SHEEP CRC

Unpublished Report

Document ID: SheepCRC_2_41

Title: Lamb Survival in Australian Flocks: a Review

Author: Hinch, G.N.

Key words: sheep; lamb survival; review

This report was prepared as part of the Sheep CRC Program 2007-2014. It is not a refereed publication. If the report is quoted it should be cited as:

Sheep CRC Report 2_41

SHEEP CRC REVIEW (2008)

LAMB SURVIVAL IN AUSTRALIAN FLOCKS: A REVIEW

G N Hinch

School of Environmental and Rural Science

University of New England

INTRODUCTION

The loss of lambs in late pregnancy and up to weaning is a significant contributor to reproductive inefficiencies in the Australian sheep industry and for that matter probably most sheep flocks around the world. The significance of this loss to the Australian sheep industry was widely recognized even in the early years of Australian settlement (Watt 1955) and the failure of ewes to rear lambs contributes to a number of inefficiencies not the least of which include reductions in the number of surplus sheep for sale, reduced options for selection and for culling and also a reduction in flexibility to change flock structures. This issue has been the focus of a number of reviews in the 1970’s and 1980’s (eg Watson 1972 and Haughey 1983, Alexander 1984) which provide the basis for much of our present knowledge. It should also be noted at the outset that neonatal lamb survival is only one aspect of sheep reproductive efficiency and that the broader topic has be extensively reviewed in recent times both in published and commissioned reviews for MLA and AWI. These include the reviews of Walker et al.(2002), Kleemann and Walker (2005a) and more recently the AWI review by Croker and Harper (2006); all have identified lamb survival as a major component of reproductive wastage and as such a topic worthy of further research.

Lamb loss studies were widely reported during the 1970s and 80s but there have been less frequent studies in more recent times. Alexander (1984) indicated that “publications reporting levels of lamb mortality in Australia and elsewhere are too numerous to list” but his synthesis of constraints to lamb survival is possibly the best available and provides the framework for the present review. It is not the intention of this review to cover comprehensively all publications on the topic but rather to benchmark levels of lamb survival in Australia, to identify key causes of loss and to highlight key areas of management that might lead to improvements in lamb survival.

In attempting to benchmark lamb survival figures we firstly need to have some appreciation of the changes that may be occurring in overall sheep reproductive efficiency as indicated by changes in average marking percentages. Table 1 is taken from a report by Barnett (2007) which summarizes from ABARE farm survey data trends for all sheep regions of Australia. There is clearly little change in the last 15 years and it seems from more detailed data that the largest declines occur for sheep production specialists during drought years. This suggests that poor nutrition impacts most on Merino reproduction probably both in terms of lowered conception rates and increased lamb loss.

The magnitude of lamb loss reported in early studies is highly variable, for example for Merinos losses of between 5 and 70% were reported (McHugh and Edwards 1958, Smith 1962, Plant et al. 1976) with losses commonly between 20- 25%. In an extensive study of ewe reproductive wastage, including over 30000 ewe records, in NSW (Luff 1980) reported that between 21.7 and 27.8 % of ewes lambed and lost all lambs implying that total losses well exceeded 30% when partial twin pair losses were included.

Table 1 Enterprise Sector Trends in Average Marking Rate (from Barnett 2007)

Enterprise Sector	1990-2000 Average Marking Rate	2001-2005 Average Marking Rate
Prime Lamb Specialists	83.4	85.2
Sheep Specialists	73.0	71.2
Mixed Sheep Enterprises	75.3	74.1
Sheep Industry Total	77.2	76.8

A search Australian publications shows a wide range in lamb losses reported for single born lambs; in Victoria: 26-31%, 6-30% (Caple et al. 1982) , 25% (Cumming et al. 1978) and 9.3-12% (Egan et al. 1972); in South Australia: 12-13% (Kleemann et al. 1991), 16.6% (Kleemann & Walker 2005b); in NSW 14-16% (Atkins 1980), 19% (Hall et al. 1995), 15-20% and 21-29%(Lax et al. 1965); in Western Australia: 8% (Knight 1975 and Beetson 1984), 6-19.9%(Kelly 1992); and in Queensland: 14-26% (Lax et al. 1965), 9-20% (Jordon and LeFeuvre 1989). The range in lamb loss between farms is clearly large, however the recent report by Fowler (2007) using data from commercial flocks with a total of nearly 100 thousand ewes highlights that within regions of NSW average losses were similar ranging from a high of 35.8 % in the Monaro to a low of 26.8% in the Northern Tablelands.

Losses in twin lambs are generally 2 - 2.5 times greater than singles in the same flock. Some examples to highlight this difference come from studies such as that of Kelly (1992) in WA commercial flocks were twin losses ranged from 19.1-63.2%, an average 22% more than singles. Likewise, Beetson (1984) in WA reported twin losses of 38%, 30% greater than singles. Kleemann et al. (1991) reported losses of 38-39% for twins compared to an average 12.5% for singles in Merino flocks in SA and Kleemann & Walker (2005a) reported 43.8% loss in twins compared to 16.6% in single Merino lambs. Holst et al. (2002) in a NSW mixed ewe breed study reported losses of 11.1% for singles, 20.8% for twins and 46.2% for triplets (for a more detailed evaluation of large litter mortality see Hinch et al. 1985a).The recent report of Fowler (2007) confirms the earlier reports with average losses in NSW of 16.5 % for singles and 31.5% for twins, the study including both Merino and crossbred ewes. Lamb mortality does differ between breeds and breed crosses (eg Fogarty et al. 2005). Breed of ewe can contribute significantly to differences in lamb survival and there is also evidence that crossbred lambs usually have higher survival than pure breeds (Fogarty 1972). The genetics of lamb survival will be examined in greater details in another review in this series.

Records of lamb losses were traditionally made on research stations were lamb carcasses could be collected, however there are a number of reports for commercial flocks, for example the extensive studies of Kelly (1992) and Kleemann & Walker (2005a). With the wider use of pregnancy scanning technology and counting of foetal number in mid pregnancy (Fowler and Wilkins 1982) more accurate estimates of commercial losses are now becoming available. Kilgour (1992) identified a difference of some 0.41 lambs between potential foeti at day 70 in Merino flocks of central NSW and lambs weaned. More recently a detailed study of flocks scattered across NSW by Fowler (2007) has been done using pregnancy scanning data as a baseline for potential lambs born. From these data, recorded in a drought year and across different production systems and ewe age groups, the average marking percentage for Merino ewes was around 90.2% and for crossbred ewes 114%. This study confirmed that twin losses were around double that of singles and that lamb losses in maiden ewes were greater than for older ewes. There were differences between regions in lamb survival but these differences were mainly attributable to differences in twinning percentages of the flocks. In that same year a detailed study in WA in a *Wean more lambs* demonstration flock showed losses from scanning to weaning of 67% for a flock with a foetal number of 131% (Reed et al. 2006).

Presently *Wean more lamb* targets (Anon 2008) assume 10% and 30% loss for single and twin born Merino lambs respectively and this seems to realistically represent average industry losses across a wide variety of regions and environments and the relative consistency, given the large climatic variation across Australia, is notable. Clearly lamb loss is a significant contributor to lowered reproductive efficiency in flocks across Australian sheep producing areas but what is also apparent is that there is considerable variability in the extent of loss within regions and between years. The reasons for this variation are not always immediately obvious but it appears that mortality figures less than 10% in singles and 20% in twins is relatively uncommon. The next section will examine the patterns of loss and the major causes, seeking some indication of the reasons for the variation identified.

PATTERNS AND CAUSES OF LAMB LOSS

Lamb deaths occur primarily at or in the first few days after birth although there can be a prenatal loss component in some studies particularly associated with disease outbreaks and also sporadic later losses particularly associated with predation and disease. The first few hours of life are possibly the most critical stage for survival as the birth process applies hydrostatic pressures and is also accompanied by a period of hypoxia, acidaemia and ketonaemia as the lamb goes through a transition from placental to pulmonary respiration.

Starvation, cold exposure and problems at parturition are all related to birthweight and are interrelated factors that can contribute to lamb deaths and these factors normally are predominate at average/core mortality level. However, higher mortality levels are often associated with specific causes such as dystocia, predation (Plant et al. 1978), poor maternal care (Stevens et al. 1982), or cold exposure (Obst and Day 1968). These causes can become predominant and additive to the core loss normally observed. Alexander (1984) suggested that ‘core loss' in most flocks is closely linked to the birth process and birthweight and this is worthy of further consideration as this aspect may not be considered by commercial producers in trying to rectify high lamb losses.

The study by Hinch et al. (1986) illustrates the normal timing of lamb losses in Merino and crossbred flocks with various littersizes and an associated paper (Hinch et al. 1985b) indicates the major causes of lamb loss at various stages post partum. Most losses occur within the first 24 hours of life and the relative importance of different causes of death can vary markedly according to fecundity of the flock, husbandry methods, breed etc. The autopsy procedure (Holst 2004) allows differential diagnosis of prenatal death, birth trauma, starvation and exposure (often linked with starvation as a complex) and provides useful information as to the factors associated with lamb loss as well as the cause. In many cases the causes of loss are not independent. Damage caused by primary predation is difficult to definitively assess and although Rowley (1970) reported autopsy characteristics associated with a number of predators, determining if predation is a primary or secondary cause is difficult. Unpublished data from a study in the predator free Tasmania (Horton pers com. 2008) suggest that total lamb losses are still comparable to other states with starvation and difficult births contributing to losses of around 25%.

There are relatively few extensive studies in Australia where autopsy has been used to identify cause of death in lambs. Table 2 summarizes the autopsy studies that have been completed, predominantly on Merino lambs, and illustrates a diversity of causes of mortality. The latest large study completed was that conducted as part of the

NSW Flock Fertility service (Luff 1980) in the Riverina of NSW with autopsy results on 2534 lambs. In this study 58.2% of lamb deaths were attributed to starvation/exposure, 17.7% to dystocia, 7.8% to primary predation and 4.4% to infection. The earlier studies of Dennis (1974) in WA and Smith (1964) in Queensland also identified starvation as a predominant cause of loss. In contrast the other large study conducted in NSW on commercial flocks (Hughes et al. 1964) recorded difficult birth as the dominant cause of loss. Likewise the more recent study by Holst et al. (2002) in a multi-breed research study indicated that “birth trauma” (including both the physical damage of dystocia and also lesions associated with hypoxia and acidaemia was by far the most significant cause of death with 66% of lambs classified in this way.

Birth trauma or prolonged birth (as evidenced by central nervous system haemorrhage) is often linked to starvation as a secondary cause of death and the interpretation of this autopsy lesion is still somewhat controversial with little attempt made to differentiate between prolonged birth and physical birth trauma. It has been suggested by (Haughey 1980) that 56-80% of lamb deaths may be associated with such lesions. Dystocia due to foeto-pelvic disproportion or to mal-presentation is relatively more obvious in terms of physical damage and occurs usually as a result of inappropriate sire selection and associated high birthweights or to small ewe pelvic size (Haughey 1983a). Incidence of classical dystocia can range widely, for example in the studies reported by George (1975, 1976) the incidence ranged from 4.1% for Merino lambs to 34% in Dorset lambs.

A large proportion of postpartum losses appear to be associated with starvation or to a complex involving difficult birth and starvation (Luff 1980) and miss-mothering is commonly thought to be a major contributor. However, the relative contribution of ewe and lamb to the starvation complex cannot be determined except by direct observation of behaviour at lambing. Many studies eg Alexander and Peterson 1961; Alexander et al. 1967; Obst and Day 1968; Egan et al. 1972; Arnold and Morgan 1975; Stevens et al. 1982) have examined the contribution of the ewe to miss-mothering events and it is clear that ewe age, breed, metabolic disease and management choices all impact on the ability of ewes to develop a bond with their lamb/s. A commonly recognized maternal problem for Merino ewes has been the poor maternal characteristics of primparious ewes which are often linked with lamb desertion (Alexander et al. 1993). In the recent study of Fowler (2007) single bearing maiden ewes had lamb survival 6.1% lower than adult ewes and this difference was greater in the study reported by Luff (1980). Poor ewe condition/nutrition can also contribute to poor ewe behaviour (Poindron et al. 1984) and Buttrose et al. (1992) reported a large number of permanent lamb separations by Merino ewes during difficult nutritional conditions of an autumn lambing in SA.

Grooming of the newborn lamb is necessary for the formation of a firm maternal bond, but inadequate grooming and poor bond formation are common with multiple births and difficult births (Alexander 1980, Szanter-Coddington 1994). The failure of mothers to recognize their lambs when lambs are learning to follow, can lead to separation and death of twin lambs, especially if the ewe leaves the birth site earlier than 4-6 h after birth (Alexander et al. 1983a). This behaviour appears to be more common in Merinos than in other breeds and separation from multiples is more common in young and inexperienced animals (Nowak et al. 2000). Recently studies in WA have shown that selection for fearfulness can impact of maternal traits in Merino ewes (Murphy 1999) and extensive field trails funded by MLA are now underway to determine if the temperament of ewes can be linked to lamb survival (Ferguson. unpublished) and can be used as a selection trait for improved maternal behaviour.

As well as poor maternal behaviour, starvation can also be the result of lack of available colostrum soon after birth and this can be a result of udder defects due to shearing injury, to mastitis (Jordon and Mayer 1989) or to delayed lactogenesis. The latter is usually a result of poor nutrition in late pregnancy (McCance and Alexander 1959, Dwyer et al. 2003) and studies on supplementary feeding of ewes in late pregnancy has shown considerable improvements in colostrum availability in Merino ewes (Hall et al. 1992, Murphy et al. 1996, Banchero et al. 2004a, Banchero et al. 2004b) with associated improvements in lamb survival.

TABLE 2 Autopsy studies on causes of lamb mortality in Australia conducted in Australia

(% of total lamb deaths attributed to each cause)

Author	**Breed of Ewe**	**Number of lambs examined (State)**	**Stillbirth**	**Dystocia**	**Starvation Mismothering**	**Exposure**	**Primary predation**
Alexander et al. 1980	Merino	634 (NSW)	?	?	?	8.7	0
Arnold & Morgan 1975	7 Breeds 7 Breeds Merino	147 11 25 (WA)	24.5 4.0		30.6 36.4 4.0	 63.6 92.0	
Dennis 1974	Merino	4417 (WA)		18.5	46.4	2.1	2.7
Haughey 1973a	Merino	199 (NSW)	1.5	34.2	47.2		5.0
Haughey 1983	Merino	173 (NSW)	0.6	31.8	24.3		1.2
Hughes et al. 1964	Merino	3503 (NSW)		53.6	6.8	8.6	7.4
Jordan & LeFeuvre 1989	Merino	115 56 58 (Qld)	3.5	16.5 19.5 10.3	67.0 53.6 69.0	8.6	8.7 25.0
Luff 1980	Merino	2534 (NSW)		17.8	58.2	?	7.8
McDonald et al 1966	Polwarth	390 (Vic)	2.8	193	31.5	4.9	33.3
McHugh & Edwards 1958	BLxMerino CxMerino	512 (Vic)	18.9	17.2	30.5	1.2	11.0
Moore et al. 1966	Merino	157 (Vic)	3.2	8.9	35.0		12.1
Moule 1954	Merino	453 (Qld)		4.9	29.8	11.0	34.2
Smith 1962	Merino Merino	27 34 (Qld)	11.0	26.0 3.0	48.0 82		
Smith 1964	Merino	981 (Qld)	1.4	12.0	66.9		14.7
Watson & Elder 1961	Corriedale	41 (Vic)		29.3	70.7		
Horton (pers com) 2008	Merino	129 (Tas)	4.0	35	34	18	0

Modified from Szanter-Coddington (1994)

The possibility that miss-mothering is a result of poor lamb behaviour has not been examined in any detail although the high incidence of CNS haemorrhage in lambs in the starvation/miss-mothering/exposure category of multiple lambs in particular (Haughey 1983a, Hinch et al. 1986) suggests the possibility that birth injury may cause lambs to be less responsive to their dam which may in turn lead to miss-mothering and starvation. This is possibly confirmed by the recent observations of Dwyer et al. (2005) who demonstrated that placental restrictions can also impact on lamb behaviour. Alexander (1984) highlighted in his review that the incidence of CNS lesions in lambs dying of starvation varied considerably between studies and that there may well be lambs that survive with such lesions. He did however recognize that problems at birth can contribute to number of complications that result in lamb loss. One of these is the possibility that lambs with damage to the CNS may not thermoregulate normally which makes them more susceptible to exposure.

In Australia lambs are more often exposed to hypothermic rather than hyperthermic conditions and consequently most studies have focused on cold exposure, as a primary cause of lamb death. Hyperthermia and dehydration can cause lamb deaths but losses are relatively small across Australia with the majority of lambs born in the cooler months of the year. Hypothermia as a primary cause of death is difficult to determine through autopsy as many lambs are predisposed to chilling because of starvation, low birth weight and birth injury etc. Therefore, as mentioned earlier, this condition is usually included as a complex with starvation and only in prolonged exposure cases is the autopsy characteristic of peripheral oedema diagnostic (Haughey 1973c). The lamb with a large surface area to weight ratio is particularly susceptible to cold conditions and low birthweight lambs are particularly susceptible to hypothermia but there is little convincing autopsy data for Australian flocks to demonstrate the significance of this cause of death. Testing the impact of shelter on survival maybe one way to test the impact of exposure and two large studies of the effectiveness of grass shelter belts indicates improvements in lamb survival of at least 10% in certain environments. This will be discussed further in a later section.

Another alternative that has been examined to improved survival in cold conditions is to utilize genetic variation in cold resistance. The study of Slee et al. (1991) has confirmed that cold resistance is a heritable trait that can be selected for within breeds and his earlier studies also showed marked differences between breeds (Slee and Springbett 1986). However the testing of individual animals for cold resistance is relatively time consuming and difficult and to date techniques for commercial application are not in place.

Birthweight differences can explain a large proportion of the variation in lamb survival (Hinch et al. 1985b, Hinch et al. 1996) and as suggested in the discussions above is interrelated to most of the causes of death in some way. Lamb survival is typically related to birth weight by a 'U'-shaped curve (eg Hinch et al. 1985a) and optimum birthweight for survival is normally reported to be in between 4.5 and 5.5 kg (Atkins 1980, Fogarty 1992, Holst et al. 2002) although this does depend on breed and ewe age. For example recent New Zealand data for the large mature size longwool breeds suggests maximum survival up to 6.5kg (Everett-Hinks pers com 2007). In these cases the birth weight-mortality curves are displaced to the left which suggests there maybe genetic components to survival independent of birth-weight. However, breed differences in survival of lambs can be largely attributed to birthweight differences with heavier breeds having higher survival levels in pure bred matings. For example *Wean more lambs* target survival levels are 90 and 70% respectively for Merinos ewes with single and twin lambs while crossbred ewe targets are 90 and 80% survival for singles and twins.

Differences in birthweight can explain differences between lamb sexes and ewe age/parity effects (Hinch et al. 1985a) on survival and a large proportion of the differences in survival of different littersizes (Hinch et al. 1996). In some studies year variation is also largely explained by birth-weight differences (probably differences in nutritional status between years) but this is not always the case and weather conditions at lambing (as measured by chill index) may also explain a component of variation in survival between years.

Low birth weight of lambs can be the result of disease, heat stress, litter size and poor nutrition to name a few causes and research suggests these effects are often mediated via placental size (Kelly 1992b). The poor survival of low birth-weight lambs is probably largely associated with retardation from insufficient oxygen and energy during late pregnancy. However, small lambs often also have poor thermoregulatory ability relatively to their size and energy reserves (Robinson 1981) and there is evidence that they are relatively less mobile (vigorous) than larger lambs (see earlier comments on CNS damage). The effects mentioned above are also seen in the context of litter size differences with larger litters having lower birth-weights and higher mortality. Twin mortality can be above that of singles of the same weight (Stevens et al. 1982, Hinch et al. 1985b) and lambs born as triplets or quads have a lower chance of survival than twins or singles of the same birth weight (Hinch et al. 1983, 1985). The energy reserves of newborn lambs are small with total reserves ranging from 2000-4000 kJ and in cold conditions, starving lambs will exhaust these reserves in less than 24 hours and within 3 days in warm conditions (Alexander 1962, 1974a), lower birthweight animals die earlier because of lower energy reserves.

Many producers believe that predators are a major cause of lamb loss but evidence for primary predation is limited except possibly for the impact of feral pigs in rangeland environments. Predation by foxes in particular has been blamed for many losses but in the detailed research studies that have been done it appears that foxes are more often scavengers and predate only lambs that would have/were dying from other causes (Alexander et al. 1967). The *Wean more lambs module* (Anon 2008) indicates losses of greater than 10% due to predation do occur and recommends control of foxes by baiting in the 3 months prior to lambing. For pigs the recommendation is for development of exclusion areas. Other predators such as dingoes, feral dogs, eagles or ravens have been reported to kill lambs (Smith 1964; Plant 1981) but their overall significance to total lamb loss is not clear. Of some 16 studies reviewed by Szanter- Coddington (1994, Table 2) only 3 had primary predation losses of greater than 10% and two of these were recorded in rangeland conditions of Queensland.

Other causes of lamb loss do not occur often but can be of great significance to individual producers in some years. They include congential deformities which may be a cause of up to 1% of deaths, various pre- and post-natal infectious diseases, deficiencies of minerals such as copper, iodine and selenium, plant toxins (Broadmeadow *et al*. 1984, Alexander et al. 1990a), and misadventure.

Although it is difficult to quantify it seems that management for many of the losses caused by predation, disease toxicity and deficiency are relatively straight forward and that producers can, and often do, implement practices that will address these causes of loss. The introduction of predator control measures, vaccination programs and routine provision of selenium, cobalt and iodine in deficient areas should reduce dramatically the proportion of losses attributable to these factors. If we accept that these losses are additive to a core loss then the introduction of such measures may reduce extremes of mortality but a core loss will remain to be addressed. From what we have seen this core loss is likely to be associated with low birthweight, weather conditions and possibly poor maternal behaviour and the next section will look at management strategies that may be able to address these causes of loss.

STRATEGIES FOR IMPROVING SURVIVAL

As has been indicated, in the absence of factors such as disease, predation or shearing damage to udders which to a large degree can be controlled by routine management choices, the major requirements for a high survival rate in lambs are a birth weight near the optimum for the breed, easy birth, protection from cold, availability of colostrum and maximum opportunity to establish a ewe lamb bond. These goals are not always easy to attain and practical and economic ways to target these traits are needed. The key areas are birthweight optimisation through pregnancy nutrition management or possibly breed choices, shelter provision and selection for cold resistance and manipulation of environmental or genetic characteristics to improve the establishment of the ewe lamb bond.

Nutrition for improved lamb survival

The nutrition of the pregnant ewe has been extensively studied for many decades and a number of reviews have been written on this topic Essentially the negative effects of under-nutrition on birthweight are well documented although the confounding of littersize and timing of nutritional restriction relative to placental development often makes application/interpretation of these studies difficult. The number of attachment sites for each foetus is determined at implantation (Robinson 1981, Dwyer et al. 2005) and the number and size of the placentomes supplying each foetus strongly influences foetal growth (Mellor 1983; Kelly 1992b, Greenwood and Bell 2003). Rapid foetal growth during the last trimester of pregnancy is when lambs are most vulnerable to inadequate nutrient supply which can result in growth retardation especially in multiples (Egan 1984). A summation of nutritional studies suggests that ewe nutrition in the first 90 days of pregnancy is important in determining placental efficiency and the potential for lambs to reach their genetic potential birthweight at the end of pregnancy. This is particularly important for litters were placental size will inevitably be compromised due to reduced placentome number per foetus.

In the study by Kleemann and Walker (2004) a positive change in ewe liveweight between mating and mid-pregnancy was negatively related to single lamb survival and McCrabb et al. (1992) reported that ewes in very good condition at mating (>3.5), but subsequently loosing weight between early and mid-pregnancy, had increased placental and fetal weights. Such effects were not seen in the studies reported by Curll et al. (1975) for crossbred ewes and Kelly et al. (1992) for Merino ewes but the ewes in the latter studies were not in as good condition at joining. In the latter third of pregnancy ewe nutrition will determine final birthweight although lambs with a large placenta in mid-pregnancy can compensate for some nutritional restriction.

In the reality of management constraints, nutrition is most easily monitored by the measurement of liveweight and/or condition score change throughout pregnancy and condition or fat score (an indictor of ewe energy reserves) is widely used as an indicator of nutritional status. The impact of condition score changes on lamb birthweight is a component of the recent Lifetimewool recommendations for Merino ewe management (Ferguson et al. 2007). A condition score of 3 is recommended to be maintained throughout pregnancy agreeing with the earlier recommendation of Croker and Kelly (1989) for WA Merino flocks. At this condition score lamb mortality levels are likely to be below the 10 & 30 percent for singles and twins defined earlier (Figure 1). The condition score 3 recommendation is largely consistent with other studies where liveweight or condition score have been used to manage pregnant ewes. Kleemann and Walker (2005a) concluded from their study of Merino flocks in South Australia that survival of lambs was positively related to maternal condition score in late pregnancy (6-16% of variation in lamb survival was explained by this trait) and also to liveweight and condition score at mating, confirming that nutrition of the ewe from conception to parturition has a major impact on survival of lambs. Fourty-one and 57 percent of the variation in single and twin lamb survival respectively was explained by liveweight at mid-pregnancy in the study of Kelly (1992) and Kleemann and Walker (2005) reported optimal values of ewe liveweight and condition score in late pregnancy of 68.8 kg and 3.3 in South Australian strong wool Merino flocks.

The earlier report of King et al. (1990) showed clearly the large variability of CS at any liveweight (ie framesize varies considerably) within a commercial Merino flock (Figure 2). This makes management based on liveweight difficult (this is possibly particularly so beyond 90 days of pregnancy when the conceptus contribution to weight change masks maternal weight changes). However, condition score was shown to be a good guide to the probability of lamb survival in the study by King et al. (1990). Ewe survival may also be compromised by low condition scores at various times of the reproductive cycle but particularly at lambing. The data of Ferguson et al. (2007) illustrates clearly that ewe survival can be severely compromised at condition scores of less than 2 at lambing (Figure 3). However, for flocks with predominantly single lambs improvements in survival with CS increases above 2 at laming appear likely to be relatively small.

The Lifetimewool calculations show that birthweights can be increased or decreased by 0.5 kg by nutritional change and that a one condition score loss to 90 days will reduce single lamb birthweight by 0.33 kg and by 0.45 kg if it occurs between 90-150 days of pregnancy. Such changes can easily move lambs outside the optimal birthweight range (4.5-6 kg for medium framed Merino ewes) and twins are usually below the optimal birthweight and consequently have lower survival. A one condition score difference at lambing such as a realistic 2 vs 3 can change the probability of survival by around 20% for twins and at least 5% for singles (Figure 1).

It would seem that twining ewes are an obvious target when attempting to identify the highest risk group. However this "high risk" category is to some degree a "moving target" as the relative contribution to lamb loss of different ewe groups depends on fecundity of the flock. Twinning ewes and their lambs are clearly usually at greater risk although low birthweight lambs of any littersize and also lambs of excessive size are at high risk. The recent report of Fowler (2007) showed that for an 'average' flock 45.5% of lamb losses were linked to 29.7 % of the ewes, the twinning ewes. This was even more pronounced for twinning Merino ewes where 33.5% of lamb losses came from only 16.8% of lambing ewes. The level of twinning varies across regions, for example there was a range of 15-41.8 % in the study of Fowler (2007) and in the report of Kilgour (1992) an average 21% of Merino ewes had twins, ranging from an average 10.4% in maidens to 35.5% in 5 year old ewes. In terms of absolute numbers, rather than percentages of lambs lost, Merino singles contribute on average a greater total loss than twins and therefore cannot be ignored for targeted nutritional management. Ferguson (2007) data suggest that the proportion of twins in a Merino flock at a condition score as low as 1.5 at joining is around 10% rising to 13% at CS 2 and 20% at CS2.5. It seems likely that the twins conceived in ewes at a condition score of less than 2 may well be 'at risk' from early in pregnancy and that not joining such animals may well improve average twin survival levels considerably. Alternatively these animals should have preferential nutrition to ensure a condition score of around 3 at lambing to maximize the opportunity for lamb and ewe survival.

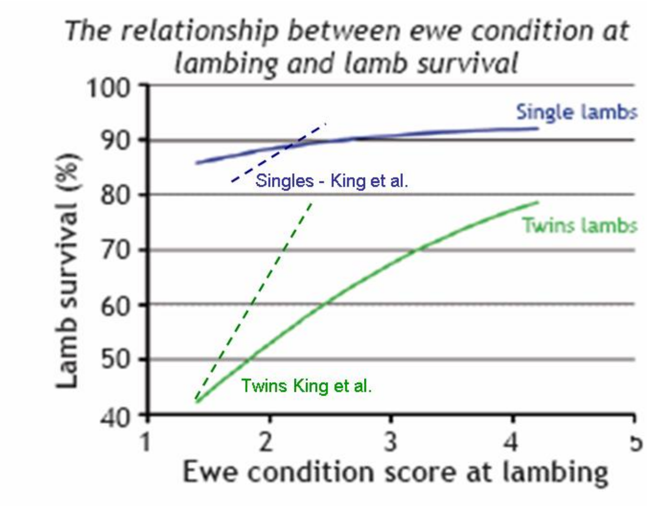

Figure 1 Lamb survival and Ewe condition relationships (from Ferguson et al. 2007 and King et al. 1990)

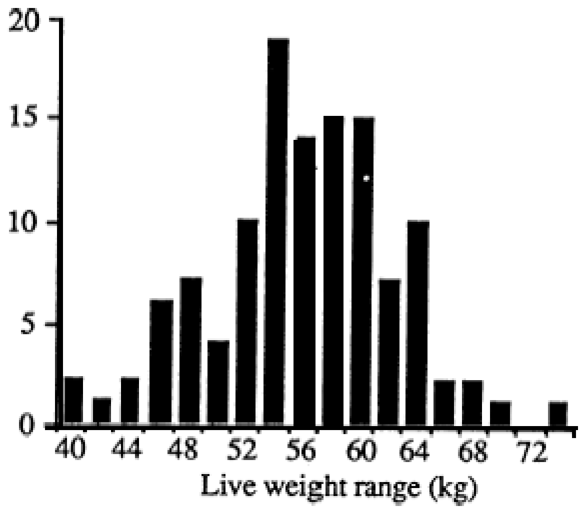

Figure 2 Liveweight range within commercial ewes at condition score 2 (King et al.1990)

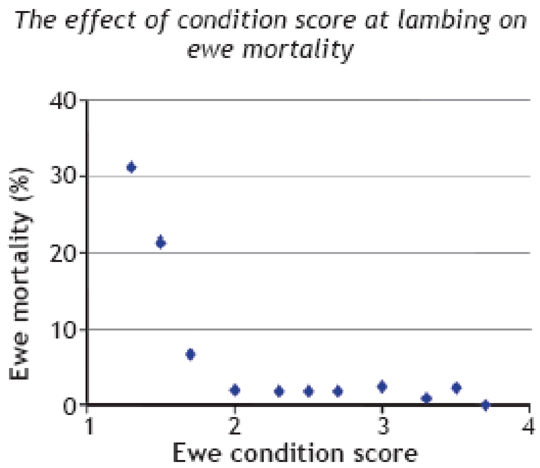

Figure 3 Ewe mortality at different condition scores at lambing (Ferguson et al. 2007)

Shelter and cold resistance

A reduction in wind velocity across a lambing paddock can reduce heat loss and consequently often increase survival of wet-new born lambs exposed to the chill of air movement, cold and wet conditions. This is particularly the case for the small animal with its higher surface to weight ratio and greater susceptibility to hypothermia. The impact of poor weather conditions on lamb survival was an area of considerable research interest in the period between 1975 and 1985 and one of the outcomes of this research was the development of a chill index that allowed prediction of the impact of combinations of wind, rainfall and temperature on survival outcomes (Holst and Cullis 1982, Donnelley et al.1984, McQuirk et al. 1984). This index is based on the cooling effects of temperature, wind speed and rain on the lamb in the first day of life and is used to determine warnings for weather events and, as the name implies, gives an accurate indication of the level of chill occurring for susceptible animals such as shorn sheep or newborn lambs. A further application of this concept was the development of a modeling package by CSIRO-*Lamb Alive* (Anon 1990) which allows a prediction of the impact on survival of shifting the month of lambing. These predictions are based on long term weather data averages for different temperate sheep production regions in Australia. This program does not seem to have been widely used and remains a DOS based version at present. However, it could be widely used to identify areas that will routinely need shelter at lambing in particular months of the year. For NSW, lambing occurs predominantly between March and October (Fowler 2007) with greatest numbers in mid-late Spring. This distribution varies with state but at present it appears that feed supply and markets probably dominate the factors determining choice of time of lambing.

The impact of shelter on lamb survival is difficult to assess because of the variability of weather conditions at lambing and also the fact that the autopsy procedures used to identify death from hypothermia are not particularly accurate, often interrelated to starvation. Therefore long term studies are necessary to quantify shelter effects and such studies were conducted at CSIRO Armidale by Alexander and Lynch in the late 1970’s and early 1980’s. These studies on the effectiveness of grass shelter belts were conducted over 5 consecutive years and are possibly the most comprehensive conducted anywhere in the world. They demonstrated clearly that enforced shelter in high chill situations can dramatically improve lamb survival particularly in twins. A consolidated review of the sequence of survival outcomes for the five years was reported by Alexander et al. (1980) and shows an average reduction in single mortality from 10 to 6 % and in twins a decline from 40 to 15%. These authors also conducted a series of experiments to determine if ewes could be encouraged to use shelter by shearing close to lambing time. The findings showed clearly that the time between lambing and shearing had to be as little as 2 weeks to be effective (Lynch and Alexander 1980) and ultimately this approach has not been adopted probably because the time frame is considered both too risky and difficult for most production systems where lambing date can be spread over at least a month and stress in late pregnancy can induce pregnancy toxemia problems in twinning ewes. Pre lambing shearing remains a common practice but usually more than 3 weeks prior to the due start of lambing.

The impact of forced shelter was also evaluated in a long term study in Victoria (Egan et al. 1976). In the years of this study average lamb mortality in singles was reduced from 12 to 4% and in twins from 25% to 14%. It seems that in environments where chill index is a regular challenge at lambing that forced shelter provides an advantage to twins of the order of at least 15% and in singles 5% or more. Such consistent differences over years and in two distinctly different environments suggest that a greater understanding of the use of shelter by lambing ewes could be a profitable area of research for the future. In New Zealand Pollard (2006) has recently reexamined shelter systems but to date has not identified management systems that provide an advance on the observation of Alexander and Lynch published more than 20 years ago. Winter conditions do not always impact on survival; for example in the report of Kleemann and Walker (2005) they indicate that flocks observed during the colder months had lamb survival levels very similar to those lambing in warmer months although this may have been associated with provision of shelter.

With a marked change in attitudes of producers to trees and shrubs on farms (Hodges & Goesh 2006) and also concepts such as edible shelter (ie shelter belts based on edible shrubs and browse) over recent years it is possibly that shelter use and design should be revisited as a means to reducing lamb loss. Low shelter provided by grass rows, for example, non-palatable *Phalaris aquatica x Phalaris arundinaceae* in New England studies (Alexander et al. 1980) at 20 m intervals across the whole lambing paddock, or in the Victorian study (Egan et al. 1972) overgrown *Phalaris* with cut access trails, have been used. The use of native shrub species including browse species is an area of renewed interest for farm tree planting programs attempting to address salinity issues and this could provide an additional advantage of improved lamb survival although this is yet to be quantified. It seems certain that those producers lambing in a high risk period (high chill probability at time of lambing) should have shelter provisions for lambing ewes. The design of such shelters and whether there are options beyond the sheltering of whole paddocks is still unclear. The added complexity of excess stocking densities causing increases in miss-mothering in restricted areas of shelter also needs to be considered.

Stocking density and husbandry at lambing

There are very limited published data on stocking density effects on lamb survival although Alexander (1984) suggested lamb loss problems increased at stocking rates of greater than 18 per ha on research lambing plots, particularly for twinning ewes. Lamb losses are likely to be greater in situations that create a greater probability for missmothering/lamb-stealing and this intuitively includes use of small paddocks, high proportions of twinning ewes, and synchronised lambing. Certainly, many of the intensive cell-grazing systems, where stock densities can be well over 200 per ha, choose to set-stock their ewes at low densities during the lambing period.

The impact of stocking rate of a set-stocked flock on lamb survival can be modified by using husbandry options such as drift lambing (separation of lambed and non-lamed ewes on a daily basis, Giles 1968) but labour-intensive systems such as this and other shepherding options are unlikely to find wide adoption in commercial flocks with economic pressures to increase the numbers of ewes per labour unit. Interventions at times of difficult birth will continue but it seems likely that producer preferences will be for minimal use of interventions such as ‘mothering up’, fostering, artificial rearing and other intensive shepherding practices that are used in more intensive systems of production overseas (Eales 1982) and sometimes in stud flocks in Australia.

In the recommendations in the *Wean more Lambs* module (Anon 2008) the impact of feed available from pasture is also highlighted as a potential issue related to lambing paddock size and also suggests the 18 ewes per ha cited by Alexander (1984) as a limit. This publication also suggests maximum flock sizes of 100-250 for mature twinning ewes, 400-500 for mature single bearing ewes and 250-400 for maiden single bearing ewes. The basis of these flock sizes recommendations is not clear but may relate to the relative dispersion of flocks and could be more important for Merino ewes were dispersion is usually less than for other breeds.

Improved ewe-lamb bonding

The Merino ewe is reputedly a poor mother (Stevens et al. 1982, Alexander et al. 1983b) and it is possible that this is partially associated with the gregarious nature of this breed which makes it ideally suited to rangeland grazing. Any attempts to change this fear related behaviour may result in animals less well adapted to extensive grazing situations. Selection criteria for mothering ability would include ability to remain isolated and in shelter, extended duration and intensity of grooming and time at the birth site and ability to recognize number in the litter. The low apparent heritability of maternal and offspring components of lamb survival, means that gains through selection are likely to be slow unless there is a focus on specific attributes. Studies in Merino ewes selected for calm temperament have been conducted in WA and it appears from these studies, using divergently selected flocks, that the rearing ability of calm ewes is considerably better than “fearful” animals. The studies show that ‘calm’ ewes exhibit better maternal behaviour than ‘nervous’ ewes (Murphy 1999) and the calm ewes where also shown to spend more time on their birth sites with their lambs and were less inclined to move away from their lambs when disturbed. Lamb mortality to weaning was approximately 10% lower for the calm ewes than the nervous ewes.

Indirect measures of maternal abilities that will allow selection for improved ewe-lamb bonding are attractive possibilities for improving lamb survival. However, to date the temperament test presently being evaluated seems to be the only option. There have been no extensive studies to evaluate the changes in cause of lamb loss associated with selection for improved maternal traits but it would be expected that the proportion of starvation losses would decline. This may only become apparent if the incidence of other factors such birth injury, slow onset of lactation, teat damage, and dystocia are low and therefore assessment of the impact of improved maternal behaviour may be difficult. The possibility of improving reproductive performance simply by culling ewes that do not rear lambs in early life has been examined and with a repeatability of rearing of 10% (McQuirk et al. 1984) such culling practices should allow within flock improvements in reproductive efficiency. However, to date there is no clear understanding of the relative contribution of maternal care, physical issues such as impaired teat function and pelvic size toward this overall improvement. Given the large number of factors potentially contributing to survival it is probably not surprising that heritability estimates for lamb survival as a maternal trait are low (Fogarty 1984, Safari et al. 2006).

The term, lamb vigour has been widely used in relation to lamb behaviour during the establishment of the ewe-lamb bond and it seems that little has been done to quantify this trait so that the lamb contribution to ewe-lamb separation and subsequent starvation can be determined. However,h Scottish work indicates that lamb behaviour does influence maternal behaviour and visa versa (Dwyer & Lawrence 1999 and Dwyer and Lawrence 2000). The fact that survival differences have been seen for different lamb genotypes reared by the same maternal genotype in the Sheep CRC Information nucleus lambing (2007) suggests this maybe an area worthy of closer evaluation.

CONCLUSION

This brief review has highlighted that lamb mortality has been and remains a major factor contributing to reproductive inefficiency in the Australian sheep industry. The losses are extremely variable between farms (large losses often associated with one major problem) and years but averages are surprisingly consistent across the country with core losses of 10 and 30% respectively for singles and twins where predation, disease and possibly exposure are limited contributors to loss. If these latter causes of loss can be minimized then it seems likely that difficult or prolonged birth, starvation and exposure will be the largest contributors to core loss and that management of birthweight can play a major role in addressing susceptibility to these.

Lambs below optimal birthweights, which includes a large proportion of twins, are at greatest risk of loss and the data examined suggest that producers need to make management decisions during pregnancy, or even at joining, that will target the groups of ewes at greatest risk. To do this they must aim to meet nutritional targets (measured as condition score or liveweight) for particular groups of ewes, and also ensure that shelter is available at lambing in areas where chill indexes indicate that the probability of hypothermia is high. Lastly the relative contribution of lamb and ewe behaviours to the ewe lamb bonding process and to starvation losses requires further examination to determine if maternal behaviour is a desirable selection trait.

RECOMMENDATIONS

- Bench mark losses against industry averages
- Identify the at-risk ewe groups within flocks
- Manage/feed ewes according to recommendations for each of the identified at-risk groups
- Determine if average chill index of a region indicates a consistent hypothermia problem and if so provide shelter
- Routinely put in place disease and predation management practices to minimize their impact in all years

REFERENCES

Alexander G and Peterson, J.C. (1961) Neonatal mortality in lambs: intensive observations during lambing in a flock of maiden ewes. *Aust.Vet.J*. 37:371-381

Alexander G (1962). Energy metabolism in the starved new-born lamb. *Aust J Agric Res.* 13:144–64

Alexander, G. Mann,T. Mulhearn, C. J. Rowley I. C. R,. Williams D, and. Winn D (1967) Activities of foxes and crows in a flock of lambing ewes. *Aust J Exp Agric and Anim Husb* 7:329-336

Alexander, G. (1980).Husbandry practices in relation to maternal offspring behaviour. Reviews in Rural Science, IV: 99-107.

Alexander G., Lynch J.J., Mottershead B., Donnelly, J.B..(1980) Reduction in lamb mortality due to grass wind-breaks: results of a 5 year study. *Proc Aust Soc Anim. Prod* 13:329–32.

Alexander G, Stevens D., Kilgour R., de Langen H., Mottershead, M.M., Lynch, J.J. (1983a) Separation of ewes from twin lambs: incidences in several sheep breeds. *Applied Anim Ethol* 10:301–17.

Alexander G (1984) Constraints to lamb survival in *'Reproduction in Sheep'*. (Eds D. R. Lindsay and D. T. Pearce.) Australian Academy of Science and the Australian Wool Corporation. pp. 199-209

Alexander G, Stevens, D, and Bradley, L R (1990a) Observations during lambing in a goitre affected flock with special reference to behaviour of lambs. *Aust. J. Exp. Agric*. 30: 749-757

Alexander G., Stevens, D, Bradley LR (1990b). Distribution of field birth-sites of lambing ewes. *Aust J Exp Agric.* 30:759–67.

Alexander, G, Bradley L R and Stevens, D (1993) Effect of age and parity on maternal behaviour in single-bearing Merino ewes. *Aust.J. Exp Agric* 33:721-8

Anon (1990) Lamb Alive - CSIRO - Risk analysis of weather-related lamb loss. - Distributed by Horizon Technology Pty Ltd 1994.

Anon (2008) Wean more Lambs in Making More from Sheep Program, AWI & MLA, http://www.makingmorefromsheep.com.au/wean-more-lambs/index.htm

Arnold G. W. and Morgan P.D. (1975) Behaviour of the ewe and lamb at lambing and its relationship to lamb mortality. *Applied Animl Ethology* 2:25-46

Atkins, K D (1980) The comparative productivity of five ewe breeds. I. Lamb growth and survival. *Aust. J. Exp. Agric. Anim. Husb*. 20: 272-279

Banchero, G.E., Quintans, G., Martin, G.B., Lindsay, D.R. and Milton, J.T.B. (2004a). Nutrition and colostrum production in sheep. 1. Metabolic and hormonal responses to a high-energy supplement in the final stages of pregnancy. *Reprod. Fert. Devel*. 16: 633-43.

Banchero, G.E., Quintans, G., Martin, G.B., Lindsay, D.R. and Milton, J.T.B. (2004b). Nutrition and colostrum production in sheep. 2. Metabolic and hormonal responses to different energy sources in the final stages of pregnancy. *Reprod. Fert. Devel*. 16: 645-53.

Barnett R (2007) Best Practice Sheep Reproduction Management: A Review of Current Extension and Adoption. Final Report MLA Project SHGEN.114.

Beetson, B. R. (1984). Influence of plane of nutrition during late pregnancy and lactation on the survival and growth of Merino and first cross lambs. In *'Reproduction in Sheep'*. (Eds D. R. Lindsay and D. T. Pearce.) Australian Academy of Science and the Australian Wool Corporation, pp. 213-5.

Biggins LA, Kleemann DO, Grosser TI, Rice IM, Rothwell JW, Mann TL. (1992) Management systems at lambing and lamb survival in South Australian Merinos. *Proc Aust Soc Anim Prod* 19:202.

Buttrose D, Kleemann DO, Rice IM, Rothwell JW, Mann TL. (1992) Incidence of permanent separation of ewes from lambs in a South Australian Merino flock. *Proc Aust Soc Anim Prod* 19:203.

Broadmeadow,A C C, Cobon, D, Hopkins, P S, O'Sullivan, B M (1984) Effects of plant toxins on perinatal viability in sheep. In *'Reproduction in Sheep'*. (Eds D. R. Lindsay and D. T. Pearce.) pp. 216--219 (Australian Academy of Science and the Australian Wool Corporation.)

Caple I W, Nugent G F, Azuolas, J K, Foot J Z and Thomposn, R L (1982) Effects of iodine supplementation of ewes on survival and growth of lambs. *Proc Aust Soc Anim Prod* 15: 535-538

Croker, K. and Harper, P. (2006) Review of Management Options to Improve Reproductive Performance of Merino Ewes – Final Report AWI (includes addendum by P.M. Harper and K.P. Croker: A review of papers published since 2003).

Croker, K.P. and Kelly, R.W. (1989). Toward higher lambing percentages. W.A. Department of Agriculture, Bull. 4148

Cumming I M, Rizzoli. Clarke, D J. and. McPhee, S R. (1978) Fecundity of the fat ewe. *Proc. Aust. Soc. Anim. Prod*. 12: 261

Curll ML, Davidson JL, Freer M (1975). Efficiency of lamb production in relation to weight of the ewe at mating and during pregnancy. *Aust J. Agric Res.* 26:553–65.

Dennis, S.M. (1969) Predators and perinatal mortality of lambs in Western Australia. *Aust.Vet. J*. 45:6-9

Dennis, S.M. (1974) Perinatal lamb mortality in Western Australia. *Aust. Vet. J.* 50:443-453

Donnelly JR. (1984) The productivity of breeding ewes grazing on lucerne or grass and clover pastures on the tablelands of Southern Australia. III Lamb mortality and weaning percentage. *Aust J Agric Res* 35:709–21.

Dwyer, C.M. and Lawrence, A.B. (1999) Does the behaviour of the neonate influence the expression of maternal behaviour in sheep? *Behaviour* 136: 367 – 389

Dwyer, C.M. and Lawrence, A.B. (2000) Effects of maternal genotype and behaviour on the behavioural development of their offspring in sheep. *Behaviour* 137: 1629 – 1654

Dwyer CM, Lawrence AB, Bishop SC, Lewis M (2003). Ewe-lamb bonding behaviours at birth are affected by maternal under-nutrition in pregnancy. *Brit J Nut.* 89:123–36.

Dwyer, C.M., Calvert, S.K., Farish, M., Donbavand, J. and Pickup, H.E. (2005). Breed, litter and parity effects on placental weight and placentome number, and consequences for the neonatal behaviour of the lamb. *Theriogenology* 63: 1092 – 1110

Eales, F.A., Small, J. and Gilmour, J.S.(1982) Resuscitation of hypothermic lambs . *Vet. Rec*. 110: 121-123.

Egan, A.R. (1984) Nutrition and reproduction in 'Reproduction in Sheep'. (Eds D. R. Lindsay and D. T. Pearce.) pp. 262-268. (Australian Academy of Science and the Australian Wool Corporation.)

Egan, J.K., McLaughlin, J.W., Thompson, R.L. and Mclntyre, J.S.(1972) The importance of shelter in reducing neonatal lamb deaths. *Aust. J. Exp. Agric. Anim. Husb*. 12: 470-472

Egan, J K. Thompson R L and. Mclntyre J S (1977) Stocking rate, joining time, fodder conservation and the productivity of Merino ewes 2. Birth weight, survival and growth of lambs *Aust J of Exp Agric and Anim Husb* 17:909-914

Egan J K. Thompson R L and. McIntyre J S (1976) An assessment of overgrown Phalaris tuberose as a shelter for newborn lambs. *Proc Aust Soc Anim Prod.* 11:157 -160

Ferguson, M, Thompson, A and Gordon D (2007) Ewe management handbook : optimizing Merino ewe nutrition to increase farm profit , High rainfall edition Lifetimewool 28pp

Fogarty, N.M. (1972) Crossbreeding for lamb production 1. Survival and growth of first cross lambs. *Aust. J. Exp Agric and Anim.Husb*. 12:234-239

Fogarty, N.M., 1984. Breeding for reproductive performance in *'Reproduction in Sheep'*. (Eds D. R. Lindsay and D. T. Pearce.) Australian Academy of Science and the Australian Wool Corporation, pp. 226-233.

Fogarty, N.M., Ingham, V.M., Gilmour, A.R., Cummins,L.J., Gaunt, G.M., Stafford, J., Hocking-Edwards, J.E. and Banks, R.G.(2005) Genetic evaluation of crossbred lamb production. 1. Breed and fixed effects for birth and weaning weight of first cross lambs, gestation length and reproduction of base ewes. *Aust.J.Agric.Res*. 56:443-453

Fowler, D. G., and Wilkins, J. F. (1982). The accuracy of ultrasonic imaging with real time scanners in determining litter number in pregnant ewes. *Proc. Aust. Soc. Anim. Prod.* 14: 636.

Fowler D G (2007) Lamb marking performance for ultrasound scanned ewes in Australian sheep flocks. Final Report AHW.131 Meat & Livestock Australia 17 pp

George,J.M. (1975) The incidence of dystocia in fine wool merino ewes. *Aust.Vet.J.* 51:262-265

George,J.M. (1976) The incidence of dystocia in Dorset Horn ewes. *Aust.Vet.J.* 52: 519-523

Giles. J.R., (1968). A comparison of two lambing management systems. *Proc. Aust. Soc. Anim. Prod*. 7: 235-238

Grosser T.I, Kleemann, D.O, Grimson, R.J, Smith D.H, Evans R.L.(1991) Effect of shearing during late pregnancy on lamb survival in South Australian Merino ewes. *Wool Tech Sheep Breed* 39:4–6.

Greenwood, PL and Bell AW.(2003) Prenatal nutritional influences on growth and development of ruminants. *Recent Adv Anim Nutr Aust* 14:57–73.

Haughey, K.G. (1973a) Vascular abnormalities in the central nervous system associated with perinatal lamb mortality 1 Pathology. *Aust. Vet.J* 49:1-8

Haughey, K.G. (1973b) Vascular abnormalities in the central nervous system associated with perinatal lamb mortality 2 Association of abnormalities with recognized lesions. *Aust. Vet.J* 49:9-15

Haughey, K G. (1973c) Cold injury in newborn lambs *Aust.Vet.J.* 49:554-563

Haughey, K.G.(1980) The effect of birth injury to the foetal nervous system on the survival and feeding behaviour of lambs. Reviews in Rural Science IV: 109-111.

Haughey, K.G. (1983) Selective breeding for rearing ability as an aid to improving lamb survival *Aust.Vet.J* 60: 361-367

Haughey, K.G.(1984) Can rearing ability be improved by selection? in *'Reproduction in Sheep'*. (Eds D. R. Lindsay and D. T. Pearce.) Australian Academy of Science and the Australian Wool Corporation. pp. 210-212

Haughey, K.G (1985) The repeatability of rearing performance of Merino and Dorset horn ewes and its relationship with mature pelvic size *Aust. J. Exp. Agric*. 25:541-549

Hall D.J., Holst, P.J. and Shutt, D.A. (1992). The effect of nutritional supplements in late pregnancy on ewe colostrum production, plasma progesterone and IGF-1 concentrations. *Aust. J. Agric. Res.* 43: 325-37.

Hayman. R.H.. Turner, H.N. and Turner, E.(1955) Observations on survival and growth to weaning of lambs from ewes with defective udders. *Aust. J. Agric. Res*. 6: 446-455.

Hinch G N, Lynch,J J , Nolan,J.V., Leng,R A, Bindon,B M, Piper, L R (1996) Supplementation of high fecundity Border Leicester x Merino ewes with a high protein feed: its effects on lamb survival *Aust .J. Exp. Agric.* 36:129-136

Hinch G N, Crosbie S F, Kelly,R.W., Owens, J.L. and Davis G H (1985a) The influence of birthweight and litter size on lamb survival in high fecundity booroola Merino crossbred flocks. *New Zealand J. Agric. Res.* 28:31-38

Hinch G N Davis, G H, Crobie, S F, Kelly, R W, and Trotter, R W (1986) Causes of lamb mortality in two highly prolific Booroola crossbred flocks and a Romney flock. *Animal Reprod. Sci* 12: 47-61

Hinch G N Kelly, R W, Davie, G H, Owens, J L and Crosbie S F (1985b) Factors affecting lamb birthweights from high fecundity Booroola ewes. *Animal Reprod. Sci*. 8: 53-60

Hodges, A. and Goesh, T. (2006) Natural resource management: results for 2004-5 from an ABARE survey of Australian farmers. *Australian Commodities* 13:568-573

Holst P.J. and Cullis, B R (1982) Meterological data as a management aid for reduction of lamb losses from inclement weather. *Proc Aust. Soc. Anim.Prod*. 14: 432-434

Holst, P.J., Fogarty, N.M. and Stanley, D.F.(2002) Birth weights, meningeal lesions, and survival of diverse genotypes of lambs from Merino and crossbred ewes. *Aust. J. Agric. Res*. 53: 175–181

Holst, P.J. (2004), Lamb Autopsy - Notes on a procedure for determining cause of death Booklet, State of New South Wales, NSW Agriculture (Book, 02/08/2004).

Hughes, K.L., Hartley, W.J., Haughy, K.G., McFarlane,D. (1964) A study of perinatal mortality of lambs from Oberon, Orange and Monaro districts of NSW. *Proc Aust Soc Anim. Prod* 5:92-99

Hughes, K.L. (1971) Perinantal lamb mortality: infections occurring among lambs dying after partutition *Aust.Vet.J.* 47: 472-476

Jordon, D.J. and LeFeuvre, A.S. (1989) The extent and cause of perinatal lamb mortality in three flocks of Merino sheep. *Aust. Vet. J*. 66:198-201

Jordon, D.J. and Mayer, D.G.(1989) Effects of udder damage and nutritional plane on milk yield, lamb survival and lamb growth of Merinos. *Aust. J. Exp. Agric*. 29:315-320

Kelly RW, Speijers EJ, Ralph IG, Newnham JP. (1992) Lambing performances and wool production of maiden and adult Merino ewes fed different amounts of lupin seed in mid pregnancy. *Aust J Agric Res* 43:339–54.

Kelly, R.W. (1992a) Lamb mortality and growth to weaning in commercial Merino flocks in Western Australia. *Aust J Agric Res.* 43:1399–416.

Kelly R.W. (1992b) Nutrition and placental development. *Proc Nutr. Soc Aust*.17:203–11.

King, J.M., Fisher,J S.,and Murphy P M. (1990) Threshold condition scores of Merino ewes for improved autumn lambing performance in Western Australia. *Proc Aust Soc Anim Prod* 18:272-275

Kilgour, R.J. (1992) Lambing potential and mortality in Merino sheep as ascertained by ultrasonography *Aust. J. Exp. Agric* 32:311-313

Kleemann, D. O., Walker, S. K., Grosser, T. I., Grimson, R. J., and Smith, D. H. (1991). Reproductive loss in commercial Merino flocks of South Australia. *Proc Aust. Soc. Reprod.Biol.* 23: 58.

Kleemann, D.O. and Walker S.K. (2005a). Fertility in South Australian commercial Merino flocks: sources of reproductive wastage. *Theriogenology*. 63: 2075-88.

Kleemann, D.O. and Walker S.K. (2005b). Fertility in South Australian commercial Merino flocks: relationships between reproductive traits and environmental cues. *Theriogenology.* 63: 2416-33.

Knight, T. W., Oldham, C. M., Smith, J. F., and Lindsay, D. R. (1975). Studies in ovine infertility in agricultural regions in Western Australia: analysis of reproductive wastage. *Aust. J. Exp. Agric. Anim. Husb.* 15: 183-8.

Lax J. and Turner H N (1965) The influence of various factors on survival rate to weaning of Merino lambs 1 Sex, strain, location, and age of ewe from single-born lambs. *Aust J .Agric. Res*. 16: 981-995

Luff A.F. (1980) A service for all seasons Final Report Australian Wool Corporation Project K/1/1051

Lynch J.J. and Alexander G. (1980) The effect of time of shearing on sheltering behaviour of Merino sheep. Proc Aust. Soc. Anim. Prod. 13:325-328

McCance, I. and Alexander, G.(1959) The onset of lactation in the Merino ewe and its malfunction by nutritional factors. *Aust. J. Agric. Res.* 10: 697-719

McCrabb G.J, Egan A.R, Hosking B.J. (1992) Maternal under nutrition during mid pregnancy in sheep: variable effects on placental growth. *J. Agric Sci Camb* 118:127–32.

McDonald, J.W (1966) Variation in perinatal mortality of lambs with age and parity of ewes. *Proc Aust Soc Anim Prod.* 6:60-62

McHugh, J.F. and Edwards, M.S.H. (1958) Lamb loss investigations at Rutherglen research station. *J. of Agric (Vic)* 56:425-438

McGuirk B.J., Ferguson, B.D., Haughey, K., George, J.M., Piper, L.R., Hanrahan, J.P. , Evans, R. Bindon,, B.M., Donnelly , F.B.(1982) Improving lamb survival in Merinos. *Proc. Aust. Soc. Anim. Prod.* 14: 23-34

Mellor, D. J. (1983). Nutritional and placental determinants of foetal growth rate in sheep and consequences for the newborn lamb. Br. Vet. J. 139: 307-24.

Moule, G.R. (1954) Observations on mortality amongst lambs in Queensland. *Aust. Vet. J*. 30:153-171

Moore, R.W., McDonald, I.M. and Messenger, J.J. (1966) Fox predation as a cause of lamb mortality *Proc Aust Soc Anim. Prod.* 6:157-160

Murphy, P.M. (1999). Maternal behaviour and rearing ability of Merino ewes can be improved by strategic feed supplementation during late pregnancy and selection for calm temperament. PhD thesis. The University of Western Australia, Nedlands, Western Australia.

Murphy P, McNeill D.M, Fisher J.S, Lindsay D.R. (1996) Strategic feeding of Merino ewes in late pregnancy to increase colostrum production. *Proc Aust Soc Anim. Prod.* 21:227–30.

Nowak R, Porter R.H, Levy F., Orgeur P, Schaal B. (2000) Role of mother-young interactions in the survival of offspring in domestic mammals. *Rev. Reprod.* 5:153–63.

Nowak, R. and Poindron, P. (2006) From birth to colostrum: early steps leading to lamb survival. *Reproduction Nutrition Development* 46: 431 – 446

Obst, J.M, Day, H.R. (1968) The effect of inclement weather on mortality of Merino and Corriedale lambs on Kangaroo Island. *Proc Aust Soc Anim. Prod.* 7:239–42.

Obst, J.M. and Evans, J.V.(1970) Genotype environment interactions in lamb mortality with particular reference to birthcoat and haemoglobin type. *Proc. Aust. Soc. Anim. Prod.* 8*:* 149-153

Oldham C.M. and Thompson A.N. (2004). Lifetime Wool. 5. Carryover effects on subsequent ewe reproduction. *Proc. Aust. Soc. Anim. Prod.* 25: 291.

Plant, J.W., Ferguson, B.D., O'Halloran and Marchant, R. (1976). Cause of infertility in individual sheep flocks. *Proc. Annu. Conf. Aust. Vet. Assoc.* 53:189-190.

Plant, J.W., Marchant,R., Mitchell, T.D and Giles, J.R. (1978) Neonatal lamb loss due to feral pig predation *Aust.Vet.J .* 54: 426-429

Plant, J.W.(1981) Field investigations into reproductive wastage in sheep. *Refresher Course for Veterinarians Proc. No. 58:* 411-440. Postgraduate Committee in Veterinary Science, University of Sydney

Poindron, P., Le Neindre, P. and Levy, F.(1984) Maternal behaviour in sheep and its physiological control. in *'Reproduction in Sheep'*. (Eds D. R. Lindsay and D. T. Pearce.) Australian Academy of Science and the Australian Wool Corporation pp. 191-198.

Pollard, J.C. (2006) Shelter for lambing sheep in New Zealand: a review. *New Zealand J. Agric Res*. 49:395-404

Reed,B., Richardson, R., and Brown, S. (2006) ASHEEP Wean More Lambs Demonstration : MLA Project SCSB.063A pp15

Robinson, J.J. (1981) Prenatal growth and development in the sheep and its implications for viability of the newborn lamb. *Livestock. Prod. Sci*. 8: 273-281.

Rowley, I. (1970) Lamb predation in Australia: incidence, predisposing conditions and identification of wounds. *Wildlife. Res.* 15: 79-123.

Safari, E., Atkins, K.D., Fogarty, N.M and Gilmour, A.R. (2005) Analysis of lamb survival in Australian Merino. *Proc. Assoc. Advmt. Anim. Breed. Genet*. 16: 28-31.

Slee, J and Springbett, A. (1986) Early post-natal behaviour in lambs of ten breeds. *Applied Animal Behav. Science* 15: 229 – 240

Slee J., Alexander,G. Bradley, LR., Jackson N and Stevens D (1991) Genetic aspects of cold resistance and related characteristics in newborn Merino. *Aust. J. Exp. Agric*. 31:175-182

Smith, I .D (1962) Reproductive wastage in a merino flock in central western Queensland. *Aust Vet J*. 38:500-507

Smith, I D. (1964) Ovine neonatal mortality in western Queensland. *Proc. Aust. Soc. Anim. Prod.* 5:100-106

Smith, I.D.(1965) Reproductive wastage on Merino sheep in semi tropical Queensland: Observations on flocks mated during spring and summer. *Aust. J. Exp. Agric. Anim. Husb. 5*: 110-114.

Stevens, D., Alexander, G. and Lynch, J.J (1981) Do Merino ewes seek isolation or shelter at lambing? .*Appl. Anim. Ethol,* 7: 149-155.

Stevens, D., Alexander, G. and Lynch, J.J.(1982) Lamb mortality due to inadequate care of twins by Merino ewes. *Appl. Anim. Ethol*. 8: 243-252.

Stevens D, Alexander G, Mottershead B, Lynch JJ. (1984) Role of the lambs in post-partum separation of ewes from twin lambs. *Proc. Aust. Soc. Anim. Prod*. 15:751.

Szanter-Coddington, M (1994) Genetic improvement of lamb survival in the Australian Merino: behavioural and physiological indicators of maternal ability M.RurSc, UNE 139pp

Watson, R.H. and Elder, E.M (1961) Neonatal mortality in lambs: further observations in a Corridale flock with a history of high lamb mortality. *Aust. Vet J* 37:283-290

Watson, R.H., Alexander, G., Gumming, I.A., McDonald, J.W., McLaughlin, J.W., Rizzoli, D.J. and Williams, D.(1968) .Reductions in perinatal loss of lambs in winter in western Victoria by lambing in sheltered individual pens. *Proc. Aust. Soc. Anim. Prod.* 7: 243-249.

Walker, S.K., Kleemann, D.O. and Bawden, C.S. (2002). Sheep Reproduction in Australia. Current status and potential for improvement through flock management and gene discovery. Final Report Meat and Livestock Australia, Sydney.

Watt R D (1955) The Romance of the Australian Land Industries. Angus and Robertson Sydney pp271