable variability in the extent of lamb loss between years within regions.

Improving the net reproduction rate (NRR), the number of lambs weaned per ewe joined, while pivotal to the future of the Australian sheep industry can also significantly improve on-farm profit (Table 1). Recent sheep enterprise gross margins per dry sheep equivalent (GM/DSE) published by Industry and Investment NSW show that increasing weaning rates by 10% can increase GM/DSE by 10% for enterprises focussing on wool production and by 15% for those specialising in meat production (Casburn 2010). The increase in GM/DSE for producers with a dual purpose wool and meat business was within the 10-15% range. For all enterprises, a further 10% increase in NRR generates a 21 to 30% improvement in GM/DSE.

Other modelling work using GrassGro® (Moore et al*.* 1997) based on November 2010 wool prices and a fine wool enterprise, indicates a benefit of 5% in $/ha for a 10% increase in NRR (P. Graham, *pers com,* 2010). The 5% improvement in returns per hectare was partly the result of a higher pasture utilisation rate. The benefits would be greater than 5% for a prime lamb based enterprise.

A potential obstacle to improving NRR is lamb survival, as the benefit of increasing the number of lambs born through improvements in fertility is often negated by decreases in lamb survival due to an increase in multiple births (Slee et al*.* 1991). Any on-farm strategies to improve NRR should therefore aim to increase the proportion of lambs surviving. Given that improvements in fertility are generally driven by an increasing proportion of ewes carrying twins relative to singles, improving the survival of twin born lambs will be crucial.

Lamb survival and animal welfare

While the lamb is *in utero*, it is exposed to a number of conditions that keep it totally unconscious. These include a low level of oxygen (25% of that in conscious adult sheep), a high level of carbon dioxide (35% above conscious adult levels) and a high level of progesterone produced by the placenta. Two metabolites of progesterone, pregnanolone and allopregnanolone, have anaesthetic actions in adult sheep and humans, while the placenta itself produces a specific inhibitor of consciousness. Warmth and a lack of tactile stimulation also assist in rendering the foetus unconscious.

At birth all of the conditions that were keeping the lamb unconscious disappear and the lamb becomes increasingly aware of its surroundings. The activation of cold receptors on the skin jolts the lamb into consciousness while the normal levels of oxygen and carbon dioxide in the air result in the lamb taking a few gasping breaths before beginning to breath rhythmically and normally. Therefore from a pain and suffering point of view, still born lambs do not constitute an animal welfare problem. The limited evidence in the literature that deals with welfare implications of a ewe bearing a still born lamb suggests that this is a short-term stressor. Without the suckling stimulus, maternal drive does not remain high for very long.

However, many welfare challenges are faced by new born lambs that survive birth. These include hunger, hypothermia, possible pain and injury resulting from the birth process and management interactions, as well as sickness from infectious diseases and distress from maternal separation (Dwyer 2008). A difficult birth can lead to the death of the lamb without significant suffering if pulmonary respiration has not been established (Dwyer 2008). However, difficult births can injure a lamb, which then suffers pain as a result of birth trauma. These lambs tend to have low vigour and a reduced ability to suck successfully which generally results in a weak relationship established with its mother. Low birth weight lambs suffer a similar suite of handicaps which can reduce their ability to maintain body temperature, increase their risk of infection, and their stress reactivity throughout life (Dwyer 2008). Low birth weight difficulties are also associated with hypoxia. However, it is likely that the lack of oxygen acts as an analgesic minimising any neonatal suffering.

Causes of lamb loss

The majority of lamb loss occurs in the early post-natal period (Brien et al*.* 2010; Hatcher et al*.* 2009; Moule 1954; Venkatachalam et al*.* 1949). Nearly half of all pre-weaning deaths occur on the day of birth (Dwyer 2008) with the rate of lamb loss greatly reduced once the lamb is one week old (Hatcher et al*.* 2009; Sawalha et al*.* 2007). An industry recognised lamb autopsy procedure (Holst 2004) identifies 10 potential causes of lamb death. The most common causes are dystocia (20%), birth injury (47%), starvation (21%) and other (12%, including exposure, predation and premature birth) (Holst et al. 2002).

Primary predation of otherwise healthy lambs is uncommon, although sporadic events do occur (Haughey 1983). On a national basis, primary predation is not a major cause of lamb loss. However, it may be in some localised regions of the country where populations of wild dogs or pigs are prevalent. Secondary predation occurs on lambs that were vulnerable and more likely to die in the absence of predation. Autopsies of dead lambs that have been partially eaten often show evidence of starvation or dystocia symptoms.

Identification of the likely cause of lamb loss can assist in developing management interventions to reduce losses. Dystocia commonly occurs due to foetal-pelvic disproportion or mal-presentation and occurs usually as a result of inappropriate sire selection, high birth weights or small ewe pelvic size (Haughey 1983; Haughey and George 1982; Haughey et al. 1985). More recently Dutra et al. (2007) identified hypoxic-ischemic (HI) lesions which appeared to be related to birth injury. These lesions may result from prolonged labour, premature rupture of the umbilical cord, repetitive cord occlusion, strong or poor myometrial contractions and dystocia. The HI episodes causing the lesions can be brief, intermittent or severe and can affect foetal breathing, body movement, heart rate, endocrine system, metabolism, central nervous system (CNS) blood supply and maternal myometrial contractions (Dutra et al. 2007).

The occurrence of birth trauma may be due to a progesterone/oestrogen imbalance at parturition as a response to reduced metabolism of progesterone (Parr et al. 1993). There is some evidence that prolonged parturition is associated with birth trauma and low survival rates among twin and triplet lambs (Everett-Hincks et al. 2007). Birth injury, as evidenced by the various forms of CNS system damage, is often linked to starvation as a secondary cause of death. Starvation consistently ranks as a major cause of lamb death. While a component of this is likely to be associated with maternal care; poor ewe nutrition in late pregnancy may be an important contributing factor. For example, the early production of colostrum and the weight of colostrum available are reliant on a rapid fall in progesterone prepartum (Banchero et al. 2006; Hartmann et al. 1973).

Factors affecting lamb survival

Lamb birth weight, birth type, maternal nutrition, dam age and sex all impact on lamb survival (Hatcher et al. 2009). Of these factors, birth weight is perhaps the most important. It has long been accepted that there is a curvilinear relationship between birth weight and survival to weaning with lamb mortality being greatest at both high and low birth weights and survival optimised between 3 and 5 kg regardless of birth type (Atkins 1980; Fogarty et al. 1992; Purser and Young 1959). This suggests that manipulating ewe nutrition during pregnancy to increase birth weight, particularly among multiples, will improve lamb survival. However, recent work has established that the relationship between birth weight and survival is distinctly different at various time periods following birth. Hatcher et al. (2009) found that the birth weight versus survival curve at birth was flatter than that at weaning (Figure 3), indicating that survival of single-born lambs at birth is not very sensitive to birth weight. In fact, any increase in the average birth weight of single born lambs is likely to increase the chance of difficult birth and dystocia and decrease survival.

The same trend was evident for twin and multiple born lambs (Hatcher et al. 2009). Therefore increasing birth weight may not be a viable solution to increase survival of multiple born lambs either. Recent evidence (Refshauge et al. 2010) showed that HI lesions determined by autopsy had no relationship with birth weight. Furthermore Vazquez-Lachas et al. (2010) showed that that probability of birthing difficulty, via evidence of subcutaneous oedema observed at autopsy, increased with birth weight with the probabilities differing significantly between years at the same birth weight. Therefore in some years more lambs will be challenged by birthing difficulties than in others, which may explain some of the between-year variation in lamb survival. Given that uterine capacity is similar across breeds of sheep (Hinch et al. 1983) and there is a general trend of a decrease in individual lamb birth weight with an increase in litter size (Cloete et al. 2002), the physical capacity of a Merino ewe to carry heavier lambs in multiple litters is questionable.

For those lambs that do survive birth, heavier birth weight was a definite advantage in surviving the early post-natal period. However, for all birth types the relationship between birth weight and survival between seven and 30 days post birth was essentially flat (Hatcher et al. 2009) indicating that manipulating birth weight would provide little improvement in survival to marking.

Female lambs are more likely to survive than males and singles relative to multiples. Mullaney (1969) reported a higher incidence of still births among male lambs which may be related to their heavier birth weights. There are many reasons for the lower survival of multiples; including increased incidence of malpresentation-induced birthing difficulties (George 1976; Nawaz and Meyer 1992), 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. For twin born lambs, Hatcher et al. (2009) found that survival to seven days of age was positively associated with the survival of their litter mate as there was an 8% improvement in survival if both twins survived birth. However, after seven days of age survival of twins was negatively related to the number surviving, favouring those whose litter mate had died. Presumably this finding is related to suckling twin lambs increasing both colostrum and milk production, which then favours the surviving lamb if its litter mate succumbs.

Many researchers have also highlighted decreased lamb survival from younger and older age dams (Dalton et al. 1980; Hatcher et al. 2009). Younger ewes tend to have lower birth weight lambs and fewer losses due to difficult labour than older ewes (Purser and Young 1964). They also tend to have poorer maternal behaviour than older ewes especially when undernourished (Lindsay et al. 1990). Older ewes have a higher potential for udder damage which can negatively affect lamb survival (Jordan et al. 1984), despite their higher physiological capacity.

Available options to improve lamb survival

The successful rearing of a lamb to weaning is the end result of a series of complex events involving animal physiology, behaviour, genetics, nutrition and the prevailing environment during late pregnancy and lambing. Many 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 flock.

Given the typical low-input Merino production systems operating in Australia and the complexity of lamb survival, the small increase in net reproductive rate of specialist sheep enterprises in Australia over the past 30 years comes as no surprise. During this time there has been a plethora of industry funded extension programs across all states. These programs have had a focus on flock efficiency and reproduction. Unfortunately on a national basis, many of them have had limited adoption in relation to sheep reproduction and lamb survival (Barnett 2007). The diverse nature of the Australian sheep industry itself, seasonal conditions, environmental variation, production systems, market opportunities and competition from other enterprises, has restricted the broad adoption of best practice sheep reproduction methods. Nevertheless at a regional level there is evidence that improvements in NRR have been achieved. In mid-2007, producers from the Yass region indicated that their participation in Prograze™ had increased lambing percentages by an average of 10% due to: (i) better knowledge of ewe feed requirements at key times of the year (conception and lambing) and matching these with better pasture paddocks specifically set aside for these two periods; (ii) altering the time of lambing to early spring to better match feed demand with the pasture growth curve; and (iii) using pregnancy scanning to better match available feed to individual ewe requirements (Davies and Graham 2007).

It is likely that the complex nature of lamb survival has meant that sheep producers have not always been able to identify where in the breeding cycle reproductive failure has occurred and consequently implement appropriate management interventions to ameliorate that failure. When poor seasonal conditions are also considered, along with accompanying restriction of cash flow, improving reproduction may often be considered too expensive to manage and too hard to achieve.

The rapid growth of the sheep meat sector and accompanying higher sheep and lamb prices along with the poor Merino maternal traits has recently accentuated the problem of low reproductive efficiency. There are three options available to commercial sheep producers to improve reproductive efficiency: (i) genetics to select future sires and dams and make future improvements, (ii) within-flock selection to make improvements in the current generation, and (iii) management, including both ewe nutrition during pregnancy, and optimising the lambing environment.

Genetic options

Selecting sheep with a genetic propensity for lamb survival is an attractive option. Genetics offers both a permanent and relatively low cost solution, the effects of which are cumulative over time. The potential to genetically improve lamb survival within a breed is reliant on a combination of factors including heritability, selection intensity, generation interval and the amount of available variation. Published estimates of the heritability of lamb survival are very low, they range between 0.008 - 0.07 and 0.002 – 0.075 for direct and maternal heritability respectively (Amer and Jopson 2003; Brien et al. 2010; Hatcher et al. 2010; Safari et al. 2005), although using data over a number of years can increase the realised heritability threefold (Lee et al. 2009a). There is also evidence that the heritability decreases with age of the lamb (Brien et al. 2009; Hatcher et al. 2010; Riggio et al. 2008; Sawalha et al. 2007; Southey et al. 2001) meaning that selecting directly for lamb survival must occur within the first week of life. The low heritability suggests that genetic solutions to lamb survival are unlikely to be significant, however, the high coefficient of variation (47–60%, Brien et al. 2010; Hatcher et al. 2010; Safari et al. 2005) of lamb survival can compensate for the low heritability.

To date no commercially useful indirect selection criteria for lamb survival have been identified. The best option available to commercial sheep producers is to select replacement animals based on NRR. A recent review (Snowder and Fogarty 2009) concluded that selection to improve reproductive efficiency and ewe productivity under most production and environmental systems would benefit from selection for a composite trait rather than for a single component trait. Australian Sheep Breeding Values (ASBVs) for the composite trait of number of lambs weaned (NLW) are now available through MERINOSELECT (Sheep Genetics 2009a). ASBVs are an estimate of the genetic potential that a sheep will pass onto its progeny (Sheep Genetics 2009b). Merino producers can use the number of lambs weaned (NLW) ASBV when making ram purchasing decisions, as rams with more positive NLW ASBVs will sire daughters that wean a higher percentage of lambs (Sheep Genetics 2009b). As at October 31 2010, there was a 46% range in the NLW ASBV in the Sheep Genetics MERINOSELECT database (-19–27%). This relatively large range implies that significant opportunities exist for genetic improvement in NLW through ram selection using the NLW ASBV.

Responses from a Southern African Merino flock divergently selected for multiple rearing ability indicate that genetic gains of more than 10% over 21 years (0.52% per annum) are possible (Cloete et al. 2009). In this flock ewe and ram progeny of ewes rearing more than one lamb per joining were chosen as replacements (Cloete et al. 2004). While gains of this scale may not be achieved in commercial situations where replacement animals are selected on other traits in addition to NRR, they do illustrate the level of potential improvement that can be achieved. Other reports from this project have identified significant differences between lambs and ewes in the High (H) and Low (L) lines. The survival of lambs was not compromised by selection for ewe multiple rearing ability, H line lambs were quicker to progress from standing to suckling than L line lambs and had heavier weaning weights (Cloete and Scholtz 1998). H line ewes experienced shorter births, tended to remain longer on or near their birth sites, were less likely to desert their lambs than L line ewes (Cloete and Scholtz 1998) and had a higher maternal cooperation score (Cloete et al. 2003). A Romney co-operative ram breeding flock in New Zealand reduced lamb mortality to just 7% in flocks with over 80% twins compared to the district average mortality of 15% with 35% of ewes twinning (Haughey 1993). As with the South African flock, this improvement was the result of selection of both ewes and rams from ewes with high rearing ability.

Recent predictions of genetic gain in lamb survival to weaning (LSW), based on genetic correlations estimated from the Sheep CRC's Information Nucleus Flock (Brien et al. 2010), suggests that LSW will decline genetically by 0.25 lambs weaned per 100 lambs born per year, even when NLW is included in the overall breeding objective. While further work is required to confirm these predictions, it is possible to slow any genetic decline in lamb survival by direct selection using half-sib records or progeny records (Brien et al. 2010). However this amount of data recording and analysis is currently not feasible for commercial producers.

Selection options

Maternal rearing ability has a repeatability of at least 0.10 (Hatcher et al. 2010; Lee et al. 2009b). 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 (Hatcher et al. 2010). Lee et al. (2009b) categorised ewes into quartiles based on their lifetime reproductive performance and found that the top 25% of ewes annually weaned one lamb more 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.

This large degree of variation, in the order of 3.5–6.5, in reproductive performance between the top and bottom 25% of ewes in a flock, indicates that achievable reproduction rates by Merino ewes are much larger than current expectations based on whole-flock means (Lee et al. 2009c). It provides opportunities to improve NRR by targeting different segments of the breeding flock. Lee et al. (2009b) identified three opportunities. The first is to increase the influence of highly productive ewes by retaining them beyond the normal culling age. In Lee's study the top 25% of ewes produced 41% of the lambs weaned. The second strategy is to remove ewes with low reproduction rates from the breeding flock as soon as they can be reliably identified. Given that the bottom 25% of ewes produced just 8% of the lambs weaned, removing these ewes from the flock at an early age can substantially improve the average reproductive performance of the flock (from 0.84 to 1.02 lambs weaned/ewe joined) (Lee et al*.* 2009b). The third opportunity is to target management interventions to those flock segments most likely to produce the largest economic responses. It is likely that responses among the bottom 25% of ewes would not be sufficient to cover input costs while the top 25% may be performing close to their reproductive potential (Lee et al*.* 2009b). The key is to be able to predict lifetime reproductive performance at an early age to identify which flock segments are likely to benefit from differential management. Lee and Atkins (1996) found that fertility in early life was indicative of both the fertility and rearing ability of ewes in later life. Their study of ewes at Trangie found that dry ewes at two and three years of age subsequently reared only half as many lambs as ewes that had reared lambs at two and three years of age.

Ultrasound pregnancy scanning is a relatively cheap and reliable technology to identify dry ewes. Moreover classifying ewes as 'wet' or 'dry' at marking will identify those ewes which have successfully reared at least one lamb. By using simple ear notches or a system of coloured tags, Merino producers can easily segment the ewes in their flock based on both fertility and rearing ability. However, these simple methods limit gains to the current generation only, as there is no link between the individual lamb ID and the ewe. More recent technology developments such as radio frequency identification (RFID) tags, in combination with Pedigree Matchmaker software (Richards et al*.* 2006), allows matching of lambs to their dams based on the number of times each lamb follows a ewe across a platform. Whilst primarily used for determining dam pedigree, Pedigree Matchmaker can be used to identify whether ewes are rearing single or multiple lambs and therefore allows both current and future generation gains to be made.

Management options

<u>*Ewe nutrition during pregnancy*</u>. Nutritional management of the pregnant ewe and lamb survival was recently reviewed by Hinch (2009), who highlighted a number of issues pertaining to ewe nutrition that impact on lamb survival. These include mineral nutrition (predominantly selenium and iodine), fatness (through its effects on dystocia and pregnancy toxemia), undernutrition (which affects colostrum availability and maternal behaviour), birth weight, and management of ewe nutrition and energy reserves (Hinch 2009). The relative importance of each is mediated primarily through the availability of energy and protein (and some minerals), but it is also affected by the stage of pregnancy and the energy stores of the ewe. Failure to adequately manage ewe nutrition during pregnancy can increase the duration and decrease the ease of parturition, lower birth weight, decrease colostrum production and negatively impact on the bond between the ewe and lamb.

The key message from the review was to maintain the condition of the ewe throughout pregnancy, with a fat score target of three on the one-to-five scale. From a purely biological perspective maintaining a fat score of at least three during pregnancy with an increase in late pregnancy will improve lamb survival, particularly that of twins (Hatcher and White 2008). However, managing the fat score of breeding ewes has a significant impact on whole farm profit through a combination of four mechanisms: (i) impacts on the future production of the surviving progeny; (ii) variation in the survival rate of the lambs born; (iii) varying production achieved from the ewes including clean fleece weight, fibre diameter and number of lambs conceived and; (iv) varying energy demands of ewes which results in changes in stocking rate and supplementary (grain) feeding (Hatcher and Graham 2008). Importantly the biologically optimum fat score profile is not the same as the economic optimum. Determining the economic optimum requires balancing the energy required to maintain or gain fat score at various stages of the reproductive cycle versus the energy required to drive the various aspects of production, be it reproduction, ewe wool production, progeny wool production or lamb survival (Hatcher and Graham 2008).

In most regions, the biologically optimal fat score profile will have a higher value of production, but will require an increased amount of supplement which will actually decrease profit. For the southern NSW sheep and cereal production zone the economic optimum fat score profile is 2.6 at joining, followed by a managed loss of condition (0.3 FS) to reach a minimum of 2.3 at day 90 and then using green pasture to regain the lost condition prior to lambing (Figure 4). However, intake can restrict the extent to which fat score can be increased in late pregnancy. In this example the biologically optimum profile returns $154/ha profit compared to the $163/ha from the economically optimum profile. Target fat score profiles for other sheep production regions of Australia can be found on the Lifetime Wool website (www.lifetimewool.com). The key to optimising breeding ewe management is to achieve the higher production from pasture wherever possible (Hatcher and Graham 2008).

Routine monitoring of ewe condition, by either fat or condition scoring about 10% of ewes at important stages of the reproductive cycle (i.e. weaning, joining, mid-pregnancy and prior to lambing), in conjunction with regular pasture assessment, will allow preparation of accurate feed budgets. This will ensure that the nutritional demands of the ewes at each stage of pregnancy are met in the most cost effective manner.

Within any flock there is a wide range of body condition among pregnant ewes (Jordan et al*.* 2006). This variability often means it is not biologically or economically feasible to apply a single standard of nutrition to the whole flock. At a basic level, information from pregnancy scanning can be used to split the flock into dry, single and multiple bearing mobs, which can then be assigned to paddocks based on available herbage mass or offered supplement as required. At a more advanced level, technology now exists that allows remote weighing and computer directed drafting to manage individual animals according to their nutritional requirements and reproductive potential (Jordan et al*.* 2006).

Lambing paddock engineering. Optimising the lambing environment can reduce reproductive wastage in average and below average years (Holst and Marchant 2002). A good lambing paddock should provide a thermo neutral environment for the lamb and ewe, provide adequate nutrition, minimise 'accidental' lamb/ewe loss, have low risk of predation, minimise social stress and reduce the risk of disease (Holst and Marchant 2002). Provision of shelter can reduce lamb mortality by 50% (Alexander et al*.* 1980; Bird et al*.* 1984) largely through reducing the effects of chill on the new born lamb (Donnelly 1984). Nixon-Smith (1972) derived an empirical model to estimate the potential of the environment to absorb heat from lambs during the first day of life. The chill index model assumes air temperature and wind speed have multiplicative effects on the rate of heat loss by new-born lambs with an additional cooling effect due to evaporation from the birthcoat or the advent of rain (Donnelly 1984).

High mortality due to inclement weather is a sporadic issue. While losses due to inclement weather during lambing can be significant in some years, overall it is not a large contributor to mortality in its own right in most regions. However, if producers are suffering regular losses due to poor weather conditions then a change of lambing time should be considered.

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 and decrease lamb viability and subsequent survival (Everett-Hincks and Dodds 2008). In 2010, wet weather towards the end of pregnancy and during lambing decreased lamb survival through negative impacts on ewe grazing behaviour and the widespread occurrence of foot abscesses particularly among ewes bearing twins.

There are a number of physical characteristics of a lambing paddock that affect the chill index (Figure 5). The aspect of a paddock is critical as it affects three of the four factors that determine the chill index.

Inclement weather can lead to high mortality rates during or shortly after the bad weather event (Nowak and Poindron 2006). These deaths are largely due to hypoglycaemia (decreased sugar level in the blood) due to depletion of body reserves of fat, which in turn produces hypothermia and death (Alexander 1984). While the provision of shelter in poor weather has been reported to reduce lamb mortality in single lambs by 3–13% and by 13–37% for multiple births (Bird et al*.* 1984), on average shelter tends to reduce lamb losses by 10%. However, it must be noted that continual rain during lambing does tend to negate the benefits of shelter. Many options are available to sheep producers to improve shelter in lambing paddocks. These include natural options such as tree or shrub belts, sowing perennial pastures into the pasture mix or artificial means such as rows of hessian panels. The key issue is that shelter in the lambing paddock must be effective in reducing the chill index, must be provided in an area the sheep use and it must be economical.

Formation of a strong bond between the ewe and her lamb/s is critical to lamb survival and can be maximised by management practices that increase the time spent at the birth site by the ewe after parturition (Lindsay et al*.* 1990). Ensuring that a lambing paddock provides adequate food, water and shelter in close proximity to potential birth sites will facilitate ewe-lamb bonding. However, contour banks, gullies, location of water points and the height of the pasture sward can lead to separation of the ewe and lamb/s unit (Holst and Marchant 2002). While some lambs may be able to suck from other ewes and survive, the chances of all separated lambs doing so are relatively slim. Stocking rate in the lambing paddock also plays a role, as the chance of separation of the lamb and ewe unit is increased if stocking density is high (more than 18 ewes/ha) (Holst and Marchant 2002) through an increase in the incidence of mismothering and lamb stealing (Lindsay et al*.* 1990). The number of ewes making use of the stock camp/s in the lambing paddock is an important consideration as high ewe density at the camps can increase mismothering particularly for twin bearing ewes. A target of 200 twin bearing ewes per paddock would alleviate this problem, although it would pose problems in terms of provision of adequate shelter for large flocks as more lambing paddocks would be necessary.

The quality of pasture in the lambing paddock must be sufficient to meet the nutrient requirements of pregnant and lactating ewes for optimal colostrum production, so that essential antibodies are transferred to the lamb from the ewe (Nowak and Poindron 2006) and subsequent milk production rates are sufficient to satisfy the lamb/s requirements. This is particularly important for twin bearing ewes, as the onset of their lactation is slower and they do not produce as much colostrum per lamb as single bearing ewes (Hall et al*.* 1992a; Hall et al*.* 1992b).

Economic analysis of management options to improve reproductive performance. Increasing reproductive performance in sheep flocks impacts primarily on stocking rate, flock structure (the ratio of ewes to dry sheep as well as wool and sheep trading income (McEachern and Sackett 2008). Economic modelling of a range of enterprises (self-replacing merino, dual purpose and prime lamb) in a range of environments (pastoral, sheep-cereal and high rainfall) identified a range from $0.50 to $26 per hectare available to spend on management interventions that might increase either conception rate or lamb survival by 10% (McEachern and Sackett 2008). The available benefit was dependent on stocking rate, the value of the products for the particular enterprise and the time of lambing in relation to feed supply (i.e. whether supplementary feed was required). The modelling was based on wool and sheep prices in the 10 years to June 2006 which clearly doesn't reflect the current value for either product, nor did it look at various precision sheep management tools which are now available and allow producers to segment their flocks and apply differential management (Rowe and Atkins 2006). It is clear that sheep producers need to have an understanding of the likely improvement in NRR that a particular management intervention will achieve with their flock and balance this against the cost of that intervention.

Time frame and expected level of response

The potential economic gains from using two of these strategies (i.e. ram and ewe ASBVs and ewe selection) were evaluated using data from the Trangie resource flocks (Lee et al*.* 2009a; Lee et al*.* 2009c) and the Smart Merino software. The base flock consisted of 2,000 breeding ewes in four age groups with 75% NRR and adult ewes producing 6kg of 20.5µm greasy wool annually. Surplus animals (908 hoggets and 458 adult ewes) were available for sale yearly. The modelling predicted an improvement in NRR to 80% in the flock in the first five years due almost entirely to ewe selection, with a further increase to 90% in 10 years (from both ram and ewe selection) (Lee et al*.* 2010). The impact of ram genetics was not evident for two years, until after their first daughters were born (Figure 6), but after 10 years would produce annual gains of about 4%. If the predicted responses in lamb survival gained from managing ewe body condition during pregnancy (Hatcher and White 2008) were included in the modelling further increases in NRR would be expected.

The next step with this work is to validate these predicted responses in commercial flocks across a range of environments.

Conclusion

Improving the reproductive efficiency of the Australian Merino would be best achieved by targeting NRR, the number of lambs weaned per ewe joined. The essential first step for commercial sheep producers is to establish where the failure is occurring in the reproductive cycle of their flock. In most instances the failure is likely to be due to poor lamb survival. There are three key strategies available to improve lamb survival, namely *genetics* via ram selection using ASBVs, *selection* of ewes within the flock based on their lifetime NRR and *management.* Management includes both monitoring and actively managing the body condition of the ewes (via fat or condition scoring) during pregnancy, and engineering a lambing paddock. The benefits of each of these options are cumulative, such that increases in NRR in excess of 14% within 10 years are possible. However, prior to the development of extension programs endorsing these three strategies to improve lamb survival, the strategies must be demonstrated in commercial flocks across a range of production environments, and proven to work over a number of seasons.

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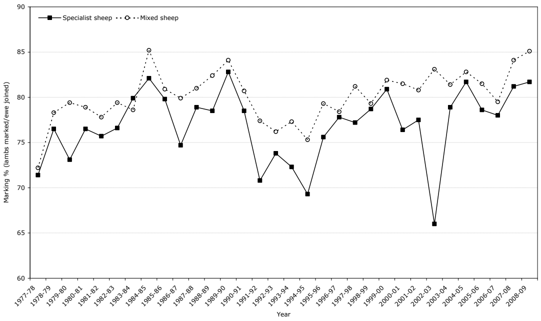
Appendix

Table 1. Improving net reproduction rate (NRR, no. lambs weaned/ewe joined) has a large positive impact on gross margin per ha (GM/DSE) for a range of sheep enterprises

Sheep enterprise	**Weaning %**	**GM /DSE**	**GM/DSE** +10% NRR	+20% NRR
Self replacing Merino enterprises				
18μm	83	24.46	27.07	29.68
20μm	86	18.40	20.69	22.98
20μm wether lambs	86	22.77	25.53	28.25
20μm wether lambs 25%Terminals	87	23.92	26.77	29.63
20μm wether lambs All Terminals	90	26.08	29.33	32.60
20μm 1st cross ewes	90	24.39	27.48	30.55
1st cross ewes				
Terminals – prime lamb	118	26.12	30.09	34.07

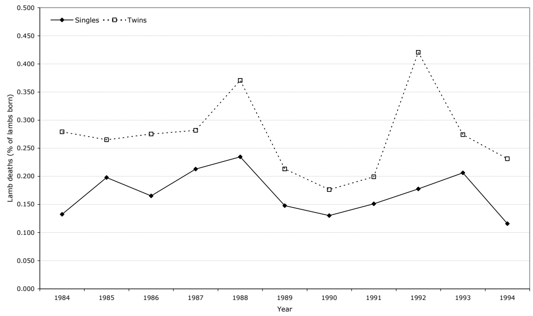
Source: Casburn (2010).

Figure 1. Lambing percentages for specialist sheep and mixed sheep enterprises from 1977 to 2009



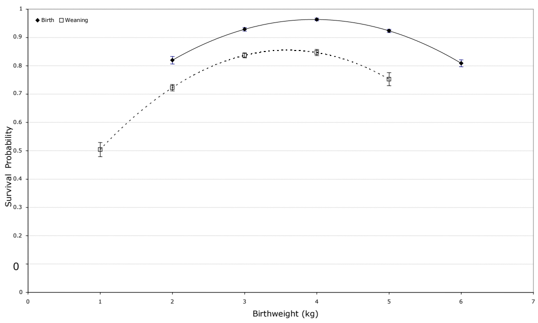
Source: ABARE (2010)

Figure 2. Annual pre-weaning single and multiple born lamb loss at TARC between 1975 and 1983.



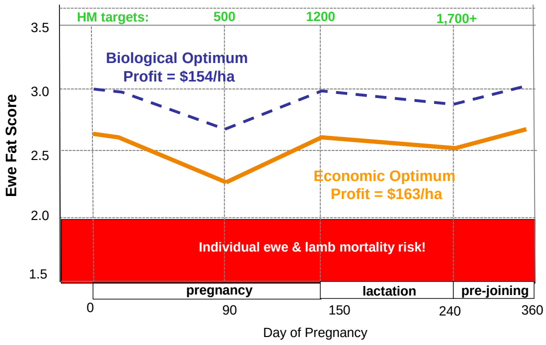
Source: Pope and Atkins (2009)

Figure 3: Birth weight (kg) versus survival for single born lambs at birth (◆ solid lines) and weaning (□ dashed lines).



Source: Hatcher et al. (2009)

Figure 4: Comparison of the biological and economic optimum fat score profiles for southern NSW sheep and cereal zone.



Source: Hatcher and Graham (2008)

Figure 5: Summary of factors affecting chill index and its impact on a new born lamb.

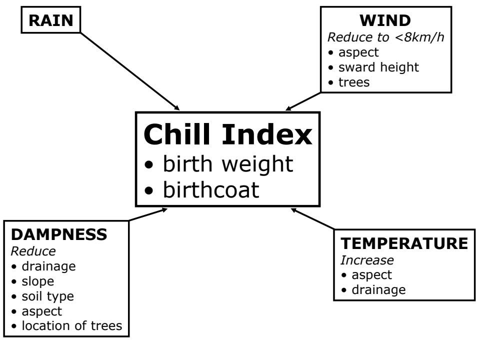
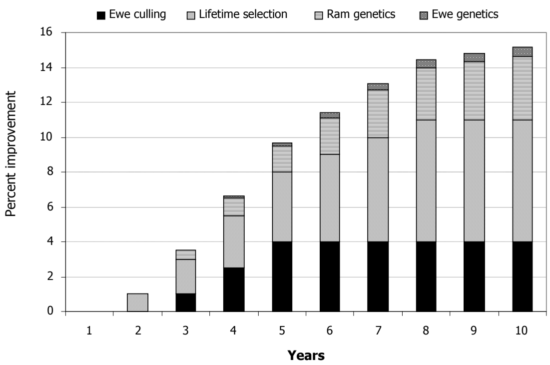


Figure 6: Potential responses in NRR over 10 years.



Source: Lee et al. (2010)