Factors influencing reproductive wastage in Victorian sheep flocks.

A THESIS SUBMITTED FOR THE DEGREE OF MASTER OF RURAL SCIENCE

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Declaration

I certify that the substance of this thesis has not already been submitted and is not currently being submitted for any other degree. All assistance received in the preparation of this thesis, and all sources have been acknowledged.

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Abbreviations

BCS	Body Condition Score
BOM	Bureau of Meteorology
BW	Body Weight
CNS	Central Nervous System
DEPI	The Department of Environment and Primary Industries
FOO	Food on Offer
GM/DSE	Gross Margin per Dry Sheep Equivalent
kgs	Kilogram
kj	Kilojoule
LH	Luteinizing Hormone
Mil	Million
MLA	Meat and Livestock Australia
MXM	Merino ewe X Merino ram
MXP	Merino ewe x Meat breed ram
NRR	Net Reproduction Rate
PXP	1st X or Composite breed ewe X Meat breed ram
RDN	Rumen-degradable nitrogen
RDP	Rumen Degraded Protein
SME	Starvation Mismothering Exposure

ABSTRACT

The cost to the national sheep industry of reproductive wastage has been estimated at around $839.6 Mil per annum (Jubb et. al. 2015). The Victorian sheep flock currently makes up 21% of the national flock with 8.9 Mil ewes, or 21% of the National breeding flock (MLA 2016 personal Communications) estimates of the financial penalty to the Victorian sheep industry from reproductive wastage would be approximately $176.3 Mil each year.

This thesis was developed to investigate the conditions which lead to reproductive wastage in Victorian sheep flocks through a review of the available literature and an investigation of data collected from commercial Victorian sheep flocks involved in the Sentinel Flock Project (DPI Victoria).

Twenty flocks of prime lamb and wool producing sheep were initially enlisted across the sheep production areas of Victoria to monitor factors influencing reproductive wastage, morbidity and mortality over a three year period. One flock retired from the project and another flock was added hence 21 flocks were assessed. As far as possible, the spread of these flocks represented the distribution of sheep across Victoria. Flocks were enlisted from the known contacts of the Department of Primary Industries Victoria, Meat and Wool Services Branch.

Target flock size was 400 – 3000 breeding ewes. Both commercial and stud flocks were eligible for consideration. The flocks husbandry, management,

reproductive performance and procedures were monitored for a period of three years and documented to evaluate the incidence reproductive wastage and livestock deaths in the participating flocks.

Deaths were investigated to establish cause. According to need, the investigation included on-farm necropsy and/or the submission of samples to the Gribbles Veterinary Laboratory for analysis and diagnosis.

Over the course of this investigation there were 82092 ewes scanned for pregnancy status including reproduction rate. The mean conception rates (number of feotus scanned per number of ewes joined) for ewes over the years 2009 to 2012 across seasons of joining (Autumn/Spring lambing's) in this work were, for the Merino Ewe x Merino Sire (MXM) 116.9%, Merino Ewe X Prime Sire (MXP) 126.7% and Prime Ewe x Prime Sire (PXP) 145.7%. The mean lamb marking (lambs marked /ewe joined) percentages were for the MXM ewes 84.6%, MXP ewes 103.2% and the PXP ewes marked 118.6%. This equated to a total loss of 23726 lambs from ultrasound scanning through to lamb-marking and a further 1107 lambs were lost from lamb-marking to weaning.

Of the lambs lost from ultrasound scanning to lamb-marking the largest losses were attributed to Starvation mis-mothering (48%) followed by dystocic birth (25%) then primary predation (7%) and there were 7% which could not be diagnosed due to the state of the lamb carcass.

The ewes in this study were monitored throughout the years of this work to determine the cause of loss. There were 1421 or 1.7% of ewes recorded as dying over the 2009 to 2012 period of this work. Investigations were carried out on a sample n=209) of these ewes to determine the cause of death. The primary cause of loss was due to endemic infectious disease (34%) followed by obstetrical disease (26%), then metabolic disease (13%). There were 17% of the ewes submitted for necropsy which were unable to be diagnosed as to cause of death due to the condition of the carcass.

In this work conception was under the control of BCS for the MXM and MXP but genotype of the sire was significant for the PXP grouping. Birth weight of the lamb which was to a large degree under genetic control was a significant factor in survival of the lamb.

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General Introduction

Meat and Livestock Australia's (MLA) 2015 report into the priority list of endemic diseases for the red meat industries listed neonatal loss in sheep as costing the Australian sheep industry $540.4 million annually . Earlier work conducted by Walker et.al. (2002) estimated the cost of neonatal loss at $250 million per annum. Meat and Livestock Australia (MLA 2010) Strategic Plan 2006 - 2011 also identified reducing mortality in sheep as the highest priority for economic benefit to the industry, with a present net value of approximately twice that of improved pasture utilisation.

Reproductive wastage in sheep can be defined as the losses that occur between conception and weaning. These losses can arise as a result of failure to mate, failure to ovulate or reach maximum genetic potential for ovulation rate (Watson 1959), failure in fertilisation of eggs released, embryonic losses, foetal losses and perinatal lamb loss and ewe mortality during pregnancy, parturition and lactation (Smith 1965) and post weaning mortality Campbell et. al. (2009). The failure of a lamb to reach maturity and reproduce could also be considered as reproductive wastage.

In their study into reproductive wastage in fine wool ewes conducted over a ten year period Willingham et. al. (1987) found that 33.5% of the potential lamb crop were lost from ovulation to implantation and that a further 16% of the potential lamb crop were lost from birth to weaning. Willingham et. al. (1987) also noted that losses were higher in multiple ovulating ewes than in single ovulating ewes.

There are a considerable number of factors which impact on conception and embryo survival through to the successful weaning of a healthy lamb. The age (Alexander 1993, Mullaney & Brown 1969), body weight (BW) (Clarke et. al. 1997), body condition score (BCS)(Yilmaz et. al. 2011), season of joining, health and nutritional status (Munoz et. al. 2008) of the ewe pre and post joining through to parturition, together with the ambient temperature (Fowler, D. G. 1969) all impact on conception, embryo and lamb survival. Other factors impacting on fertility of the ram including ambient temperature, pre joining nutritional and health status, along with the age of the ram also have a bearing on conception, embryo survival and the weaning of a healthy lamb.

As with any complex biological system, interactions between the various components of the environment in which sheep are managed together with the genetic influences of the sheep can lead to a multitude of outcomes, both beneficial and restrictive. In this review it is the intention to outline the various interactions and impediments to the successful mating, conception and delivery of live healthy lambs through to weaning and those interactions which have a negative influence on the reproductive performance of sheep in Victorian sheep farming systems.

Chapter 2

Literature Review

There are many factors which contribute to reproductive wastage in sheep. Delayed onset of puberty or failure to ovulate or conceive are among a long list of contributing factors to reproductive wastage in sheep. Embryonic wastage, foetal loss, perinatal loss and losses of lambs at weaning are also considered to be components of reproductive wastage. The loss of ewes at or around the time of parturition through obstetrical or metabolic disease are also components of reproductive wastage.

Lamb loss from day 3 post-partum until lamb marking is usually markedly reduced in comparison to the earlier post-partum period Hyland (1960). Lamb survival is markedly increased with the mortality rates of around 12-15% in the first 72 hours dropping to around 1-2% at lamb marking Hyland (1960) with Safford and Hoversland (1960) finding that 56 % of all lamb deaths occurred in the first three days and that 73 % occurred in the first five days.

The environment can have a major impact on survival due to a number of factors and so the topography and provision of shelter should be carefully considered when deciding upon lambing paddocks. Where possible flat open paddocks should be avoided as these exposed paddocks are where the lamb faces the greatest challenges due to exposure to environment if the weather turns bad (cold wet and windy). The impact on losses can be substantially greater in particularly bad seasons, that is, in seasons of severe feed restriction or extreme seasonal conditions (cold, wet and windy at the time of lambing) with Lindsay (1996) stating that if a lamb does not have enough reserves of food it is likely to perish in cold weather. Whilst Alexander (1984) concluded that cold exposure was a primary cause of perinatal lamb loss and observed increases in lamb losses during periods of cold wet and windy conditions where the temperature fell below 5°C. Other factors impacting on the severity of losses can be in times of greater than normal numbers of predators present at the time of lambing Lugton (1993) or periods of low pasture availability and poor nutritional supplementation.

The importance of the nutritional status of the ewe cannot be overstated as it can have direct and devastating consequences for the lamb if the ewe is nutritionally stressed. The nutritional level of the ewe pre and post conception has a bearing on the successful conception and survival of the embryo Wallace et. al. (1994), Kelly et. al. (1976), Nottle et. al. (1997), likewise, nutrition throughout gestation can also impact on the survival of the lamb. Robinson (1996) observed that extremes in nutrition have a detrimental effect on both embryonic development and survival, particularly undernutrition.

The last trimester is particularly important for the development and survival of the lamb but also for the lactation capacity of the ewe through to weaning. Egan (1984) suggests that nutrition in mid to late pregnancy should be viewed as priming the lactational pump rather than feeding the foetus. Whilst McCance and Alexander (1969) observed that in Merino ewes on a poor plane of nutrition milk secretion was compromised and that these nutritionally stressed ewes did not secrete milk until several hours post-partum, and further more nutritionally stressed ewes never reached their potential in terms of milk production. With this in mind the survival of the lamb from parturition through to weaning is directly related to the nutritional status of the ewe.

Also impacting upon the nutritional status of the ewe is the peri-parturitient relaxation of nematode resistance in the ewe. Roca et. al. (2004) stated that peri parturient rise in nematode infection had been well documented in numerous studies and believed that this was due to the nutritional and reproduction rate challenges faced by the ewes at the time of parturition. Zuck and McKean (1996) suggested that the immunosuppressive effects of progesterone may play a role in the suppression of resistance to infection. Furthermore, in times of severe nutritional stress at lambing this relaxation only compounds the difficulties faced by the newborn lamb and places further hurdles in front of the lamb, as this combination of factors can drastically impede milk production and threaten the survival of the lamb.

As with all animal production systems best practice in terms of animal health and nutritional procedures for the breeding ewe can only serve to enhance the survival of the newborn lamb. This review is not intended to delve into husbandry practices for breeding ewes but a brief description of these issues is appropriate in light of the impact they have on lamb survival.

Post 72 hours from birth, the lamb is subject to attack from disease as mentioned earlier. Bacterial and viral challenges are inevitable in any lambing environment. The immunological status of the ewe can have a bearing on the survival of the lamb as passive immunity to some of the clostridial bacteria in particular, is passed on to the lamb via the ewe's colostrum Alves et. al. (2015) and Blood and Radostits (1989) provided the ewe has had a properly maintained vaccination program against these diseases.

Other occasions when the lamb may be challenged by disease are at lamb marking when the opportunity for disease to invade the body of the lamb through cuts and lamb marking equipment is high. The lamb is also prone to disease in the form of infection from bites and pecks of predators Belschner (1965) these infections are usually the result of crows, and the resulting anaerobic infection can result in death in 3 – 4 days. The challenges on the ewe and lamb are at times significant and these challenges impact on the reproductive performance of sheep.

This review has been compiled to align with the production cycle of the flocks that were monitored and the sequence of data collection flowing from the Sentinel Flock Project (DPI Vic).

Attainment of Puberty/Maturity in Young Ewes and Conception

The failure to attain sexual maturity by the first mating can be considered a form of reproductive wastage. Both rams and ewes attain puberty at a stage of maturity rather than at a chronological age. Watson and Gamble (1961) observed in their study of puberty in the Merino ewe that no young Merino ewe mated at < 26.7 kg conceived at younger than 122 days of age and inferred that a combination of seasonal and environmental factors had a direct bearing on puberty and conception. In their work investigating the influence of protein and energy on puberty in crossbred ewe lambs, Boulanouar et. al. (1995) concluded that if diets were deficient in either protein or energy which resulted in reduced growth rates the onset of puberty would be delayed. Ebling and Foster (1988) also demonstrated that there was a greater sensitivity to photoperiod for spring born lambs at puberty than for adult sheep. Thus the season of birth combined with body weight exert a great deal of influence on the attainment of puberty in ewes.

The nutritional status and body weight (BW) of ewe lambs has also been identified as playing a significant role in the control of puberty and ovulation with Fitzgerald et. al. (1982) finding that the physiological signal linking first ovulation to nutrition and growth rate appears to be directly related to gonadotrophin secretion. Howland and Ibrahim (1973) in Fitzgerald (1982) suggested that lower nutritional levels influenced the suppressive effects of oestrodial which has a negative effect on the pulsatile release of Luteinizing Hormone (LH) which it is contended has a negative impact upon sexual maturity. In their study into liveweight and metabolic changes in maiden Barbarine ewes, Ben Salem et. al. (2009) suggested that the lower reproductive efficiency of ewe lambs in their study may be related to the ovulation of immature follicles.

Earlier work on pubertal lambs by Edey et. al. (1976) revealed that even though the Merino and Perindale ewe lambs in their study appeared to exhibit oestrus a portion of these ewe lambs ranging from 6.6% in Perindales up to 33.3% in Merinos failed to ovulate even though they produced large (>8mm) follicles. These workers concluded that although the age and weight required for puberty had been attained, the pituitary-ovarian system had not reached the stage of development where puberty could be initiated.

Stellflug et. al. (2001) also suggested that birth date, nutrition during rearing and breed are three major factors that affect onset of puberty in ewe lambs. In their study Stellflug et. al. (2001) also acknowledged that adequate nutrition played a role in earlier conception of ewe lambs (7 – 8 months of age) and noted that the onset of oestrus was affected by significant differences in body weight.
Growth and nutrition of ewe lambs together with breed, body weight and age of the ewe lamb all play key roles in the onset of oestrus and the capacity to conceive and maintain pregnancy to full term.

The current recommendation for the joining of maiden Merino sheep is to join at >40 kilograms for medium wool Merino sheep Hatcher et. al. (2007) or 75-80% of adult weight (Making More From Sheep 2008) to achieve an acceptable lambing percentage. For optimum lambing percentages maidens should be in >3 score and weigh 40 – 45 kilograms. Figure 1: Ferguson et. al. (2011) provides a diagrammatic expression of joining weight compared to foetuses scanned per 100 ewes and demonstrates the influence of body weight on conception. Although the pregnancy scanning percentage in Figure 1: shows that at around 35 kg body weight ewes scanned 80% conception it must be remembered that 30% or more of the scanned lambs will not survive to lamb marking Alexander (1984).

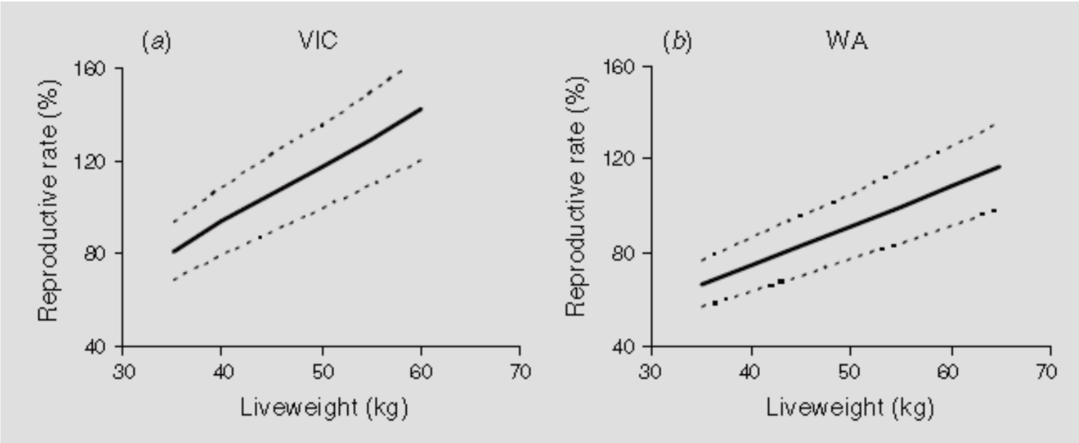


Figure 1: The number of foetuses scanned per 100 ewes joined increases linearly with increasing liveweight at joining. Source: Ferguson et. al. (2011).

The age of the ewe at joining has also been demonstrated to have bearing on embryonic survival with Quirke and Hanrahan (1977) recording 33% survival of cleaved ova from lambs as compared to 73% survival of cleaved ova from adult ewes. The experiment by Quirke and Hanrahan (1977) demonstrated that the potential survival of 8-16 cell ova from ewe lambs is less than half that of 16-18 cell ova from adult ewes in similar conditions.

Kelly (1984) suggested that there may be important differences in uterine conditions in young ewe lambs as compared to older ewes which contribute to poorer embryo survival in these ewe lambs. Michles et. al. (1998) also suggested that a smaller and more variable periovulatory LH surge and a smaller increase in plasma progesterone concentration early in the pregnancy of very young sheep (7 months) contributed to an unsuitable environment for the maintenance of pregnancy as compared to older ewes.

In his work investigating the influence of bodyweight, age and subsequent reproductive performance, McLaughlin (1970) stated there is no appreciable change in reproductive performance with age for Merino ewes whilst in the Corriedale ewes in his study there was a 0.9% increase in the incidence of multiple births with each year of age and a 2.5% increase in the incidence of multiple births for each kilogram increase in bodyweight. Thus indicating that bodyweight played a greater role in improved reproductive performance than age.

This would suggest that the attainment of puberty in the ewe is dependent on a number of factors including the genotype of the ewe, chronological age and stage of maturity. Season of birth also exerts some influence upon the attainment of sexual maturity in the ewe along with the physiological state and body weight of the young ewe.

With the trend towards joining more ewe lambs at 7 – 9 months of age there is need to better understand and manage the growth and nutrition of young (7 – 18 month) sheep to attain puberty as this is a contributing factor to reproductive wastage.

Conception in Mature Ewes

Body condition

Age at joining in adult ewes is of less importance to the reproductive capacity of the ewe when compared to body condition score (BCS). With very few ewes being retained in the flock for breeding past 6 years of age which is the suggested peak of the ewe's reproductive potential (de Hass and Dunlop 1968 and Newton-Turner and Dolling 1965) there may be potential to improve the reproductive performance in some flocks by maintaining some of the more fecund ewes or ewes which have a history of weaning healthy lambs annually for longer in the flock and removing some of the poorer performers in the younger age groups. Body condition as opposed to bodyweight is of greater importance to conception (*McInnes & Smith 1966, Hatcher et.al 2007)* in mature ewes. The lifetime wool project (2004) demonstrated that the body weight of ewes is independent of BCS and that BCS is a more reliable method of assessing the physiological state of the ewe for reproduction (Van Burgel et.al 2011).

Caldeira et. al. (2007) investigating the effects of BCS on blood metabolites and hormone profiles in non-lactating and non-pregnant Serra da Estrela ewes suggested that ewes in BCS 3 exhibited a more balanced metabolic profile than ewes in high BCS 4 which exhibited high insulin, glucagon and urea level. Whilst the low BCS 1.5 – 2 ewes displayed lower levels of plasma glucose along with lower levels of thyroxine and triiodothyronine and other important hormones. Other workers in this field (Yillmaz et. al. 2011 and Meza-Herrer et.

al. 2007) also confirm the relationship between BCS, ovulation rate and reproductive success with sheep of different genotypes managed under different environments.

The Lifetime Wool project (2004) looking into the relationships between nutrition, reproduction and wool production in Merino sheep contends that it is desirable to present ewes for joining in BCS 3> as there is a strong relationship between BCS, conception, lambing percentages and survival of the lamb. Figure 2 (Yillmaz et. al. 2011) illustrates the strong relationship between BCS of the ewe and lamb conception and survival. and this has been confirmed by many other researchers e.g. Caldeira et. al. (2005), Meza-Herrer et. al. (2007) and Curnow et. al. (2008)

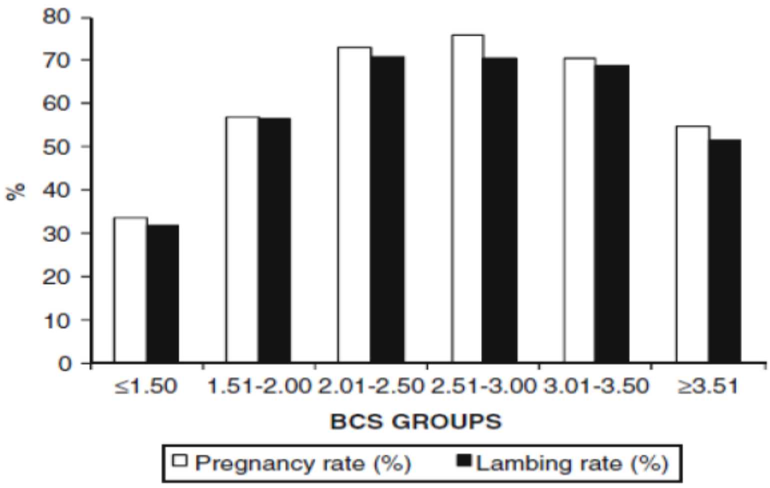


Figure 2: Pregnancy rate (percent) and lambing rate (percent) for ewes with different BCS. Source: Yilmaz (2011).

Lifetime Wool project (2004) recommendations propose that it is acceptable to allow the ewe to decline to >2.5 BCS in the mid-stages of pregnancy with Holst and Allan (1992) also suggesting that nutritional restriction at around day 75 of pregnancy was acceptable, whilst Munoz et. al. (2008) suggested that nutritional restriction in early pregnancy was beneficial to lamb resilience, improved immune status and lamb survival but Bennet et. al. (1964) in Hodge (1966) maintained that severe nutritional restriction in early to mid-pregnancy had an effect on the number and birthweight of lambs born. It should also be remembered that these ewes will require adequate supplementary feed if high quality pasture is unavailable to return these ewes to BCS 3 at parturition to avoid small weak lambs (Oldham et. al. 2011) and minimise the risk of metabolic disorders such as hypocalcaemia and pregnancy toxemia in the ewe (Hocking Edwards et. al. 2011 & Blood & Radostits 1989).

There is also a strong relationship between ewe BCS and ewe survival (Figure 3 Curnow, 2008). The work of the Lifetime Wool Project, a national project which ran from 2001 -2008 highlights and reinforces the importance of ewe nutrition and the reproductive response to best practice nutritional management of breeding ewes in reducing the incidence of reproductive wastage and ewe loss.

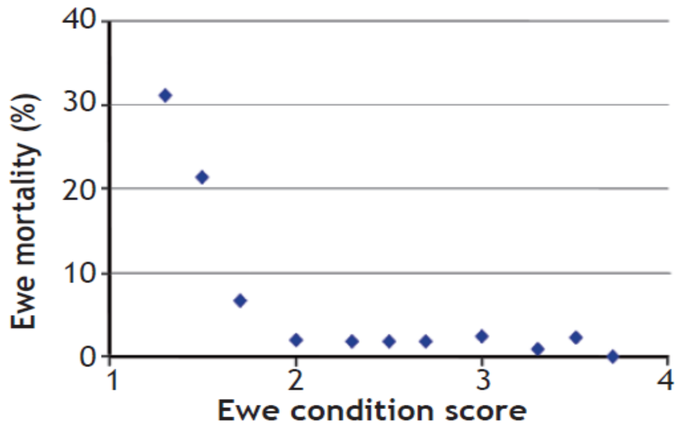


Figure 3: Relationship between condition score and ewe survival at lambing. Source: Curnow et. al. (2008).

Nutrition at joining

The concept of flushing ewes (*Oldham & Lindsay 1984, Nottle et. al.1997)* for 7-14 days prior to joining has been accepted as a common practice as a means of increasing ovulation rates in ewes. Ewes fed between 750 grams/head/day of lupins for only 6 days, had an increase of an extra 20 corpora lutea/100 ewes mated (Nottle et.al. 1997) without increasing body weight. Conversely a reduction in body weight at the time of joining has been shown to have a detrimental effect on conception rates (Maurya et. al. 2004 & Yilmaz et. al. 2011). Alison (1977) also demonstrated that ewes on a high plane of nutrition had a higher mean follicle score as determined by the sum of follicles >2mm present on the ovaries of individual ewes and indicated that there was a higher incidence of ovulation where no oestrus was detected in the group of ewes on a lower plane of nutrition in the study.

Pre-joining nutrition has a large bearing on conception. Egan (1984) concluded that the supply of metabolites from the feed can meet the specific requirements of the foetus and milk supply but may not be adequate for other key reproductive events to occur and also impact on future reproductive performance.

McInnes & Smith (1966) also demonstrated an increase in the number of twin births independent of any pre-flushing levels of nutrition whilst in a study carried out by Nottle et.al (1997) the combined effects of flushing and the ram effect were evaluated. In this study the ewes were isolated from rams for six weeks then introduced to vasectomised rams for two weeks. Twelve days after the introduction of the vasectomised rams (teasers) the ewes were fed a supplement of 500 grams/head/day of lupin grain. Two weeks after the teasers were introduced they were withdrawn and replaced with fertile rams.

Table 1 provides a summary of the results of Nottle's study highlighting the effect of flushing to increase the ovulation rate in the ewe but not affect the conception rate in the ewes.

Table 1*: Reproductive performance of Merino ewes synchronised using the ram effect and supplemented with lupin grain for 14 days. Commencing 12 days after introduction of vasectomised rams on two commercial properties. Source: Nottle et.al. (1997).*

Attribute	Treatment		Farm	
	Control	Lupins	Farm A	Farm B
Ewes lambing per ewe exposed to rams (%)	94.61 (456/482)	94.81 (458/483)	96.0 (478/498)	93.4 (436/467)
Lambs born per ewe lambing	1.21 (552/456)	1.36 (624/458)	1.33 (634/478)	1.24 (542/436)
Lambs weaned per lamb born (%) single	79.7 (287/360)	78.1 (228/292)	89.8 (298/322)	65.5 (226/330)
Twin %	68.8 (132/192)	73.5 (244/332)	89.1 (278/312)	46.2 (98/212)
Overall %	75.9 (419/552)	75.6 (472/624)	89.4 (576/634)	59.8 (324/542
Lambs weaned per ewe exposed to rams (%)	89.6 (419/482)	97.7 (472/483)	113.9 (576/498)	69.4 (324/467)

In their work conducted on Collinsville strain of Merino ewes, Pearse and McMeniman (1994) demonstrated that feeding ewes 750g/h/d of lupins 8 days (insertion time 14 days) after insertion of progestagen sponges into the ewe had a positive impact on ovulation rate which was independent of BCS and that ewes would have shown an increase in ovulation rates regardless of BCS. In a study into the impact of flushing Sarda ewes with soybean meal Molle et. al. (1997) observed an increase in ovulation rates and the number of lambs born for medium term feeding (14 days) but the ewes subjected to long term feeding (21 days) had a lower conception. Whilst the practice of flushing ewes to promote an increase in ovulation rates is to be encouraged, the practice of feeding high protein and energy feed sources needs to be carefully controlled and monitored.

Excessive feeding or the sudden introduction of feed sources high in protein (Parr 1992; Wallace et, al, 1994) and energy at the time of mating has been shown to lead to lower rates of reproduction. McEvoy et. al. (1995) demonstrated that the effect of feeding high quality feed to ewes at the time of insemination in superovulated ewes resulted in a lowering of the circulating progesterone levels below the level necessary to support pregnancy. This was due to the higher circulation rate of blood through the liver resulting in a higher clearance of progesterone from the ewe which confirmed the earlier work of Parr (1992) who reported that the sudden increase in feed quality over the joining period for up to 14 days post mating resulted in lower pregnancy rates due to higher circulation rates and clearance of progesterone through the gut and liver of the ewes with most of the progesterone being metabolized after one passage. Parr (1992) argued that the corpus luteum was unable to increase the rate of progesterone secretion to maintain homeostasis and that most of the embryo's died at 12 days of age.

Other nutritional factors such as diets with an excess of rumen-degradable nitrogen (RDN) leading to microenvironments high in ammonium (McEvoy et. al. 1997) also can impact on embryonic survival. Branca et. al. (2000) stated that an excess of dietary rumen degradable protein (RDP) was reported to impair conception rate when the RDP was given in the form of soybean meal or urea and was linked to decreased survival of fertilized ova.

Meza-Herrer et. al. (2010) in their study into early pregnancy loss in Rambouillet ewes also support the contention that higher levels of protein supplementation at the time of conception leads to a lowering in the pH levels in utero, but also suggested that the surviving embryos were affected by reductions in their weight and that this reduction may compromise foetal growth and later birth weight. Meza-Herrer et. al. (2010) also contended that the impact was greater in terms of early embryonic loss for nutritionally challenged mothers.

Oestrogenic clovers in some areas of Victoria still have an influence on reproductive wastage. These clovers containing phyto-oestrogens cause severe and even permanent infertility in ewes grazing these pastures and can have a major influence on the reproductive performance of a breeding flock. Kelly et.al. (1976) and Nottle et.al (1997) demonstrated in their work that only 17% of ewes grazing oestrogenic pastures came into oestrus compared with 92% of the controls clearly showing the deleterious effect on conception and embryo survival for ewes grazing oestrogenic clover based pastures. However Kaltenbach and Davies (1970) demonstrated clearly that sperm transport in the ewe was the main mechanism for infertility rather than embryonic mortality that was also affected adversely by phyto-oestrogenic plants.

Early Embryonic Loss

Post implantation Nutrition

Nutrition of the ewe post implantation is important for the maintenance of both the conceptus and the ewe. The correct nutritional input to maintain metabolic balance throughout pregnancy is necessary to ensure the wellbeing and survival of both the ewe and her progeny. As with pre joining nutrition, the over or under supply of nutritional inputs is to be avoided for a successful reproductive outcome to be achieved. Wallace et.al. (1994) demonstrated that with increases in levels of nutrition comes an inverse level of progesterone which is necessary to maintain the pregnancy. This reduction in the levels of circulating progesterone may lead to the loss of the embryo. Although this study did not confirm that the low levels of progesterone were reached in the trial, they suggest that there is a threshold and a time frame probably outside of the parameters of their study at which these levels would be reached.

Sosa et. al. (2004) contended that under nutrition was also responsible for embryonic wastage by provoking a reduction in sensitivity to progesterone in the endometrium which may affect embryo survival. Holst and Allan (1992) maintain that a nutritional restriction at around day 75 of pregnancy was acceptable but it should be remembered that this restriction should only be for a short period. Redmer et. al. (2004) observed that the effects of foetal nutritional restriction from day 28 – 80 of gestation were variable and in some cases led to reductions in foetal weights at day 80 by up to 32% and in other cases led to compromised fat and cardiovascular function in the resulting lamb. These findings were confounded by the nutritional regime applied and the age and genotype of the ewe.

Other contributing factors to early embryonic loss

In humans, chromosomal abnormalities are said to be a major cause of early embryonic loss Goff (2002) but chromosomal abnormalities are less important in ruminants Blockey et. al. (1975) in their work in maiden Merino ewes indicated losses of 42% - 56% of fertilized ova and found that the reduced activity of the rams in the flock and the shorter oestrus of the maiden ewes contributed to the high early embryonic loss (12 days mating). Whilst Goff (2002) contended that the major cause of preimplantation embryonic mortality is related to signaling difficulties between the embryo and the mother resulting in asynchronous development and the failure to produce sufficient quantities of INF-τ to maintain luteal function. Ashworth (1992) suggested that the ewes that lost embryos within the first two weeks post-mating had different (lower) progesterone profiles to those ewes which maintained their pregnancies. Ashworth (1992) also suggested that this led to an unfavourable uterine environment in which pregnancy could not be sustained.

Discussion

The provision of adequate pre and post joining nutrition has been demonstrated to have a positive influence on reproductive success. The success of ovulation, fertilization and implantation are strongly influenced by the provision of the required amounts of protein and energy to address the metabolic needs of the periconceptional and pregnant ewe. Excesses and deficits in nutrition during the periconceptional and gestational periods are to be avoided as they have been demonstrated to lead to reductions in reproductive performance of the ewe through a variety of mechanisms including, ewes on low plane of nutrition presenting with silent oestrus or sub optimal ovulation rates (Alison 1977) and ewes on high plane of nutrition presenting for joining with sub optimal uterine environments to sustain pregnancy (Meza-Herrer et. al. 2010).

The flushing of ewes at joining has also been demonstrated to have a beneficial effect on the ewe with ewes being fed on lupin grain (McInnes & Smith 1966 and Nottle et. al. 1997) demonstrating increased ovulation rates as a result of this practice. Maternal nutrition is a key driver of conception, fetal development and subsequent delivery of a viable lamb or lambs. Adequate maternal nutrition is also important for lactation and weaning of healthy lambs and for subsequent health, productivity of the progeny throughout it’s life.

Disease

There are many diseases both infectious and non-infectious which impact on reproductive efficiency in numerous ways. Infectious and non-infectious disease can inhibit oestrus or fertilization of the oocytes, or can be detrimental to the developing embryo. They can affect the ewe, lamb or ram and may manifest themselves as, failure to conceive, embryonic death, perinatal death, or even death of the ewe. Some of the better known infectious diseases involved in reproductive wastage are listed in Table 2.

Table 2: Diseases known to cause abortion in sheep. Source: Reproduction in sheep (1984) and Blood and Radostits (1989).

Disease/Causal agent	Transmission	ime of abortion	Symptom
Campylobacteriosis *(Campylobacter fetus)*	Ingestion	Last two months of gestation	*C fetus* causes a severe endometriosis and necrotising placentitis
Toxoplasmosis *(Toxoplasma gondii)*	Unknown	Late or stillbirths	Infection of pregnant ewes results in placentitis with subsequent death or neo-natal mortality
Bacterial infections *(Histophilus ovis, Streptococcus spp, Corynobacterium spp)*	Various	Various throughout gestation	Miscellaneous causes of abortion and mastitis in ewes.
Ovine Brucellosis *(Brucella Ovis)*	Mainly through coitus		Causes abortion and neo natal death if pregnant ewes are infected although far less virulent in ewes.
Enzootic Abortion of Ewes Chlamydeous abortion *(Chlamydia psittaci)*	Ingestion	Last 2 – 3 weeks of gestation	Disease manifests as near term abortion, still births or weak lambs.
Akabane disease *(Akabane virus)*	Believed to be an insect vector		Believed to be the cause of an outbreak of microencephaly in newborn lambs in NSW in 1977 can result in abortion and congenital birth defects.
Listeriosis *(Listeria monocytogenes)*	Probably ingestion, possibly coitus	Last 2 months of gestation	Foetal death is attributed to bacterial invasion of the placental choronic epithelium with subsequent necrosis and interruption of the foetal nutrient supply. The abortion rate in infected flocks can be from 2% - 20% in some cases (Rahaley1988) with some lambs dying postpartum.
Ovine vibriosis *(Vibrio fetus)*	*Ingestion*	Last 2 months of gestation	Abortions usually occur in the third or fourth month of gestation with weak live lambs born in the fifth month.
Toxoplasmosis *(Pestivirus)*		Lambs from conception through to 2 weeks of age	Clinical disease occurs when pregnant ewes are infected between 12 and 80 days into gestation can result in foetal death and abortion. Uncommon usually affects only a few flocks in Australia.
Salmonosis (*Salmonella abortusovis*	Probably Ingestion	Last 6 weeks of gestation	Causes metritis after abortion.
Salmonosis (*S. dublin)*	Ingestion	Last month of gestation	Causes metritis after abortion, neonatal mortality.

Some of the more important non-infectious diseases include:

Pregnancy toxemia *(Ovine Ketosis)* This metabolic disease of sheep, usually occurs in the last six weeks of gestation. Also commonly known as Twin Lamb

Disease, pregnancy toxemia is usually seen in ewes carrying multiple (two or more) foetuses (Belschner 1965). Pregnancy toxemia is a disorder of fat metabolism and is characterized by high ketone levels in the blood usually a sign of nutritional stress (Belschner 1965 and Blood & Radostits 1990).This disease of the ewe is responsible for a significant proportion of the ewe losses around final stages of gestation. Harmeyer & Schlumbohm (2006) contend that the disease coincides with an inability of the ewe to adequately meet the energy requirements of the growing foetuses and that it is accompanied by hyperketonaemia along with elevated non-esterified fatty acids levels in the plasma and hypoglycaemia. Harmeyer & Schlumbohm (2006) also state that the hyperketonaemia significantly depresses hepatic glucose production in the effected ewe. There is a belief that ewes with impaired hepatic function (Blood & Radostits 1990) may be more susceptible to pregnancy toxemia due to their inability to effectively carry out the process of gluconeogenesis which can lead to hypoglycemia and an accumulation of ketone bodies in the ewe. Ovine Ketosis is said to be highly fatal (Blood & Radostits 1990) and can present in some flocks as a significant cause of reproductive loss.

Hypocalcaemia (Lambing Sickness) This metabolic disease can affect all ruminants and is caused by low calcium levels in the blood (Belschner 1965). In pregnant ewes the predisposing factors which can lead to hypocalcaemia are inadequate or unbalanced nutrition particularly in late gestation and can manifest in the last weeks of gestation or the first weeks of lactation (Mavrogianni & Brozos 2008) and if the ewe is untreated, hypocalcaemia is usually fatal. Robalo-Silva and Noakes (1984) in their study into the effect of calcium on uterine activity noted that low blood calcium levels had a detrimental impact on the uterus at the time of parturition and observed that uterine activity was suppressed during periods of low blood calcium depending on the stage of parturition. In the early stages of parturition the study showed a delay in parturition if blood calcium levels were below 6.5 mg/100 ml, but noted that uterine activity was difficult to suppress in the second stage of parturition. Other conditions mentioned by Robalo Silva and Noakes (1984) were incomplete or non-dilation of the cervix and cervico-vaginal prolapse which can also have detrimental impacts on ewe and lamb survival.

Other Diseases

There are many other common diseases of sheep which can lead to reproductive wastage and significant financial cost (Jubb et. al. 2015) through various mechanisms and are common causes of losses in sheep flocks these include the clostridial diseases ($31.7 Mil), nematode infection ($436 Mil) and infection caused by ecto-parasites such as the sheep blow fly (*Lucilia cuprina*) ($173 Mil). It is not intended to delve into these diseases in detail in this review, but rather just to reinforce the implications which disease can have on reproductive wastage.

Disease can impact on ewe and lamb survival and reproductive performance through a variety of mechanisms. Reproductive wastage from diseases such as the bacterial and viral diseases which cause infertility, abortion and death of either the lamb the ewe, or both, together with the metabolic diseases such as hypocalcaemia ($11 Mil) and pregnancy toxemia ($16 Mil) which are caused as a result of inadequate or imbalanced nutrition, the ewe and lamb face a number of challenges. There are a number of strategies which can be implemented to minimise these loses due to disease and include a sound animal health and nutritional regime.

Ambient temperature

Nutrition has been shown to exert a large influence on the successful conception and delivery of healthy lambs but there are other influences which can also significantly influence the success of reproduction in ovine and indeed other species. Heat stress has been identified as one of the causes of early embryo loss in both sheep and cattle with Silanikove (2000) and Goff (2002) indicating that losses due to heat stress occurred at around 12 – 14 days.

High ambient temperature (extended periods of 35°C - 40°C) has been shown to influence conception rate and embryo survival in sheep. The main effect of high ambient temperature in breeding ewes is to disrupt the expression of oestrus (Sawyer et.al. 1979) causing a shortening or a complete blocking of behavioral oestrus. It would appear that the duration and length of high temperature in relation to the estrus cycle influences the degree of disruption to oestrus with earlier work of Thwaites (1971) finding that the embryo was susceptible to high ambient temperature in the very early stage (2 – 3 days post fertilization) and only in extreme heat waves. Sawyer et. al. (1979) also demonstrated some level of hormonal disruption of levels of progesterone and Luteinizing hormone leading to early losses.

Bell (1984) reported that extended periods of overheating in mid to late gestation caused a decrease in placental size, however this change was reversible as the placenta displayed an ability for compensatory growth during this mid gestational period. Bell et. al. (1989) noted the retardation of placental growth and observed the loss of one fetus from each of the twin bearing ewes in the study group but no losses from the controls which they concluded was as a direct result of the thermal stress. Marai et. al. (2007) also found that an increase in ambient temperature in mid to late gestation resulted in a decrease in the size of the placenta and a reduction in embryonic cell size and also resulted in lower birth weight and growth rates a pattern which confirmed work by Miller et. al. (1999) who observed that the flow of blood through the placenta was reduced during times of thermal stress which may lead to foetal stress, growth retardation and decreased viability of the lamb.

Takahashi (2012) also observed that in ewes, levels of progesterone declined and there was also a decline in the LH surge in sheep as a result of heat stress. He also indicated that there was a detrimental effect on placental weight and placentome size as a result of heat stress confirming the early review findings of Bell (1984).

As with the ewe, ram fertility is also affected by high ambient temperatures, Fowler (1969) stated that when rams are exposed to high ambient temperatures their fertility and seminal quality were negatively affected. Takahashi (2012) noted that rams, like most other male mammals were adversely affected by heat stress. With impacts on fertility ranging from impeded spermatogenisis, decreased embryo quality post fertilisation and noted that heat stress also adversely affected the biochemical and endocrine status of the male.

The environmental stresses imposed on sheep in the Australian farming environment for the most part are conducive to the successful reproductive outcomes, however, extremes in temperature and conditions can influence the outcome of the reproductive process in sheep.

Discussion

As with any complex biological system, interactions between the various components of the environment together with the genetic influences of the sheep can have a multitude of outcomes, some beneficial and some not so beneficial. The various interactions and impediments outlined above impact on the successful mating, conception and delivery of live healthy lambs from conception to parturition in Southern Australian sheep farming systems.

A modest improvement in net reproduction rate (NRR) has been shown (Hatcher et. al. 2010) to provide an estimated increase in gross margin per dry sheep equivalent (GM/DSE) of 21 – 30 % therefore the successful mating at the first opportunity for a young female sheep is critical to the overall reproductive performance of the ewe. This success is dependent on a number of factors, these include the season of birth (Stellflug et. al. 2001) BW (Watson and Gamble 1961; Hatcher et. al. 2007) and age at joining (Quirke & Hanrahan 1977 and Kelly 1984). BCS, as opposed to BW is of critical importance to conception (McInnes & Smith 1966, Hatcher et.al. 2007 and Curnow et. al. 2008) in mature ewes. Caldeira et. al. (2005) investigating the effects of BCS on blood metabolites and hormone profiles in non-lactating and non-pregnant Serra da Estrela ewes maintained that ewes in BCS 3 exhibited a more balanced metabolic profile than ewes in high (BCS 4) and low (BCS 1.5 – 2) BCS. This supports the work of Lifetime Wool (2004) which contended BCS >3 was the optimum profile to present a ewe for joining.

The provision of adequate nutrition plays a key role in the successful completion of the reproductive process for all biological systems and its importance cannot be overstated for the successful completion of the reproductive cycle in sheep. Pre-joining nutritional balance has been demonstrated to impact on ovulation rates (McInnes & Smith 1966, Oldham & Lindsay 1984 and Nottle et. al. 1997) and the maintenance of a suitable uterine environment (Meza-Herrer et. al. 2010) to maintain pregnancy. Pre-joining nutrition also play’s a significant role in the successful fertilization and implantation of the fertilized ova (Oldham & Lindsay 1984 and Nottle et. al. 1997). Whilst over supply of nutrition (Wallace et. al.1994 and Parr et. al.1987) has been demonstrated to lead to the loss of fertilized ova through the clearance of progesterone in the liver as a result of increased blood flow due to higher intake of protein in the diet.

Ambient temperature has also been demonstrated to impact on embryo survival (Takahashi 2012) due to a decline in LH surge and progesterone level due to heat stress and also lowered reproductive potential in the ram due to impeded spermatogenisis, decreased embryo quality post fertilisation, heat stress also adversely affected the biochemical and endocrine status of the male (Takahashi 2012). In cattle Dunlap and Vincent (1971) demonstrated a significant difference in conception rates in Hereford heifers exposed to high (40.0 C and 38.5 C) ambient temperatures at joining,

The impact of disease can also have major implications for the successful completion of the reproductive cycle. Metabolic diseases such as pregnancy toxemia and hypocalcaemia can at times be the cause of high rates of reproductive wastage (Belschner 1965 and Blood & Radostits 1990) and are in the main, nutritionally controlled and subject to manipulation. Other significant diseases such as the bacterial and causes of loss in both the unborn lamb and the pregnant ewe such as toxoplasmosis, listeriosis and pestivirus and others mentioned can also have a detrimental impact on survival. Internal and external parasites also have some negative impacts on survival of the ewe and lamb through a number of mechanisms outlined above.

Perinatal loss

Losses of both ewes and lambs can occur throughout the perinatal phase due to many factors, these factors can include losses at parturition or in the hours leading up to or post parturition. Parturition can be a traumatic event for both the ewe and lamb. Fogarty (1984) reported that annual mortality rates of lambs at parturition in Australia can be as high as 20% from birth to marking. Whilst other studies (McHugh & Edwards 1958, Smith 1962, Plant et. al. 1976 cited in Hinch & Brien 2014 and Watson 1959) have reported lamb losses of between 5 and 80 %. Fogarty (1984) also reported that 5% of lambs are born dead with a further 14% dying in the first three days postpartum. For this reason the subject of ewe and lamb mortalities at parturition will consider all deaths in the first seventy two hours to be within the scope of this discussion.

Live weight of the ewe is not a critical measure of the ewe in terms of lamb survival, as the body weight of the ewe will naturally increase with the progression of gestation due to the increase in the size and weight of the gravid uterus. There is however, a direct relationship between the survival of the lamb and the body condition score (BCS) of the ewe, as can be clearly demonstrated in Figure 4. Figure 4 also highlights the importance of BCS of the ewe to lamb survival for multiple conceptions.

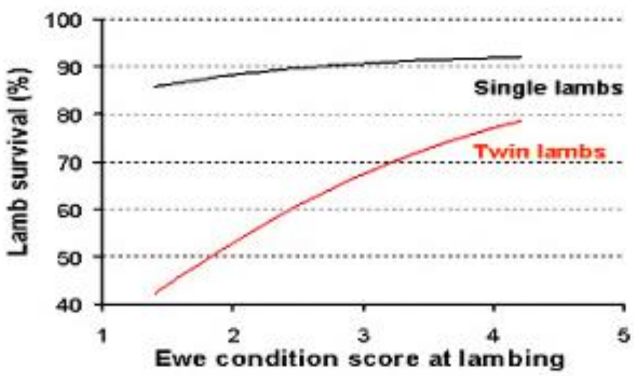


Figure 4: Relationship between condition score of the ewe and lamb survival. Source: Curnow et. al. (2008).

Caldeira et. al. (2007) noted that the BCS of the ewe was directly related to metabolic state, with ewes in BCS 3 being in metabolic balance as compared with ewes in low (1.25) or high (4) body condition scores. Caldeira et. al. (2007) also stated that the energy required for maintenance varied widely with BCS score. They also indicated that energy requirement tables must be utilized with care when considering requirements for ewes as they appear to have been formulated for animals in a satisfactory BCS. As BCS of the ewe has been shown to influence lamb survival it follows that maintenance of BCS is a key component of reduced reproductive wastage.

Other issues impacting on the survival of lambs are starvation miss-mothering, dystocia or difficult birth, lamb birth weight, predation, exposure, disease, environmental factors, and the inability of the ewe to feed the lamb due to disease (mastitis), injury to the teat or poor nutrition leading to failure to lactate.

Starvation miss-mothering exposure (SME Complex)

The complex known as starvation/miss-mothering/exposure (SME) is the single most devastating set of circumstances that can visit the new born lamb, with Hinch & Brien (2014) maintaining that there were a number of conditions which can lead to SME. These conditions are for the main nutritionally instigated (Geenty et. al. 2014 and Refshauge et. al. 2016) and changes to management practice may reduce the incidence of SME but not eliminate this problem. Some of the factors which are said to influence SME complex are poor mothering particularly in young ewes (Alexander 1960), lamb stealing, lamb birth weight (Hinch 2008) and difficult birth resulting in damage to the (CNS) central nervous system (Alexander 1984) of the newborn lamb. The exposure component of the

SME complex will be discussed separately in this review but is often combined in the diagnosis.

Poor mothering ability

Primparious Merino ewes are considered notoriously poor mothers when compared to their older more experienced counterparts, with Fowler (2007 Cited by Hinch 2008) reporting that single bearing maiden ewes had a lamb survival 6.1% lower than adult ewes. Nutrition of the ewe plays a role in the mothering ability of ewes, Dwyer et. al. (2003) contended that ewes in poor condition at lambing had impaired mothering ability and as a consequence lambs born to under nourished ewes had a reduced chance of survival.

Lamb Stealing

Lamb stealing is also said to have an impact on the survival of newborn lambs. Alexander (1984) cites many incidents of lamb stealing with varying outcomes. Some of the lambs which are stolen (Gonyou and Stookey 1985) are successfully adopted by ewes which have lost lambs of their own or sometimes even shared by two ewes, this is a benefit to the lamb involved. However, on some occasions the lamb is stolen by a ewe which has yet to give birth, in this incidence the outcome is quite often that the stolen lamb is rejected upon the birth of the ewes own lamb or the ewe rejects her own lamb in favor of the stolen lamb.

Inability of the ewe to feed the lamb

The inability of the ewe to feed the lamb arises from several different conditions afflicting the ewe. Conditions such as cut teats, mastitis and once again poor nutrition of the ewe can all have a significant impact on the ability of the ewe to feed her lamb.

In a study into the effects of udder damage on Merino ewes, Jordan and Mayer (1989) showed a relationship with udder damage and decreased survival rates. As can be seen in Table 3 this study and an earlier study by Jordan et. al. (1984) demonstrates clearly the affect that a damaged udder can have on the survival of newborn single lambs in times of nutritional stress for the ewe, but more significantly for twin and triplet born lambs.

Table 3. The effect of ewe udder soundness and level of nutrition on ewe and lamb performance to 4-6 weeks post-lambing Source: Jordan and Mayer (1989).

	Level of nutrition (% of requirements): 110		90		70	
	Sound	Damaged	Sound	Damaged	Sound	Damaged
Ewe milk yield (mL/day)	1260a	1031b	1144a	996b	1014b	862c
Lamb survival (% lambs born)	93·9a	85·9a	82·6ab	68·1bc	82·2ab	64·8c
Lamb growth rate (g/day)	200·2a	156·0b	186·8a	152·2b	154·7b	122·8c
Lamb water intake (mL/day)	431d	709c	718c	397d	966a	855a

The injuries to udders and teats can be caused by several factors including shearing cuts, cheesy gland (*Caseuos lymphadenitis)* or mastitis. These injuries can cause either partial or total damage to the udder and render the ewe unable to feed lambs. In a study of Queensland properties, Jordan et. al. (1984) identified a significant number of damaged udders in the properties surveyed, the results of this survey are shown in Table 4.

Table 4: Incidents of udder damage in fourteen Merino flocks. Source: Jordan et. al. (1984).

Area and Year	Age of ewes at previous shearing	No. of Ewes	% Damaged
Julia Creek 1982	1 to 7 years	160	7.5
Blackall 1980	3 to 7 years	1277	9.7
Blackall 1979	7 years	100	3.0
	5 years	100	4.0
	6, 7 years	100	9.0
	6, 7 years	111	17.1
	6 years	100	8.0
	8 years	84	9.5
	6, 7, 8 years	120	13.3
Charleville 1979	6, 7 years	150	9.3
Roma 1982	2 to 6 years	150	7.3
	2 to 6 years	219	2.3
	5 months	93	3.2
Goondawindi 1982	5 months	244	7.0
Total		3008	8.4

Table 4 highlights the significant damage incurred by breeding ewes and the earlier Table 3 demonstrates the ramifications of such injuries on milk production and hence ability to successfully feed and nourish the lamb. Other complaints such as mastitis can also have a catastrophic effect on the ewe as well as the lamb, with mortality a distinct possibility without treatment with antibiotics.

Stocking Density

Stocking density at parturition is believed to have an influence on lamb survival with Langlands et. al. (1984) in their work investigation the impact of stocking density (10 – 20 sheep/ha) observed a marked increase in the mortality rates of singleton lambs with increases in stocking rate and also noted this increase in mortality was greater for twin lambs. In this study the effect of stocking rate was greater than the net effect of age at lambing over a number of years. Alexander (1983) in Alexander (1984) noted a disproportionate increase in mis-mothering as the stocking rate increased above 18 DSE (dry sheep equivalents) also reinforcing the importance of stocking rate in the survival rate of the perinatal lamb.

On some occasions the lamb may be orphaned either through mis-mothering or the death of the ewe. In such cases the age of the lamb will be the determining factor as to whether or the lamb will survive. In their study into rumen development in the lamb, Wardrop and Coombe (1961) concluded that a lamb could not be considered a true ruminant until it is approximately 8 weeks of age and that prior to this, pasture intake is negligible and a lamb cannot be forced to ingest plant material in any quantity. Table 5 from Wardrop and Coombe (1961) illustrates the effect of the intake of plant material in the lamb.

Table 5: Nutrient intake of the lamb. Source: Wardrop and Coombe (1961).

Age (weeks)	Group A				Group B			
	"Milk" (g/day)	Liveweight (kg)	Hay Intake (g D.M /day)	Ratio Intake to Liveweight (%)	"Mi k" (g/day)	Liveweight (kg)	Hay Intake (g D.M./day)	Ratio Intake to Liveweight. (%)
2	1330	6.43±0·91	2±0	0·03	665	6·43±0·26	2± 0	0·03
4	1170	8·17±0·91	6±3	0·07	580	6·81±0·21	7± 4	0-10
6	1020	10·21±1·03	16±5	0·16	510	8·25±0·71	55±11	0·67
8	800	11·47±0·57	67±14	0·58	400	9·53±0·81	132±38	1·39
10	600	13·28±0·80	198 ±41	1·49	300	10·90±1·42	186±66	1·71
12		14 -19±0·57	327±2	2·30		11·27±1·90	291±70	2 58
14		14 ·64±0 - 57	427 ±16	2·92		12·26±1·36	408±58	3·33
16		15·18±1.33	464 ±8	3·06		12·41±1·25	397±11	3·20

Wilson and Tribe (1961) contend that the parotid gland, the gland responsible for the secretion of saliva which aids in buffering the contents of the rumen were not functionally formed until around 10 weeks of age thus concluded that lambs should be weaned at around this age. Therefore lambs orphaned at an early age had little chance of survival until 7 – 10 weeks of age without intervention from the farmer.

Lamb birth weight

Birth-weight of the lamb plays the major role in the survival of the lamb past the perinatal period. Figure 5 highlights the interaction between reduced survival of high birth weights (7 – 8 kg) and the potential damage caused by CNS trauma (classical dystocia) and at the other end of the spectrum, low birth weight lambs (1.5 – 4 kg) are equally at risk of perishing due a variety of conditions including starvation and exposure.

Environmental extremes also play a large role in the mortality of lambs in the low birth weight category, lambs under 3 kilograms in weight (Alexander 1984) are more sensitive to these extremes. Fogarty et. al. (1992) concluded that low birth weights were a major cause of mortality in their study, due to starvation mis-mothering exposure (SME) syndrome. In particular, multiple birth lambs were more susceptible to this condition due to the lower birth weight. Where as singleton births are the major cause of post-partum loss was from dystocia. Ferguson et. al. (2004) showed that the ideal birth weight for the survival of a Merino lamb is between 4.5 and 5.5 kgs and for prime lambs 5.5 and 6 kgs.

Difficult Birth Resulting in CNS Damage

Difficult births resulting in haemorrhage to the central nervous system are believed to contribute to the SME complex (Haughey in Alexander 1984) by interfering with the ability of the lamb to thermo-regulate. Alexander (1984) also suggested a relationship between CNS damage as a result of difficult birth and mis-mothering of lambs with Haughey (1981) contending that less severely damaged lambs exhibited a reduced ability to walk and feed together with a higher susceptibility to adverse climatic conditions. The impact of CNS injury in perinatal lambs has also been confirmed by Holst (2004), Dutra et. al. (2007) and Refshauge et. al. (2016).

Dystocia

Dystocia including loss of ewe and lamb and losses in production is said to cost the Australian sheep industry $291 million per annum (Jubb et. al. 2015). Dystocia (a slow or difficult labor or delivery, Morrison and Gibb 1972) may also be associated with mal-presentation of the lamb at birth, however there are numerous causes of dystocia which can lead to the loss of both the ewe and lamb. Mal-presentation is indicated as a cause of dystocia in sheep (Alexander 1984) with this condition in Romney Marsh sheep in New Zealand (Quinlivan et. al. 1966) being responsible for 13.1% of the 28.6% of assisted births. In a study into obstetrical disorders in Awassi ewes Majeed and Taha (1995) found there were 51% of ewes which presented with dystocia and of these, 19.6% were due to mal-presentation.

Poor conformation in the ewe has also been implicated in the occurrence of dystocia (Cloete et. al.1998) in sheep, with small pelvic dimensions contributing to an increased incidence. Birth weight of the lamb is probably the biggest contributor to dystocia. Figure 5 (Curnow et. al. 2008) demonstrates the relationship between survival of the lamb and birth weight and highlighting that once past a certain birth weight, for Merinos around 5kgs (Alexander 1984), the survival of the lamb is adversely affected predominantly due to dystocia. The relationship is similar for other breeds of sheep of similar body weights but Alexander (1984) indicated that the rates of dystocia were greater for pure breeds of sheep than they were for crosses of breeds and there was a higher rate of difficult births in male lambs as compared to female lambs. Some breeds of sheep appear to be more prone to dystocia than others, the Australian Dorset has previously been reported to have a high rate of dystocia (Alexander 1984).

Figure 5: Influence of birth weight on lamb survival. Source: Curnow et. al. (2008).

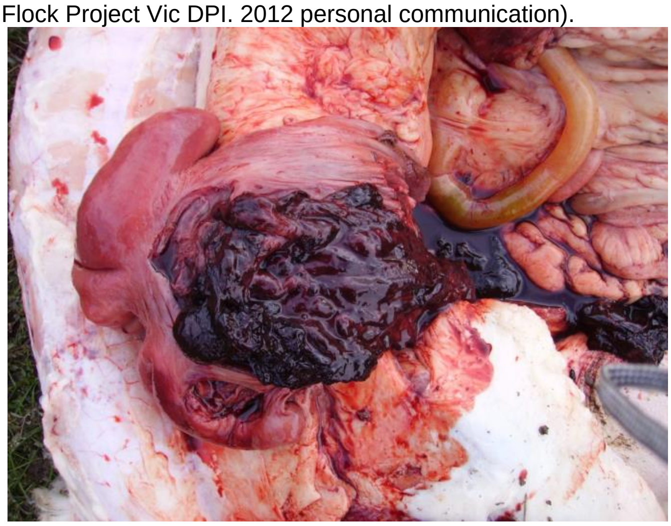
One of the issues surrounding large lamb size at birth is the damage caused to the CNS and the subsequent death of the lamb up to three to four days post-partum, with Alexander (1984) stating that the incidence of CNS involved in dystocic deaths is almost 100%. Plate 1 illustrates a classic CNS injury caused during dystocic birth. It shows the damage caused to the CNS and highlights the potential outcome of inadequate attention to BCS management of pregnant ewes during the final trimester of pregnancy (Curnow et. al. 2008). Alexander (1984) argues that some of the deaths attributed to starvation mis-mothering are also as a result of CNS injury as a result of dystocia, Haughey (1983a) in Alexander (1984) contended that birth injury caused lambs to fail to behave or thermo-regulate normally and in some cases the lambs can die two to three days post-partum due to injuries sustained during parturition.

Plate 1: CNS injury as a result of dystocia. Source: (Sentinel Flock Project Vic DPI 2012 personal communication).

Other injuries which may also be sustained during parturition can include laceration or puncturing of the liver (Holst 2004) which is usually fatal (Plate 2) or rupturing of the uterus of the ewe (Plate 3) resulting in the death of both the ewe and lamb. The major cause of perinatal loss (Walker et. al. 2002) are said to be due to the SME complex and Dystocia. These two diagnoses are said to be responsible for a significant proportion of loss in perinatal lambs (Refshauge et. al. 2016, Hinch 2014 and Hinch 2008) these diagnoses are well accepted as the major cause of loss however there are other complications that can result in losses in the perinatal lamb.

Plate 2: Severe laceration of the liver during dystocic birth. Birth weight of lamb, 8.6 kg, Source: (Sentinel Flock Project Vic DPI. 2012 personal communication).

Plate 3: Ruptured uterus of a Merino ewe during parturition. Lamb birth weight 8.7kg. Source: (Sentinel Flock Project Vic DPI. 2012 personal communication).



Environmental factors (Primary Exposure)

The newborn lamb is particularly susceptible to extremes in both low and high temperature which can have an overwhelming effect on lamb survival. The devastating combination of cold wet and windy weather has been responsible for the loss of a vast number of newborn lambs worldwide and has been the subject of much research. As with most of the challenges facing the newborn lamb, the environmental factors are strongly linked to the nutritional status of the neonate lamb Alexander (1984).

Exposure is an important cause of neonatal; mortality in sheep Alexander (1984) states that the energy reserves of the new born lamb are 4000kj and in mild conditions the starving new born has reserves for 3 days in comparison to 20 hours reserves in cold conditions.

Extremes in temperature are not confined to cold in the Australian environment with high temperature also playing a role in lamb mortality. Nolan et. al. (1980) demonstrated a link to lower birth weights and lamb survival following maternal hyperthermia. Hyperthermia is said to be just as devastating to the new born lamb with Stevenson (1984) contending that new born lambs are highly susceptible to heat stress and ewes lambing in high temperature without shade had little chance of delivering a live lamb. Stevenson (1984) links poor lamb survival to high ambient temperature, this situation is particularly relevant in the arid pastoral zones of New South Wales, Queensland, South Australia and Western Australia where hot dry conditions can prevail for months.

Lifetime Wool (2004) demonstrated that the body weight of the lamb also has a direct influence on the survival of the lamb with lambs under 3kgs (Alexander 1984) having a poor survival rate particularly in inclement weather. The Australian Bureau of Meteorology (BOM) has a sheep weather alert for forecasting the onset of cold, wet and windy weather which may be deleterious to the survival of newborn lambs and freshly shorn sheep, this highlights the well accepted impact the weather can have on the newborn lamb. Alexander (1961) describes the effects of hypothermia on newborn lambs as if the rate of heat loss is greater than the summit metabolism then the lamb will probably die. Alexander (1961) suggests that hyperthermia will probably suppress the lamb's willingness to suckle.

Predation

In most sheep producing regions of Australia predation is considered by producers to be a major cause of lamb losses. The species considered to be important are shown in Table 6.

Table 6: Common predators of Sheep.

Common Name	Scientific Name
Fox	*Vulpes vulpes*
Wedge Tailed Eagle	*Aquila audax*
Crows/Raven	*Corvus spp.*
Feral Pig	*Sus scrofa*
Domestic Dog	*Canis f. familiaris*
Dingo	*Canis familiaris dingo*

Rowley (1969) concluded that for the vast majority of lamb death attributed to predation that the lambs would have died anyway and that the predator only hastened the inevitable. However, Flemming et. al. (2006) stated that the fox (anecdotally the most important predator) is estimated to cost $227 million per annum in control and biodiversity losses. Of further interest is a study into the eating habits of the red fox (*Vulpes vulpes)* carried out in Western New South

Wales in which Lugton (1993) presented conflicting evidence into the predation of newborn lambs.

Lugton (1993) suggested that the predation of lambs by foxes may be as high as 30% in areas of high fox numbers and also noted that larger sized mature foxes were more likely to be responsible for the predation of newborn lambs although there are limited other published data to confirm this. He also suggested that the more immature foxes were likely to be carrion eaters rather than primary predators of newborn lambs.

The wedge tailed eagle (*Aquila audax*) for many years was believed to be a major source of lamb mortality in the Australian sheep flock. This was disproved in a number of studies into the feeding habits of this bird (Starker-Leopold and Wolfe 1969, and Brooker & Ridpath1980). Starker-Leopold and Wolfe (1969) showed that the diet of the wedge tailed eagle consisted of a small amount (7%) of lamb, and maintained that this number was made up of probably 50% of lambs which would have died any way. In their study in the Canberra area Starker- Leopold and Wolfe (1969) concluded that about 6-7 lambs were taken from the 4000 ewes in the range of the nesting pair of eagles, which equates to 0.15% losses due to eagles in their study. This figure is even less concerning as it is possible that 50% of lambs taken by eagles would probably have died anyway.

Corvids (*Corvus spp.*) (crows/ravens) are present in all sheep breeding areas of Australia and also have been blamed for large lambing losses. The Corvids are all opportunistic scavengers (Rowley 1969) visiting the lambing paddocks throughout the lambing to devour placenta and any carcasses they may find. Corvids have been known to attack healthy lambs but these attacks are usually fruitless if the ewe is with the lamb and the lamb is healthy. Table 7 from Rowley (1969) gives an illustration of the predatory habits of Corvids.

As with the previously mentioned animals, crows are more inclined to attack lambs which are either abandoned or probably going to die anyway.

Table 7: Intensities of predation and carrion feeding by Corvids during one season in 1962 on four properties at Geary's Gap, Source: Rowley (1969).

Category of Dead Lamb	Property A	Property B	Property C	Property D
Number Examined	114	104	73	85
Number Assessable	114	104	73	84
Percentage of wounded	7.0	24.0	46.5	63.5
Percentage of healthy when attacked	1.7	6.7	17.1	7.1
Percentage of dying when attacked	2.5	12.5	21.4	33.3
Percentage of dead when attacked	2.5	4.8	5.7	22.6
Month of lambing	Aug.	Aug.	July	Aug.*
Method of predator control	Poison, scare-gun	Nil	Scare-gun, rifle	Nil
*Property D was stocked at twice the rate of the other properties on very productive sown pastures				

Feral pigs (*Sus scrofa*) in the pastoral areas of Australia can have a significant impact on lamb survival and excluding them from the lambing paddocks can have a positive effect on lamb marking percentages (Pavlov et.al. 1981). In a study into reproductive wastage in Queensland, Smith (1965) concluded that the feral pig was responsible for the death of viable lambs but Smith (1961) in Rowley (1969) contends that not all pigs in a group will kill lambs.

The domestic dog (*Canis f. familiaris*) is said to be responsible for losses in livestock production. Likewise the Dingo (*Canis familiaris dingo)* is also said to have a major impact on lamb survival, with combined losses estimated to be around $66.3 million per year (Flemming 2006). So it reasonable to consider their impact on lamb survival collectively, as either pure strains, hybrid crosses, or a combination of these wild dog breeds have been associated with at times, major losses of lambs. The tendency for wild canids to kill surplus to their requirements (Flemming 2006) means that at times they can have a devastating effect on lambing results ranging from 0.25% to 36% losses being recorded (Flemming 2006).

The overwhelming evidence suggests that in most instances, predation of lambs is not a primary cause of lamb mortality rather that most predators in Australia prefer to attack lambs which were going to die anyway. However in some circumstances the presence of these predators can have a devastating effect on lamb survival with MLA (2015) reporting up to 40% losses due to primary predation.

Disease in the Neonatal Lamb

There are a number of diseases which impact directly on the survival of the lamb post-partum; these are in addition to the earlier mentioned diseases that can afflict the ewe. Some of the more important diseases in new born lambs are listed in Table 8.

Table 8: Diseases of the new born lamb Source: Vein (2009).

Common Name	Causal Agent
Navel ill	Infection of the umbilicus, gangrene and peritonitis, caused by numerous bacteria, some of the more common causative agents of Navel ill are: *Clostridium septicum, C chauvoei, C novyi*
Pneumonia	*Pasteurella haemolytica or P multocida*
Enteritis	Septicaemia and Loptomeningitis – *Escherichia coli*
Peritonitis	*Pasteurella haemolytica or P multocida*
Polysynovitis	*Erysipelothrix insidiosa and Chlamydia spp.*
Pyaemia	*Staphylococcus aureus, Streptococcus spp, Corynebacterium spp and Fusobacterium necrophorum*

Conclusion

The many causes of reproductive wastage which have been described above have been investigated by numerous workers. In the context of the Victorian farming system there have been very few large scale investigations into reproductive wastage in a commercial setting. The failure to conceive or early embryonic loss, or failure of the ewe to deliver healthy lambs is the cause of significant economic (Jubb et. al. 2015) loss and welfare issues for the Victorian sheep industry. This review highlights the complex interactions between genetics, environment and nutritional management of sheep which contribute to reproductive wastage in the Australian sheep production system.

Whilst the overarching goal of the Sentinel Flock Project was to provide an audit of the health status of the Victorian sheep and goat industries, the data collected during this project also provided an opportunity to investigate the causes of reproductive wastage in the Victorian sheep industry.

Chapter 3 (Experimental Section)

Factors Influencing Reproductive Wastage in Victorian Sheep Flocks

The sheep and wool industry in Victoria is the third largest agricultural industry in terms of its contribution to the state's economy (DEPI Vic 2014) and was estimated to be worth $1.497 billion in 2013 – 2014. Victoria currently produces 44% of Australian lamb production (DEPI Vic 2015) and over 70,000 tonnes of wool per annum which makes the Victorian sheep industry a significant contributor to the state's economy.

This program was initially developed as a disease audit to gain an understanding of the factors influencing productivity and profitability and provide market assurance on the health and welfare of the sheep and goat industries to Victoria's trading partners, but the project had particular focus of the issues contributing to reproductive wastage in the Victorian sheep and goat industry, including the loss of ewes at parturition and the impact of ewe management on lamb survival to lamb-marking and weaning.

Methods

Twenty flocks of prime lamb and wool producing sheep were initially enlisted across the sheep production areas of Victoria to monitor factors influencing reproductive wastage, morbidity and mortality over a three year period. One flock retired from the project and another flock was added hence 21 flocks were assessed. As far as possible, the spread of these flocks represented the distribution of sheep across Victoria. Flocks were enlisted from the known contacts of the Department of Primary Industries Victoria, Meat and Wool Services Branch.

Target flock size was 400 – 3000 breeding ewes. Both commercial and stud flocks were eligible for consideration. The flocks husbandry, management, reproductive performance and procedures were monitored for a period of three years and documented to evaluate the incidence reproductive wastage and livestock deaths in the participating flocks.

A detailed history of flock husbandry, animal health program and management information, including an annual calendar of operations and reproductive performance was collected for 20 sheep flocks (Table 9) located across the sheep production areas of Victoria (Fig 6).

These flocks were selected on the basis that they were representative of the Victorian sheep flock which currently consists of approximately 8 million breeding ewes (MLA 2016) of which approximately 6.3 million or 78% are Merino (MLA Personal Comm 2016). Victoria currently produces 44% of Australian lamb production (DEPI Vic 2015) and over 70,000 tonnes of wool per annum which makes the Victorian sheep industry a significant contributor to the state's economy. The location, area managed and makeup of the flocks is provided in Table 9.

Data collected in this project were analysed using Genstat®, SAS® and Minitab® statistical software.

Table 9: Flock makeup area managed and ewe numbers of the project participants.

Flock Number	Location	Breed MXM = Merino X Merino (Wool) MXP = Merino X Prime Sire (Meat/Wool) PXP – 1ST X Ewe X Prime sire (Meat)	Area Manage d/ha	Number of Breeding Ewes
1	Meredith	PXP	240	2000
2	Ballan	PXP	5600	12000
3	Kolora	MXM	970	2500
4	Timboon	PXP	400	1200
5	Glenthompson	MXM	430	1050
6	Toongabbie	MXM 75% MXP 25%	1200	1400
7	Road Elmore	MXM 50%, MXP 50%	840	1900
8	Boort	MXM 50%, MXP 50%	1100	1080
9	Dollar	MXP	340	1600
10	Bungalally	MXM	2332	1500
11	Nagambie	MXM	850	1929
12	Ravenswood	MXM 50%, MXP 50%	1100	3000
13	Darriman	MXP 50% MXP 50%	1370	4153
14	Benalla	PXP	1100	670
16	Seymour	MXM	1600	2500
17	“Lismore	PXP	730	3500
18	Coldstream	PXP	720	2000
19	Castle Creek	MXM	800	1300
20	Kotupna	PXP	450	1300
21	Kilmore	MXM	2400	1452

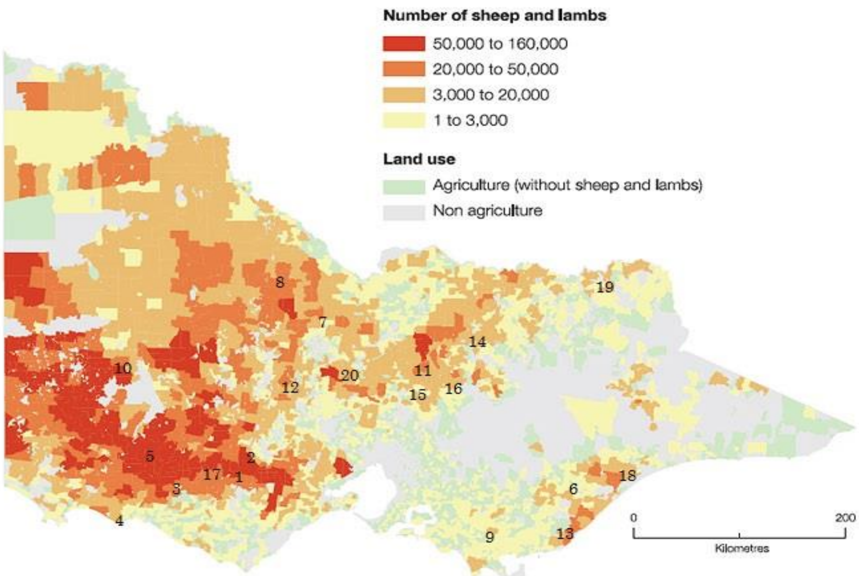


Figure 6: Map of Victoria showing sheep population and research sites, DPI Vic sheep density map.

The 20 ewe flocks were monitored over a 3.5 year period from 2009 to 2012. One flock retired from the project and was replaced with flock of similar size and in a similar geographic location, hence 21 flocks in the Table 9. The information collected annually over the life of the project included:

A random sample of 50 ewes from each group were condition scored five times throughout the year at, pre-joining, ultrasound scanning, pre-lambing (4-6 weeks), post lambing at lamb marking and then at weaning using the method described in the Lifetime wool (2004) program and a mean BCS was recorded for each visit.

The results were recorded using Lifetime Ewe condition score sheet (Appendix B) Food On Offer (FOO) as visually assessed by a qualified team member was also recorded in a data sheet (Appendix B) at these times using the protocol developed by the Lifetime Wool (2004). This data was not analysed in detail as BCS was used to inform the nutritional management decisions made by the farmers.

Rams used in the flocks throughout the project were individually assessed annually for fitness at joining. The pre-joining assessment included checking the teeth, feet, testicles, BCS and an inspection of the penis to ensure animals were sound in accordance with the DEPI sheep notes (2015). The results of these examinations were recorded on a yard sheet developed for the project (appendix B) then transferred to an excel spreadsheet.

Pregnancy testing of all ewes was conducted via ultrasound scanning (Anwar et. al. 2008) between day 60 and 80 post joining using commercial ultrasound contractors, day 1 being the day the rams were introduced to the ewes. Ewes were scanned for singles, multiples and not detectable (dry) on flock mean basis with no individual animal results being recorded. All data was collated and transferred to an Excel spread sheet. The flocks involved in the project were requested to manage the ewes on the basis of their pregnancy status (multiples, singles and scanned empty) with two flocks also managing triplets separately.

Participating properties were visited at least 3 times per week during lambing to record information regarding lamb losses including the number and sex of all lambs lost and the mob from which the lambs came (Single or Multiple Mob) and to collect any dead lambs for disease investigation by project staff. As the joining period varied from 5 to 8 weeks on the properties the visits continued throughout the period of lambing. Dead lambs were examined using the protocol developed by Holst (2004). Results were recorded on a perinatal lamb necropsy data sheet by the project team member (Appendix B) and data and final diagnosis transferred to an excel spreadsheet by the project leader. Where ewes died and were identified within 1-3 days post mortem examinations were conducted by suitably qualified project team members using the protocols developed by Jubb and Button (2005).

The complete animal health program of the participating farms was also recorded (Table 10), these data are not presented in this study.

Table 10: Management data collected in the program.

Management program	Treatment applied
Vaccination status	5-in-1' or '6-in-1, Gudair™
Internal parasite program	Fecal Egg Count (FEC) Fecal Egg Count Reduction Test (FECRT) Genetic selection (WEC)
External parasite program	Chemical used and dose rate Method of application
Mineral supplementation if any	Selenium Copper Cobalt Testing history
Husbandry practices	Stocking rate Supplementary feeding

The reproductive management of each ewe flock was documented by project staff. This included, date and length of joining, percentage and breed of rams used, BCS of ewes and rams, FOO as visually assessed by qualified staff throughout the year. As the joining time ranged between 5 – 8 weeks it was decided not to examine the length of joining as a factor in loss. Details on the breed of rams and breed of ewes being managed on each farm were recorded.

Data was analysed using a mixed model approach using Genstat®, SAS® and Minitab® statistical software. Flock means for percentage of single, twin and triplets conceived and number of ewes which scanned empty (dry ewes) as determined by ultrasound scanning contractor (Anwar et. al. 2008) along with lambing marking results were examined using analysis of variance to determine the effects of ewe breed, season of birth and BCS at lambing and then further analysed using generalized linear models to examine interaction between breed of ewe and ram (genotype) and season. Pregnancy results reported are for number of lambs marked to number of ewes joined.

Ram breed effects on ewes was examined using analysis of variance. Effects of interaction between breed and BCS and age were also examined.
A generalized linear model was used to examine the effects of birth weight, ewe breed and season of birth on cause of death. The data collected, which was relevant to reproductive wastage analysed utilising Genstat®, SAS® and Minitab® statistical software.

Results

Food on Offer

Throughout the life of the project the FOO available for the ewes and lambs was within acceptable limits of 800 kg/DM/ha up to 2100 kg/DM/ha which was within the guidelines set out in lifetime wool (2004) and was not deemed to be a contributing factor in ewe BCS as ewes were supplemented with cereal grain during times of FOO shortage. Mean food on offer for the ewes is displayed in Figure 7 FOO was not limiting (< 100kg - Lifetime wool 2004) at the time of lambing in most years with the possible exception of the Autumn lambing ewes in 2010.

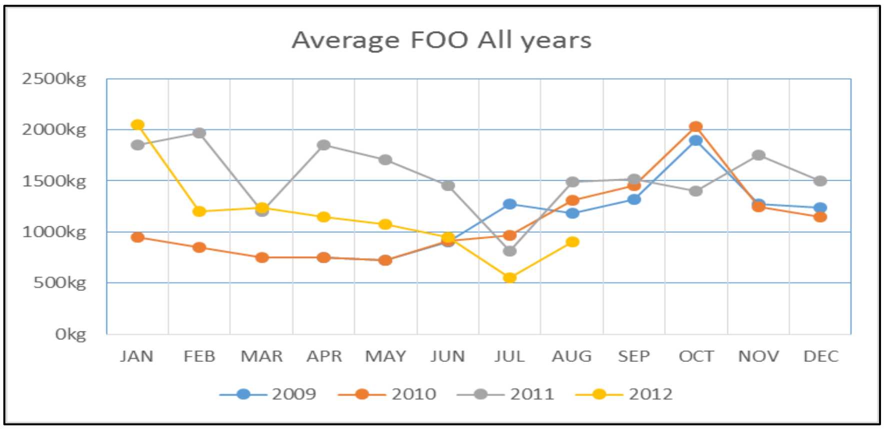


Figure 7: Mean Food on offer (kg/DM/ha) for each month in all years of the study.

Rams

Pre-joining examinations showed that 28.1% (n=169) of the rams used on properties were below the Lifetime wool (2004) recommended BCS of 3 and a further 13% (n=79) were unfit for joining due to lameness or unsound testicles including 19 confirmed cases of Ovine Brucellosis. Table 11 shows the breed means for BCS of the rams examined prior to joining. The variation between breeds in BCS of the rams prior to joining was significant, (P<0.001, Appendix

B) but as data linking the rams to individual mating performance was not available so it was not possible to determine the impact of BCS on individual ram conception rates. Merino (2.76 BCS) and Poll Merino (1.8 BCS) were lower in BCS than the other breeds in the project.

Table 11: Mean and Standard error of BCS for Breed of rams.

Level	Number	Mean	Std Error
Border Leicester	19	3.13	0.13
Composite	31	3.14	0.10
Coopworth	66	3.07	0.07
Dorset	63	3.74	0.07
Merino	193	2.76	0.04
Poll Dorset	10	3.84	0.19
Poll Merino	9	1.88	0.20
South Hampshire	70	3.07	0.07
Southdown	64	3.64	0.07
White Suffolk	76	3.30	0.06

The mean age of the rams used in the program was 3.55 years (Table 12) with individual rams being as young as 1 year old and the oldest 9 years of age.

Table 12: Mean and Standard error for Age (years) of Rams of different Breeds.

Level	Number	Mean	Std Error
Border Leicester	19	4.07	0.33
Composite	31	2.01	0.25
Coopworth	66	3.96	0.17
Dorset	63	4.29	0.18
Merino	193	3.94	0.10
Poll Dorset	10	4.45	0.45
Poll Merino	9	3.38	0.47
South Hampshire	70	2.90	0.17
Southdown	64	4.00	0.17
White Suffolk	76	2.92	0.16

The breeds differed significantly ($P < 0.001$) in mean age. (Appendix B) with younger rams for Composite (1.5 to 4.5 years old) and South Hampshire (1.5 to 5 years of age) the Merino and Poll Merion rams (1 to 9 years of age).

Reproduction Rates

Season of joining and Reproduction Rates

In the period 2009 – 2012 a total of 82092 ewes were ultrasound scanned for pregnancy status. The summary statistics for reproduction rates of the ewes for each years by genotype and season of lambing is shown in Table 13.

Table 13: Mean reproduction rate (lambs per ewe scanned) of ewes for years breed grouping and season of lambing.

Year	Breed Group/Season of lambing	Mean %	SE Mean	Mini %	Max %
2009	MXM/Autumn	1.19	0.05	1.06	1.41
2010	MXM/Autumn	1.17	0.08	0.88	1.44
2011	MXM/Autumn	1.17	0.14	0.80	1.47
2012	MXM/Autumn	1.16	0.09	0.90	1.32
	Average	1.17	0.09	0.91	1.41
2009	MXM/Spring	1.18	0.08	0.99	1.45
2010	MXM/Spring	1.13	1.13	0.75	1.36
2011	MXM/Spring	1.16	0.10	0.76	1.41
	Average	1.16	0.44	0.83	1.41
2010	MXP/Autumn	1.30	0.20	1.09	1.51
2011	MXP/Autumn	1.31	0.11	1.03	1.71
2012	MXP/Autumn	1.35	NA	1.35	1.35
	Average	1.32	0.16	1.16	1.52
2009	MXP/Spring	1.48	NA	1.48	1.48
2010	MXP/Spring	1.34	0.13	0.98	1.54
2011	MXP/Spring	1.21	0.10	1.10	1.41
2012	MXP/Spring	1.13	NA	1.13	1.13
	Average	1.29	0.12	1.17	1.39
2009	PXP/Spring	1.41	0.44	1.29	1.58
2010	PXP/Spring	1.38	0.84	1.18	1.62
2011	PXP/Spring	1.59	0.51	1.44	1.73
2012	PXP/Spring	1.37	NA	1.37	1.37
	Average	**1.44**	**0.59**	**1.32**	**1.58**

There was a significant (P<0.041)) difference in reproduction rates between MXM and MXP groupings of ewes and a greater significance (P<0.001)) for PX P groupings of ewes for conception. Year (P=0.948) or season (P=0.116) of joining was also not significant for conception in this work.

BCS at Joining and Reproduction Rates

Breed differences in relationship between BCS at joining and conception rate are shown in Figure 8. MXM (bottom line) and MXP (top line) breed groups had a similar positive relationship between BCS and conception rate although the MxP ewes tended to have a higher conception rate within the range of CS measured (P<0.001).

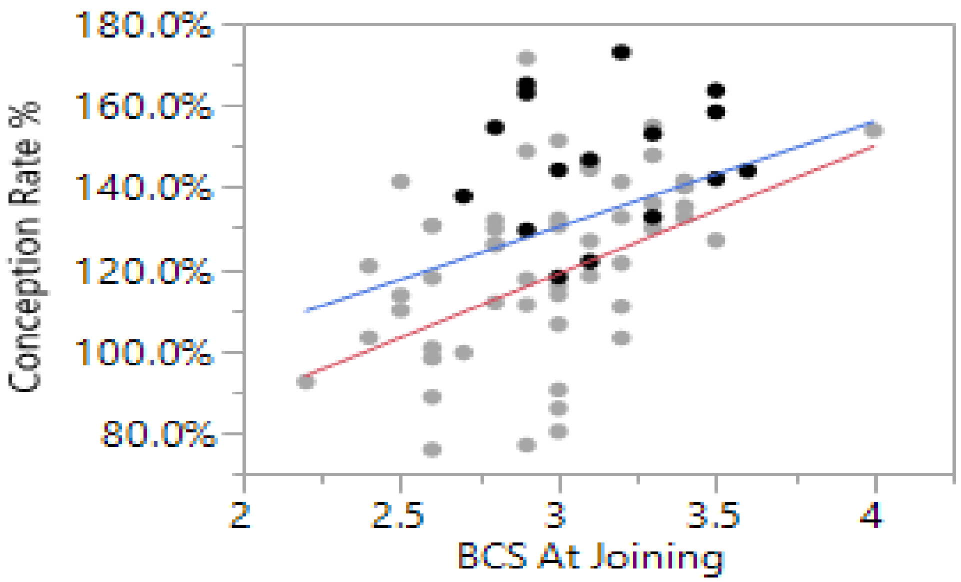


Figure 8: Conception rate at different body condition scores for Merino X Merino (red, bottom and Merino X Prime sire (blue top) breed groups over all years.

The relationship for the PXP breed group (Figure 9) which were only mated in the Autumn showed the conception rate to be less responsive to BCS within a higher and narrower range of condition scores.

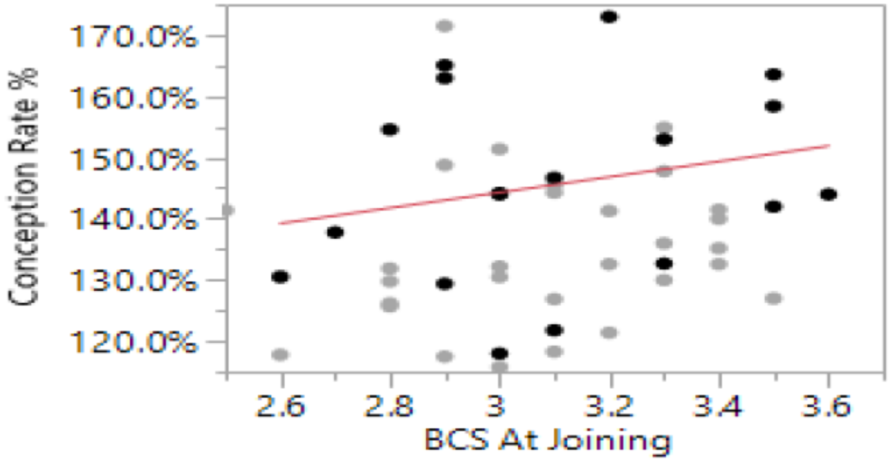


Figure 9: Prime (meat) ewe X Prime sire, body condition scores X Conception all years.

BCS Pre-lambing and Lamb-marking Percentage

There was no significant (P=0.110) relationship between BCS pre-lambing and lamb-marking percentage of the PXP group (Figure 10).

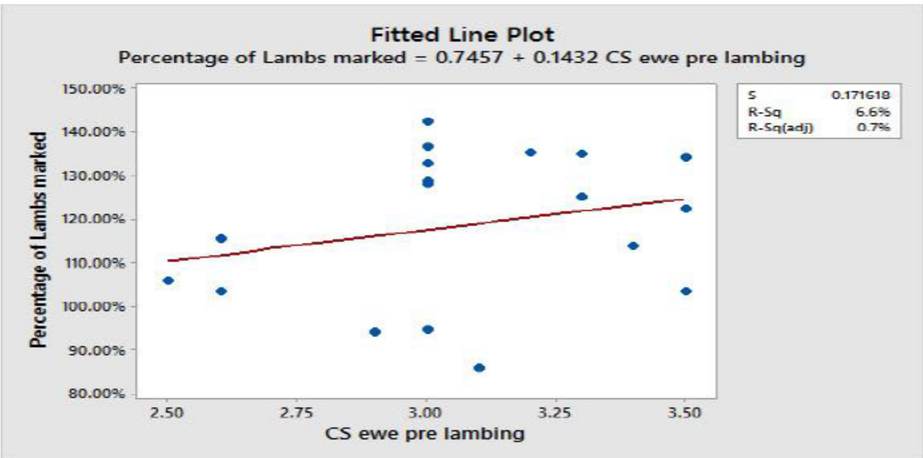


Figure 10: Regression line plot of percentage of lambs marked at different mean BCS pre-lambing for the PXP ewe group.

For the MXM group there was also no significant (P=0.897) relationship between BCS pre- lambing and lamb-marking percentage (Figure 11).

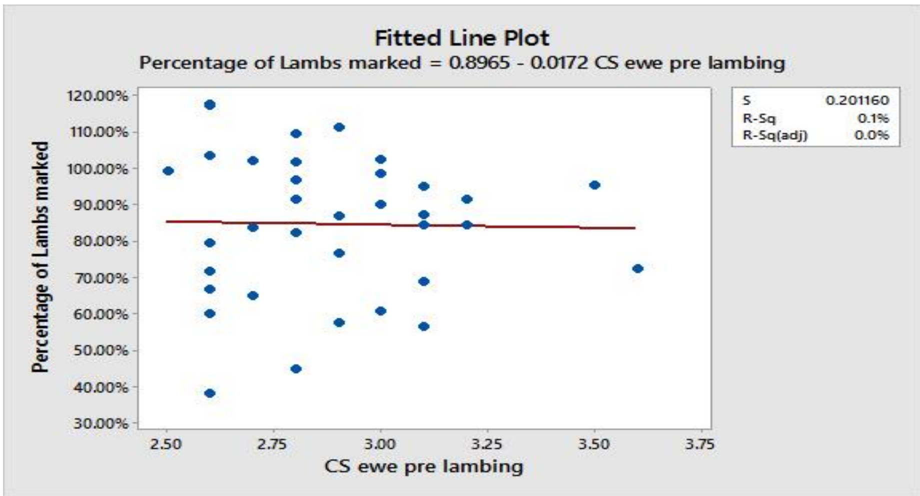


Figure 11: Regression line plot of percentage of lambs marked vs BCS of ewe pre-lambing MXM ewes.

The non-significant relationship of BCS on lamb-marking percentage (P=0.417) was also apparent for the MXP group of ewes (Figure 12).

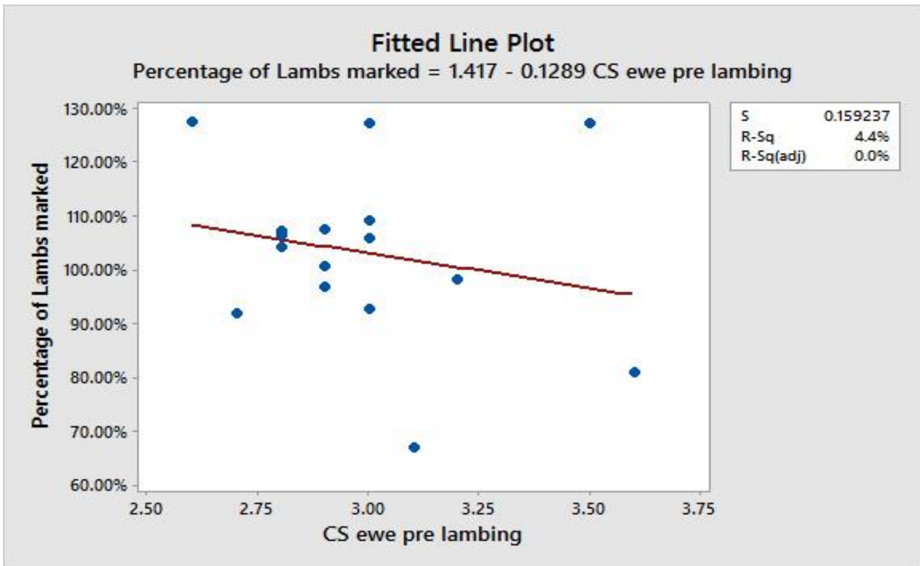


Figure 12: Regression line plot of percentage of lambs marked vs BCS of ewe pre-lambing MXP ewes, 95% CI for the mean.

A comparison of mean BCS of the breed groups across seasons showed a slightly significant (P<0.048) difference between the groups (Figure 13) with the MxM (2.89) being significantly lower than the MxP (2.97) and PxP (3.08).

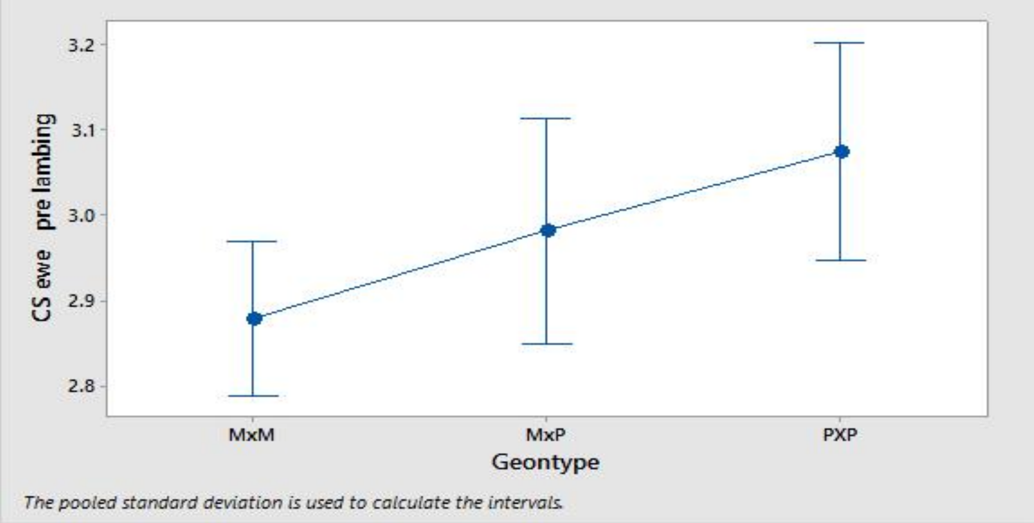


Figure 13: Interval plot of BCS of ewe x genotype all years.

The percentage of lambs lost between ultrasound scanning and lamb-marking was not significantly related to flock mean BCS (P=0.682, Figure 14) throughout all years.

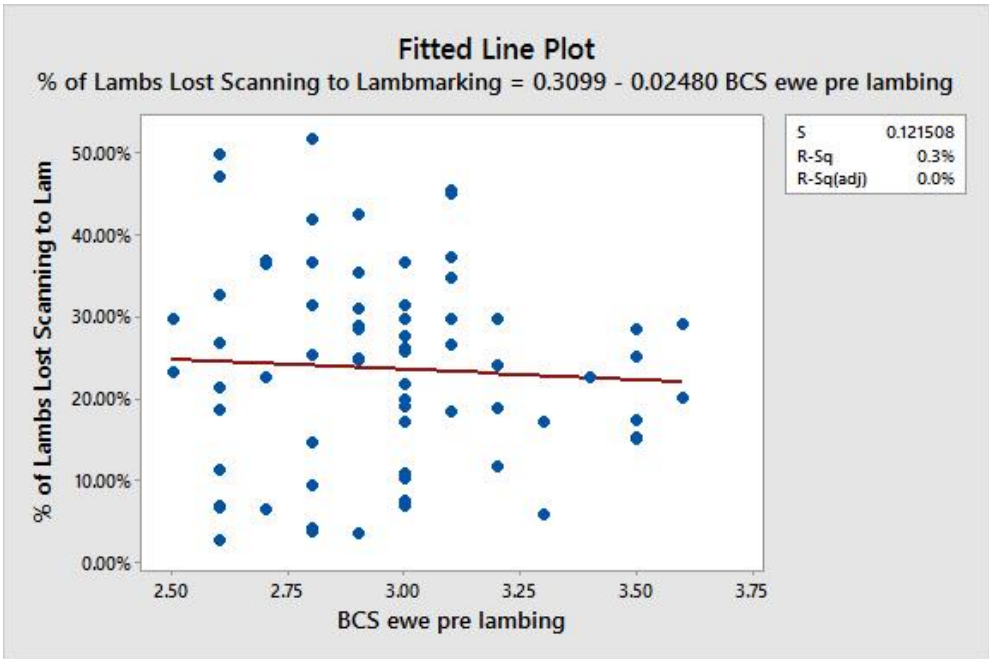


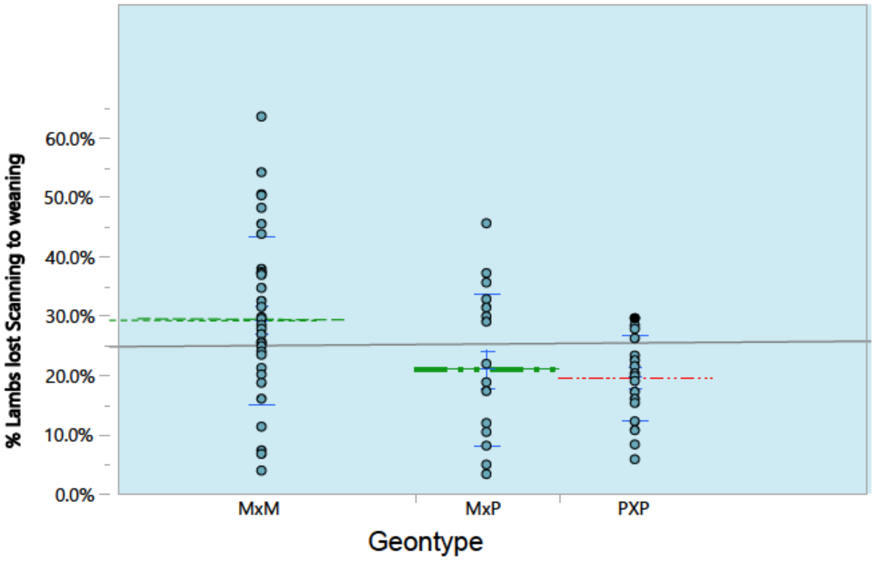
Figure 14: Regression line plot of BCS of ewe x percentage of lambs lost from ultrasound scanning to lamb-marking all years.

Lambs lost from ultrasound scanning to lamb-marking

Merino ewes mated to the Merino sires (MXM) had a mean loss across both seasons of joining between ultrasound scanning and lamb-marking (Figure 15) of 29.3% over the years of the study. In contrast the Merino ewe mated to a prime (Terminal meat) sire (MXP) had an average loss of 21.1% over the project which was significantly lower (P=0.0474) than the MxM flocks. The PXP flock showed an average loss across the project of 19.6%.

When examined to see if there could be any other interaction using a general linear model, the test revealed that only genotype (P=0.019) was a significant factor and that genotype x season were not significant (P=0.567) with BCS of the ewe pre-lambing also not (P=0.811) a significant factor in the loss of lambs from ultrasound scanning to lamb-marking in this work.

The percentage of lambs lost between scanning and lamb-marking in the Spring show breed group differences (P= 0.017) with a significantly greater loss for the MxM (27.6%) compared to the MxP (20.0%) and PxP (19.1%).



Level	Mean	Std Error
MxM	0.293250	0.02075
MxP	0.211059	0.03020
PXP	0.196389	0.02934

Figure 15: Oneway Analysis of the percentage of lambs lost from scanning to weaning by Genotype all groups.

Lamb marking

Lamb-marking results summarised in the Table 14, show a significant ($P<0.001$) influence of breed group with the MxM mean loss from scanning to weaning being lower than the MXP or PXP groups.

Table 14: Mean and Standard error for lamb-marking proportion of breed groups average across years.

Level	Number of flocks	Mean	Std Err Mean
MxM	36	0.846	0.033
MxP	17	1.032	0.038
PXP	18	1.186	0.040
Mean All Years		1.021	0.037

Perinatal necropsy

Perinatal lamb necropsies averaged 11.04% (n=2627) of losses (n=23777) across all breeds and seasons of the study. Cause of death of across all years is shown in Figure 16 with starvation exposure and dystocia making up the largest proportion of causes of loss.

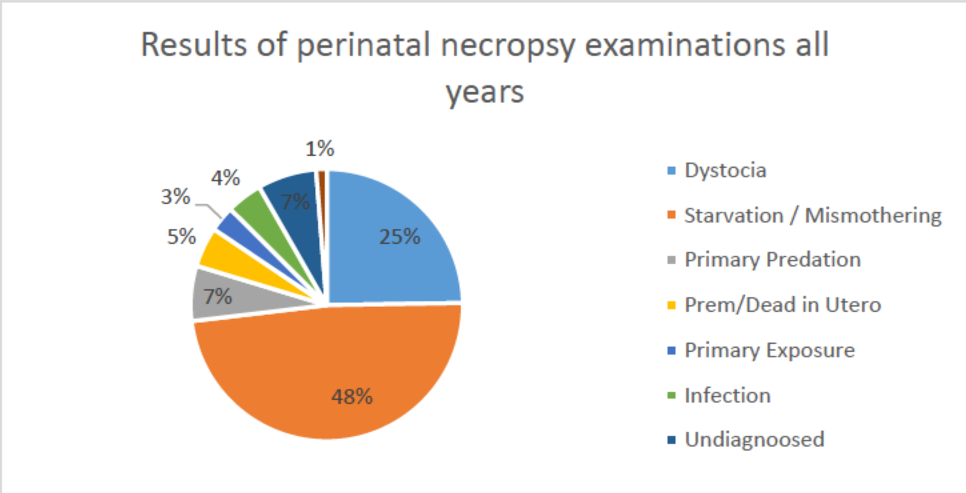


Figure 16: Percentage of perinatal lamb losses all genotypes by cause of death for all years of the study.

There were significant differences in distribution of cause of loss for different breed groups (P=0.002) (Figures 17 MXM, 18 MXP and 19 PXP).

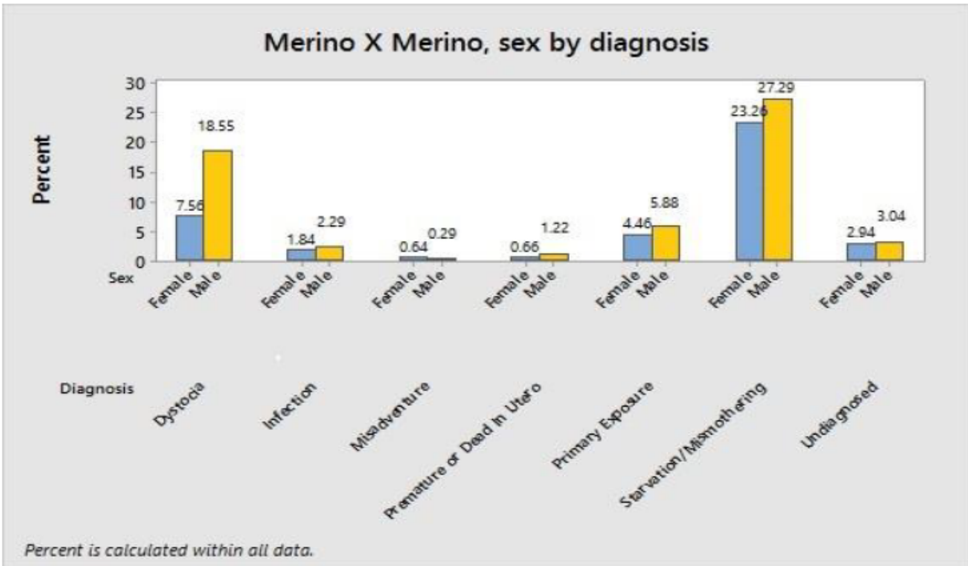


Figure 17: Sex X diagnoses for the Merino X Merino lambs all years.

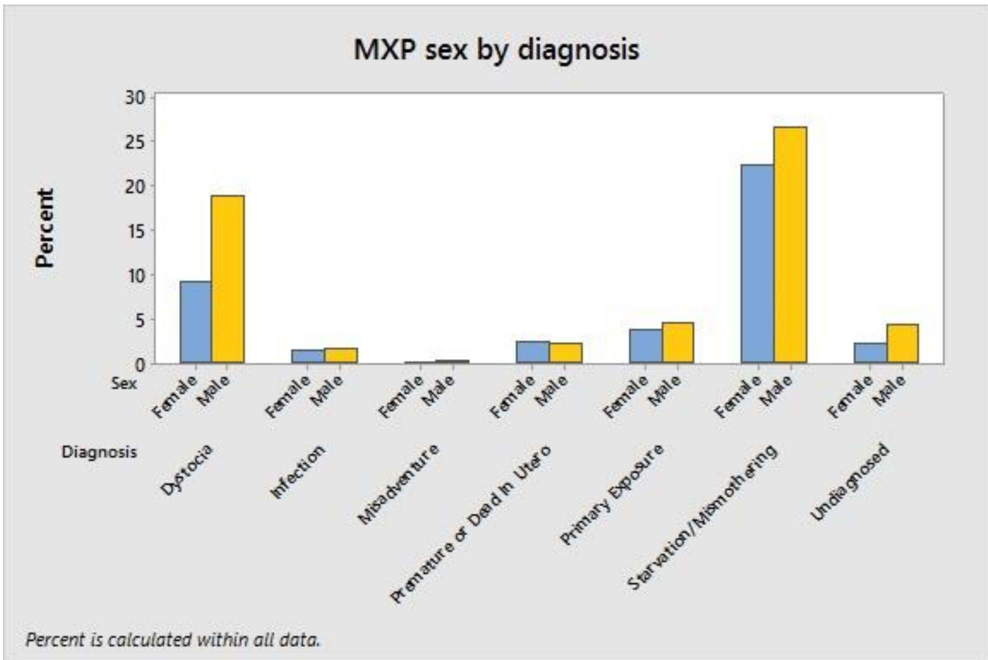


Figure 18: Sex X diagnoses for the Merino X Prime lambs all years.

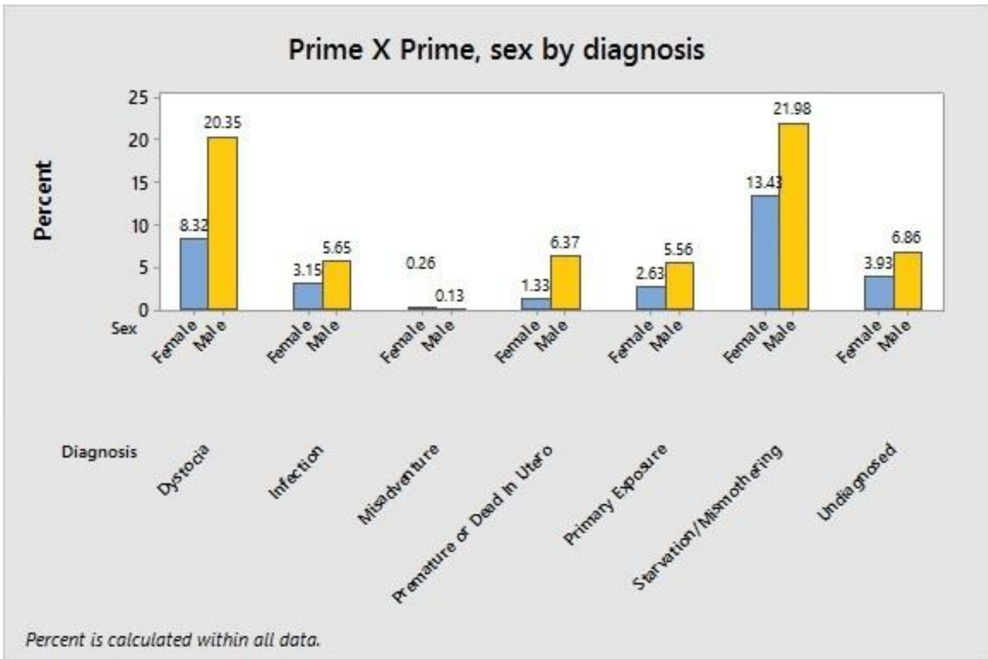


Figure 19: Sex X diagnoses for the Prime X Prime lambs all years.

Cause of death categories differed significantly (P<0.001) in mean weight of the animals examined (Figure 20) with higher birthweight in the dystocia and infection groups compared to others in the study.

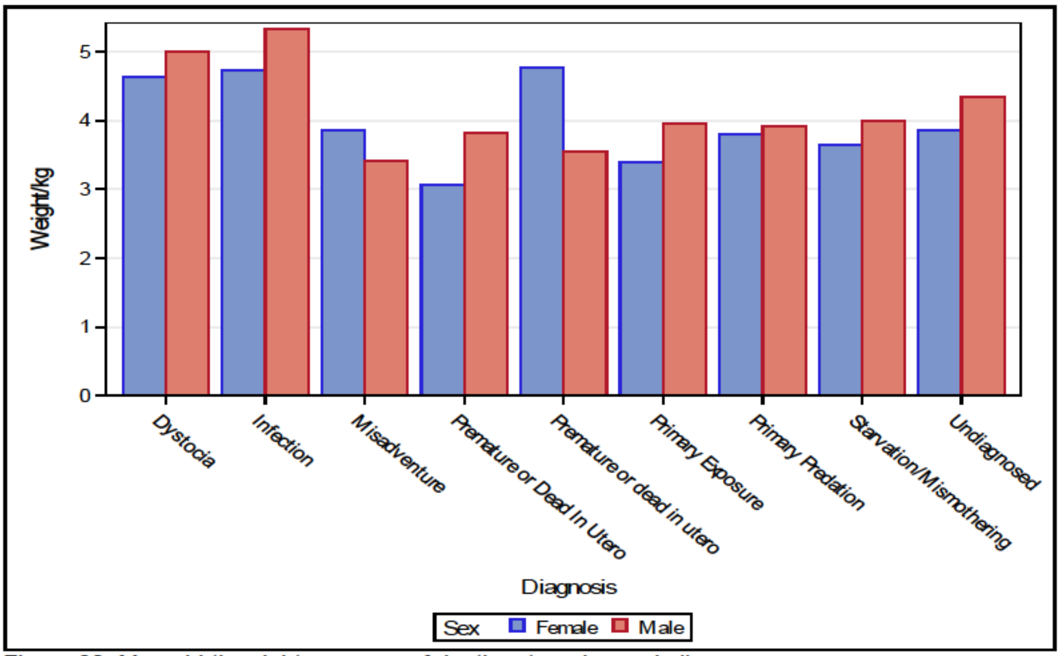


Figure 20: Mean birthweights x cause of death categories and all years.

Lamb sex and breed type were significant for mean birthweight of dead lambs males being heavier than females (P<0.001)) and the MxM being lighter in birthweight than the other breed groupings (P<0.001). There was no significant interaction between breed and sex (Table 15).

Table 15: Mean of bodyweight x sex and genotype of lambs.

Genotype	Sex	Mean birthweight
MxM	Female	3.75
MxM	Male	4.20
MxP	Female	3.91
MxP	Male	4.45
PxP	Female	4.05
PxP	Male	4.39

Perinatal Loss categories

Dystocia

Dystocia was diagnosed as the cause of 25% of deaths in the lambs examined. Of the 651 lambs diagnosed as dying due to dystocia, males made up the largest (68.6%) proportion with females accounting for 31.3%. Within this grouping (Table 16) there was a significant effect of genotype (MXP) on birth weight (P=0.006), with sex (male) of the lamb (P=0.004) and reproduction rate (P=0.001) also significant factors. However season of birth. (P=0.648) was not significant.

Table 16: Sex and breed group difference in body weight for the lambs diagnosed as dying of dystocia.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Min	Max
Dystocia	Female	MxM	69	4.40	1.25	2.00	8.50
		MxP	78	4.68	1.56	2.24	8.00
		PxP	57	4.82	1.41	1.60	8.60
	Male	MxM	150	4.92	0.98	1.50	8.70
		MxP	159	5.14	0.94	2.00	9.00
		PxP	138	4.92	0.83	2.00	8.00

Starvation/Mis-mothering

Starvation mis-mothering was the most common (48%) cause of the total loss of lambs to (Table 17) 54% (n=698) of the lambs were male and 45.1% (n=574) were female. There were significant differences in effect of breed grouping (P<0.001, MXM vs PXP)), sex (P<0.001, Female x Male)), and reproduction rate (P<0.001, Triplet v Twin V Singleton) and there was also a significant difference (P=0.008) for season of birth with a greater proportion lambs dying of SM in the Autumn (57.9%) compared to Spring (43.1%). Birth weight differed significantly for breed group with lower weights in the MXM group compared to the MXP group (P<0.01). Sex differences in weights were significant in this death category, males heavier than females (P <0.001) Litter size was also a significant influence on mean birthweight (P<0.001) with the twins and triplets being lighter than singles.

Table 17: Sex and breed group effects on mean birthweights of lambs dying from Starvation/Mismothering.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Min	Max
Starvation/Mismothering	Female	MxM	262	3.61	1.02	1.25	7.75
		MxP	188	3.69	0.77	2	6
		PxP	124	3.62	0.94	1	5.7
	Male	MxM	288	3.88	0.98	1.5	7
		MxP	223	4.10	0.94	1.9	8
		PxP	187	4.02	0.83	1.25	8.5

Primary Predation

Only 7% (n=173) of lambs were diagnosed as dying from primary predation (Table 18). Within this grouping 41% (n=71) were female and 59% (n=102) were male with no significant difference between the groups. Breed grouping for birthweight was significant (P<0.001) with the MXM in this death category being lighter than the MXP and PxP lambs.

Table 18: Sex and breed group mean birthweight for of lambs diagnosed with Primary Predation as the cause of death.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Minimum	Maximum
Primary Predation	Female	MxM	33	3.31	1.081	1.5	7
		MxP	19	4.17	1.43	2.5	9
		PxP	19	4.27	1.12	2.5	7
	Male	MxM	42	3.60	1.02	1.5	6.6
		MxP	28	4.32	2.19	2.28	15
		PxP	32	4.00	0.44	2.5	5

Premature or Dead in Utero

Premature or Dead in Utero (Table 19) was a minor cause of death accounting for 5% (n=124) of the diagnoses. Within this category there was a significant (P=0.003) difference between breed group in terms of birthweight means with the MXM group. Season of lambing and litter size had no significant effects on birthweight as these lambs were not significantly lighter than lambs in other groupings. (The major cause of loss in this grouping was suspected to be *Campylobacter fetus* but this was not confirmed by laboratory analysis.

Table 19: Mean birthweights X sex and breed grouping of lambs diagnosed with Premature or Dead in Utero as the cause of death.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Minimum	Maximum
Premature or Dead In Utero	Female	MxM	10	3.03	1.36	1.75	5.5
		MxP	21	2.91	0.97	0.92	5.62
		PxP	11	4.02	1.37	2.5	6.8
	Male	MxM	14	3.60	1.66	1.5	7
		MxP	18	3.28	0.92	1.8	5
		PxP	50	4.05	0.34	2.5	5

Primary Exposure

Primary exposure as a cause of death (Table 20) was only 3% (n=80) of deaths, with males accounting for 55% (n=44) and females 45% (n=36). The MXM group comprised (55%) of this category with the PXP (17%) and MXP (27%) Breeds did not differ in birthweight within this category but males were heavier than females (P=0.005) and singles heavier than multiples (P=0.010).

Table 20: Sex and breed group effects on mean birthweight of lambs diagnosed with Primary Exposure as the cause of death.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Minimum	Maximum
Primary Exposure	Female	MxM	22	3.40	0.95	1.60	5.00
		MxP	12	3.44	0.73	2.30	4.30
		PxP	2	3.00	0.70	2.50	3.50
	Male	MxM	22	3.95	0.73	2.75	5.50
		MxP	10	3.94	0.95	2.50	5.60
		PxP	12	4.00	0.16	3.50	4.1

Infection

Infection (Table 21) was a minor (4%) contributor to the loss of lambs Males accounted for 56% (n=64) of losses and females 44% (n=49). Birthweights did not differ for breed group, season of birth, sex or litter size (P>0.10).

The main cause of loss within this group was diagnosed as navel ill with liver abscess and peritonitis observed and confirmed by laboratory analysis.

Pneumonia was the other cause of infection identified by laboratory testing.

Table 21: Sex and breed type effects on mean birthweights of lambs diagnosed with infection as the cause of death.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Minimum	Maximum
Infection	Female	MxM	15	4.891	1.351	3	7.5
		MxP	13	4.311	1.411	2.76	8
		PxP	21	4.881	2.031	1.5	11.7
	Male	MxM	17	5.291	2.051	3	10.5
		MxP	14	5.351	1.9711	3.5	11
		PxP	33	5.331	2.081	3.5	12

Misadventure

Most of the lambs (n=17, Table 22) dying in this category were involved in collisions with farm vehicles at the time of supplementary feeding of ewes.

There were no significant effects of breed, sex, litter size or season on birthweights.

Table 22: Sex and breed group effects on mean birthweight of lambs diagnosed with Misadventure as the cause of death.

Diagnosis	Sex	Genotype	N Obs	Mean	Std Dev	Minimum	Maximum
Misadventure	Female	MxM	7	3.67	0.92	2.25	5.00
		MxP	1	4.00	.	4.00	4.00
		PxP	2	4.40	2.26	2.80	6.00
	Male	MxM	4	3.08	0.48	2.60	3.75
		MxP	2	3.75	0.35	3.50	4.00
		PxP	1	4.00	.	4.00	4.00

Undiagnosed

Of the 7.4% (n=197) of lambs where cause of death could not be identified 42% (n=83) were female and 58% (n=114) were male. There were no significant effects of breed, sex, litter size or season on mean birthweights within this category.

Ewe Mortality associated with the Preinatal period

There were 1421 ewes recorded as dying over the period of the study which equates to 1.7% loss of the ewe flock over the 3 years of study. A sample of the ewes (n=317) dying during the gestation, lactation and perinatal period were necropsied to determine the cause of death. General diagnosis of the ewes necropsies (Figure 21) shows that endemic infectious disease was the main (34%) cause of death. Followed by obstetrical disease (26%) then (17%) were unable to be diagnosed.

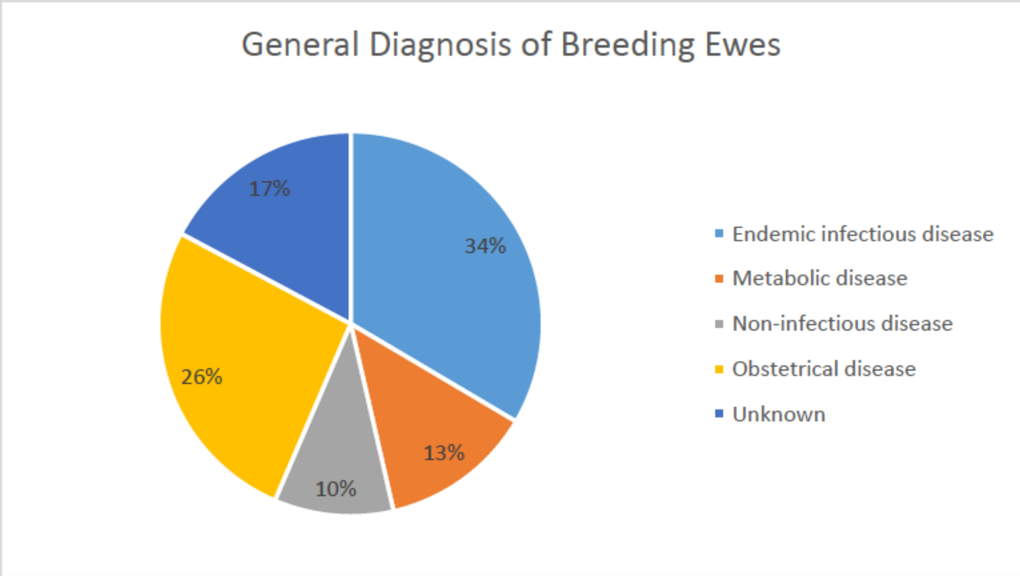


Figure 21: Results of Ewe Necropsies all years.

Age of the ewe appeared to have no significant (P=0.343) effect on cause of death. Likewise genotype (Figure 22), did not differ significantly (P=0.532) in cause of death of the ewes

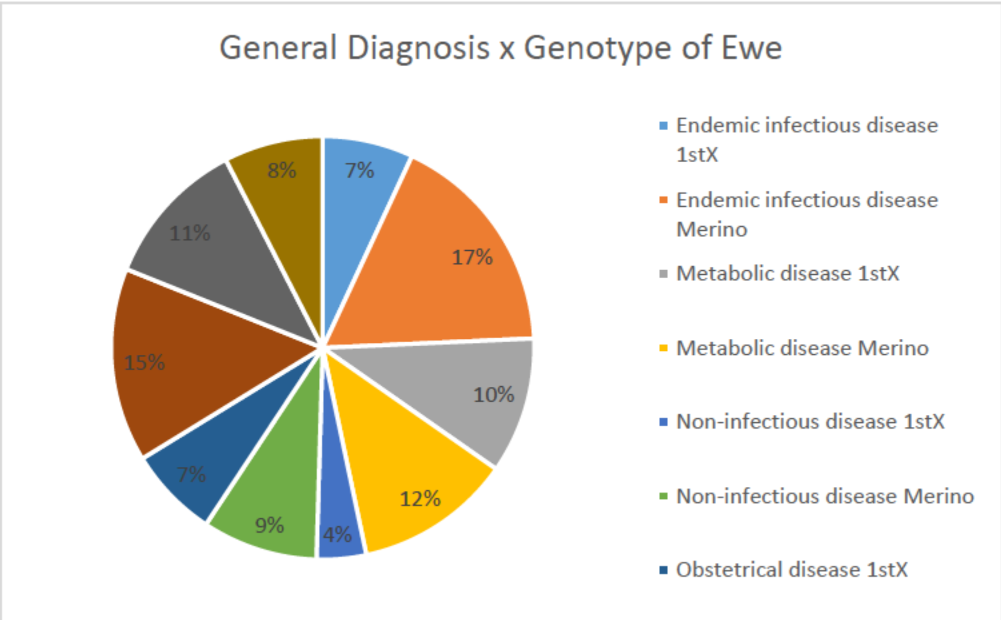


Figure 22: General diagnosis x ewe genotype.

Discussion

From joining, conception through to weaning the ewe and lamb face a great number of challenges to survive. These challenges come from a number of different areas in the production cycle from the health of the ram and ewe through to the environment into which the lamb is born, the lamb faces an uphill battle. The presence of predators can at times be devastating to the lambing flock although the vast majority of opinion seems to point to mainly sick and abandoned lambs falling prey to such a fate.

Rams

The rams used on the participating properties were assessed for fitness of purpose including an extensive examination annually. Due to the lack of data linking the rams to individual mating performance it was not possible to make any reasonable conclusions as the influence of the age or BCS of the rams on the conception rates achieved. It is however worth noting that 28.1% (n 169) of the rams were below the (Lifetime wool 2004, Ott and Memon 1979 and Merc 2014) recommended BCS of 3 and a further 13% (n79) were unfit for joining due to lameness or unsound testicles including 19 confirmed cases of Ovine Brucellosis. The variation between breeds in BCS of the rams prior to joining was significant, ($P<0.001$) and there was also a significant ($P<0.001$) range of the rams for age. The age at first joining appears to be lower (1 year of age) compared to the more traditional 18 months to two years of age. This combined with the retention of rams in some flocks until 9 years of age would suggest that the Victorian producers are attempting to extend the working life of their rams probably due to the steady increase in the purchase price of replacement rams.

Pregnancy Scanning Season of Joining and Conception

The data used in the analysis of the ewe conception was a mean of each flock and no individual data for reproductive performance was recorded. When analyzing the scanning results of the joining's for the different genotypes, the MXM joining's showed no significance for the season of lambing returning P=0.8329 and the MXP joining's showed P= 0.5333, these results would indicate that for the MXM and MXP joining's season of lambing had little influence on conception rates. The above results are in general agreement with Watson and Radford (1966) which concluded that for Merino ewes the difference in conception rates of ewes mated in summer or autumn is more likely to depend on the prolificacy of the ewes rather than season of joining and Obst et. al. (1991) who concluded that the differences in conception rates were more likely due to nutritional effects than season of mating for Merino ewes mated for a May or August lamb. As the Merino ewe was the genotype of ewe in both the MXM and MXP groups, it is therefore reasonable to assume that there was a genetic influence exerted over the conception by the P (Prime) sire in the MXP mating's.

The PXP ewes were all joined for spring lambing's, therefore it was not possible to determine if the season of joining influenced conception for this group of sheep. However analysis of across years showed no significance for year of joining. It would be reasonable to conclude that the pregnancy results were significantly under genetic control rather than any significant interaction from season or year of joining in this work.

BCS at Joining and conception rates

The BCS assessments were carried out 5 – 6 weeks prior to the commencement of joining. The MXM and MXP groupings did demonstrate a positive ($P<0.001$) relationship between mean BCS and conception rate. This is in general agreement with Hatcher et. al. (2007) and Yilmaz et. al. (2011) who state there is a positive relationship between BCS and conception rate. The PXP group showed a much lower response ($P=0.33$) to BCS at joining on conception rate. However it must be stated that in reality there could be some question around the random sampling of 50 ewes to be condition scored and the variability of the assessors.

As the mean data only was available for this analysis the sample data may well have a larger variation within it. If the BCS followed a normal distribution then it would not be unreasonable to conclude that there were a number of ewes which were well under the required BCS of 3. The Lifetime Wool (2004) program recommendations around the number of ewes (25) to have their BCS monitored through the reproductive phase may require some further recommendations to be developed to cater for larger flock sizes and different genotypes. The results of this study would have benefited from a far larger sample size of ewes being monitored or a more intense monitoring of a smaller sample size to confirm the impact of BCS on conception rates.

BCS of the Ewe Pre-lambing and Lamb-marking Percentage

The impact of BCS pre-lambing on lamb-marking percentage is well accepted with many workers (Yilmaz et. al. 2011 and Thompson et. al. 2004) noting the impact of BCS on lamb birthweight and survival. In this work the impact of mean BCS on lamb-marking rates was not clear, with the MXM grouping showing little (P= 0.897) interaction of BCS on marking percentage.

The response from the MXP group also demonstrated no significant (P=0.417) response on marking percentage by mean BCS when compared to the MXM. As the genotype of the ewes in this group is Merino it must be considered that difference between that two groups (MXM & MXP) may be related to the vigor of the prime sire which had some impact on the birth weight, and therefore an influence on the survival of the lamb to lamb-marking.

Within the PXP group there was no also significance (P=0.110) for the influence of mean BCS on lamb-marking percentage. Which disagrees with Thompson et. al. (2004), Yilmaz et. al. (2011) and van Burgel et. al. (2011) have documented the significant influence that BCS has on the survival of the lamb due to increased birth weight of the lamb and improved outcomes for the ewe, due to lower incidences of metabolic disease. In this work the impact of mean BCS has proven to be not significant for the all groups of ewe on the percentage of lambs marked. But again sample size could have confounded this result.

The influence of Genotype on Lamb-marking

Lamb losses from ultrasound scanning through to lamb-marking were also examined to investigate the influence of genotype on survival of the lamb. In this work there was a significant (P=0.012) interaction of genotype between all groups on the survival of the lamb, again related to the birthweight of the lamb with season, and season and genotype also being important for lamb survival. But again, sample size of the ewes is an issue in the interpretation of this data. This highlights the need to reassess the methodology being postulated in the Lifetime Ewe Management program as the variation in ewe BCS means that there are a number of ewes which must be under the recommended BCS 3 at lamb-marking which highlights the need to separate lower BCS ewes out prior to lambing for the provision of a higher plane of nutrition to allow them to achieve BCS 3 at lambing.

Lamb marking results

The genotype of the ewe and ram exerted a significant (P<0.001) influence on the percentage of lambs marked in this work. Although the mean lamb-marking percentages were within the parameters as described in Hatcher et. al. (2010) there were some extreme results achieved for some of the individual MXM flocks within the grouping. In these flocks the low mean BCS pre-lambing in all years was an issue with a mean BCS of 2.6 recorded annually pre-lambing and regular losses of up to 50% of conceived lambs.

Food On Offer (FOO)

FOO was visually assessed by qualified members of the project team but was not deemed to be in deficit during the course of the project as in times of reduced FOO supplemental grain was provided.

Perinatal necropsy results

The results of the perinatal necropsy examinations concurred with the conclusions of many other workers (Alexander et. al. 1984, Hinch 2008 and Hatcher 2010). In this work the strong influence of genotype of the lamb on birthweight played a significant role in the survival of the lamb to lamb-marking, particularly for the MXM and MXP ($P<0.001$ and $P=0.178$) genotypes.
As no surviving lambs were weighed to assess the differences between lambs surviving and those succumbing to disease, it was decided to use the well accepted survival weight (Curnow et. al. 2008 and Ferguson et. al. 2004) of 4.5 - 6 kg as the birthweight which would likely result in survival of the lamb.
When the primary exposure diagnosis is separated out of the traditional Starvation Mismothering Exposure (SME) complex as per Holst (2004) recommendations it highlights the requirements to focus more attention on the remaining Starvation Mismothering component of the SME syndrome as this complex contributes so significantly (54%) to lambing loss.

For this work the results would indicate that there is a significant interaction between birth weight, genotype and sex of the lamb, which have important implications in the survival of the perinatal lamb. However the lack of data from surviving lambs means that a comparison of birth weight as a contributing factor can only be done using the accepted survival weight of other workers.

Ewe Mortality associated with the Preinatal period

For the breeding ewe in this work the major cause (34%) of loss was endemic infectious disease. This diagnoses included diseases such as mastitis (*Staphylococcus aureus or Mannheimia haemolytica)*, clostridial disease and Ovine Johnes Disease (*Mycobacterium paratuberculosis).* The second most significant (26%) cause of death in the breeding ewe flock in this work was obstetrical disease including dystocia, uterine prolapse and ruptured uterus. Metabolic disease accounted for a further 17% of loss in the ewe flock mainly pregnancy toxemia.

Of the non-infectious diseases recorded (10%) there were caused by lactic acidosis or plant toxicity. There was a small significance (P=0478) for the influence of the genotype (MXM) of ewe in relation to the diagnosis of the cause of death

Conclusions

In this study there were a number of limitations in the project design. The requirement to use mean BCS of only 50 randomly selected ewes and flock ewe data together with the lack of data from surviving lambs particularly around body weight was a project design issue.

However, the results above have identified the cause of ewe loss to be substantially related to endemic infectious disease, obstetrical and metabolic disorders which are in the main under the control of the farmer.

The reproduction rate of the flocks in the study are in general agreement with other workers (MLA 2016) but the loss of lambs from ultrasound scanning to lamb-marking does require further investigation. The reproductive performance of the Merino when joined to the Merino ram returned a significantly higher loss from scanning to weaning over a larger and lower range of mean BCS than did the Merino ewe joined to the prime sire. The consistently lower mean BCS of the Merino ewes in the project is certainly a factor in the lower performance recorded in these ewes and of concern given that this is under the direct control of the farmer. The Australian Bureau of Agricultural and Resource Economics (ABARE 2016) gives the mean lamb marking percentage of Victorian sheep flocks as 95.6% which in disagreement with the project mean result of 102% across all years.

The loss of lambs in the project was attributable to the interaction of the genotype of the sire of the lamb having a greater vigor and higher birth weight which is a significant factor in the survival of the lamb, however it should be noted that the mean BCS of flocks within MXM grouping was below the recommended BCS of 3 at all phases of the work, in some cases on the same property as MXP flocks which were a mean of BCS 3.

The results of this work to date has demonstrated that the influence of genotype and birthweight of the lamb is significant and that the season and BCS of the ewe play a less important role in the conception and survival of lambs to lamb-marking if adequate supplement is provided in periods of nutritional deficit.

These results are in general agreement with Ferguson et. al. (2004) and Smith (1997) in that the means for most categories are below the acceptable birth weights for survival. The category of dystocia in the perinatal lamb results is also in general agreement with the above authors in that the birthweights recorded have a number of lambs weighing up 9 kg and lambs weighing as little as 1.6 kg, mal-presentation was a factor in some of these diagnoses. It must be noted that as no birth weights of the surviving lambs were collected, no direct comparison can be made between dead and surviving lambs to attribute body weight as a direct cause of death, however the work of Lifetime wool (2004) and others shows a clear link between lamb survival and birth weight.

The nutritional status of both the ewe and ram prior to and during the joining period plays a pivotal role in the conception and wellbeing of the ewe and feotus through to parturition. Moreover the nutritional status of the ewe in the last trimester and through the lactation period is crucial to the survival of the new born lamb.

The loss of ewes in this project was below (1.7%) industry standards of 3-5% per annum (Hall et. al. 2013). Although small, these losses do contribute to the overall reproductive wastage in the flocks monitored and therefore do require attention from farmers to minimise these losses.

The husbandry and nutritional management practices of the farmer are extremely important in terms of reducing reproductive wastage in Victorian and indeed the national sheep flock. The provision of adequate fodder and water to meet the nutritional requirements of the ewe to conceive and rear a healthy lamb together with a well-managed vaccination and internal parasite program for the ewe are critical, as these animal health practices have a direct impact on the ewe's overall physiological condition and ability to give birth to and successfully rear the lamb to weaning and reduce reproductive wastage.

Also of great concern was physiological condition of the ram. With some of the rams to be used being diagnosed with ovine brucellosis and others being too old or just unfit for joining. This highlights the need to provide these animals with the same level care of afforded to the ewe flock. This work identified that 28% of rams were below BSC 3, 13% of rams in this work were unfit for joining due to structural or testicular issues and 3% of the rams examined were diagnosed with Ovine Johnes disease. These factors would certainly be a contributing factor to reproductive wastage in the Victorian sheep flock.

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Dpi Vic Sheep population map

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Appendix A:

Project data collection sheet

Prenatal Necropsy Sheet

Perinatal Lamb necropsy data sheet

Owner: PIC: 3 Breed: Date: / / 200 Staff:

No.	Birth Wt: Kg	Birth: Natural / Assisted N / A	Sex: M/F	Parity Single Twin Triplet	Weather	Age at death (days)	Cleaned Y / N	Wa ked Y / N	External Abnormalities	Predation Y / N & Sites? Bird/Fox/other	Oedema head / neck /extremities	Liver damage Y / N	Breathed Y / N	Fed Y/N	Fat metabolised Y / N	Cranial & Spinal haemorrhage Scores 1(nil) – 5(severe) Eg. C2 / S2	Death Category 1 – 10 **(See reverse)**	Samples Y / N

Ram Breeding Soundness Examination sheet

Breed	Identification Ear Tag/Horn Brand		Condition Score	Age						Scrotal circumference (cm)	Comments: (Other abnormalities)
	Colour	Number		2T 1 ½ yrs	4T 2 ½ yrs	6T 3 ½ yrs	FM 4 ½ yrs	SM >5 ½ yrs	BM Aged		

FM: full mouthM - sound mouth   BM – broken mouth

Condition Score Sheet

Condition Score Record

Property: **Date:**

Mob: **Day of pregnancy:** **OR Days since lambing started:**

No. ewes assessed: **CS Average:**

20																	
19																	
18																	
17																	
16																	
15																	
14																	
13																	
12																	
11																	
10																	
9																	
8																	
7																	
6																	
5																	
4																	
3																	
2																	
1																	
CS	**1.0**	**1.3**	**1.5**	**1.7**	**2.0**	**2.3**	**2.5**	**2.7**	**3.0**	**3.3**	**3.5**	**3.7**	**4.0**	**4.3**	**4.5**	**4.7**	**5.0**
Totals																	

Food On Offer Record Sheet

FOO Assessments

	Green		Dry
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	
11		11	
12		12	
13		13	
14		14	
15		15	
Total		Total	

Average		ME		Average		ME	

Quality		Digestibility	
Very High		60%	
High		55%	
Medium		50%	
Low		45%	
		40%	
		35%	

Additional Notes:

Target CS		Target CS Date	

Total supplement required to achieve Target CS:

Grain		G/day	Hay/Silage		G/day