final report

Project code: L.LSM.0001

Prepared by: Dr Andrew Thompson and John Young
Murdoch University

Date published: 9th June 2018

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Improving the reproductive performance of ewe lambs – Management guidelines, economic analysis and decision support tools

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Increasing the number of ewes joined to lamb as yearlings at 12 to 15 months could be an effective avenue to rapidly build ewe numbers and increase lamb supply. However, the reproductive performance of ewe lambs is much lower and more variable than that achieved by adult ewes. A lack of information on the longer-term impacts of joining ewe lambs, both on the young ewe and her offspring, plus the cost-effectiveness of joining ewe lambs has also contributed to relatively poor adoption of the practice. Previous projects (B.LSM.0038 and B.PDS.0903) identified the importance of using teasers, liveweight at joining, growth rate during joining and sire genetics to improve the reproductive rate of ewe lambs. The current project extended this earlier work and completed a metanalysis of datasets relating to the reproductive performance of ewe lambs from Australia and New Zealand, including the effects of: (i) liveweight profile of ewe lambs on the birth weight, survival and growth of their progeny to weaning; (ii) carryover effects of ewe lamb reproductive performance on their hogget reproductive performance, and (iii) growth, wool production and reproductive performance of progeny born to ewe lambs compared to progeny born to adult ewes. The project also used the outputs from this metanalysis to inform economic modelling using MIDAS to developed management guidelines to cost-effectively improve the reproductive performance from ewe lambs. However, the number of scenarios modelled was limited and the determination of the management guidelines with respect to live weights profiles from weaning to joining, during joining, during pregnancy and between weaning and the 2 year old mating to maximise profitability were not clear. It also became apparent during this project that the prediction equations for energy requirement or intake capacity of maternal sheep require updating and hence the maternal component of this analysis could be incorrect. Additional analysis, using refined feeding standards for maternal ewes, across environments and different lambing times, plus lambing young ewes 1-2 months later that the adult flock, is still needed to formulate more robust management guidelines that optimise the profitability from joining ewe lambs.

Executive summary

Increasing the number of ewes mated to lamb as yearlings at 12 to 15 months could be an effective avenue to rapidly build ewe numbers and increase lamb supply. However, the reproductive performance of ewe lambs is much lower and more variable than that achieved by adult ewes. A lack of information on the longer term impacts of mating ewe lambs, both on the young ewe and her offspring, plus the financial ramifications of joining ewe lambs has also contributed to relatively poor adoption of the practice. Previous projects (B.LSM.0038 and B.PDS.0903) identified the importance of using teasers, live weight at joining, growth rate during joining and sire genetics to improve the reproductive rate of ewe lambs. The current project extended this earlier work and completed a metanalysis of datasets relating to the reproductive performance of ewe lambs from Australia and New Zealand, including the effects of: (i) liveweight profile of ewe lambs on the birth weight, survival and growth of their offspring to weaning; (ii) carryover effects of ewe lamb reproductive performance on their hogget reproductive performance and (iii) growth, wool production and reproductive performance of progeny born to ewe lambs compared to progeny born to adult ewes.

The key data sets included the Maternal Efficiency flock in WA for Merinos (n = 1,471 records), Cashmore Oaklea (n = 7,437) for Maternal Composites, and from Massey University (n = 15,445) for Romneys. Key outputs from this analysis include:

(a) Liveweight at the start of joining was a major determinant of the reproductive success of ewe lambs joined at 7 to 9 months of age. Reproductive rate and weaning rate increased linearly in response to increasing liveweight at joining for Merinos and there was no evidence of a threshold response for either trait at least up to 50 kg. Reproductive rate and weaning rate increased by 3.4% and 2.6% per extra kg of liveweight at joining and the responses were not influenced by the ewe lambs own birth or rear type or their age at joining (average 7.5 months). By contrast, the reproductive rate and weaning rate responses of Maternal Composite ewe lambs were curvilinear and there was a significant effect of their own birth type and age at joining. When Maternal Composite ewe lambs achieved 45 kg at joining their reproductive rate and weaning were within 2 to 3% of their maximum. On average, at the same joining liveweight the reproductive rate and weaning rate of triple born Maternal Composite lambs was about 17% and 11% greater than twin born lambs which were in turn 14% and 7% better than that achieved by single born lambs. The age effects was also quadratic, and the difference in reproductive rate between lambs joined at 6.5 *vs*. 7.5 months of age was 38% whereas only 6% between those joined at 7.5 *vs*. 8.5 months of age.

(b) Improving the nutrition of Merino ewe lambs during joining significantly increases their reproductive rate, and the effects of liveweight at joining and growth rate during joining are additive. For every 100 g/day increase in growth rate during joining the reproductive rate in Merino ewe lambs increased by 20%, and most of the effect of growing faster during joining on reproductive rate was in addition to the fact that faster growing lambs are obviously heavier at the time of conception. Growing an extra 100 g/day during joining had a similar impact on reproductive rate as an extra 5 kg of liveweight at the start of joining. The effects of growth rate during joining on reproductive rate have not been quantified for Maternal lambs, but it is reasonable to expect that the effects of growth rate during joining will be similar for Merino and Maternal ewe lambs until confirmed otherwise.

(c) Liveweight at joining and throughout pregnancy influenced the birth weight and weaning weight of their progeny, but these effects were variable across ewe types. The progeny from ewe lambs which were 10 kg heavier at joining were about 0.2 kg heavier at birth and 1.3 to 2.9 kg heavier at weaning, and these responses were similar regardless of birth type.

Liveweight change during pregnancy can also influence the birth weight and weaning weight of progeny from Romney ewe lambs, however there was no suitable data to validate these responses in Merino or Maternal Composite ewe lambs. For Romneys, a 10 kg gain in liveweight between Day 90 of pregnancy and lambing increased the birth weights of their single and twin born progeny by about 0.6 kg, but increasing liveweight between joining and Day 90 of pregnancy had no significant effect on birth weights. A 10 kg gain in liveweight between joining and Day 90 of pregnancy or between Day 90 of pregnancy and lambing increased the weaning weight of their progeny by 0.8 kg and 3.2 kg respectively. The effects of liveweight gain in the different periods was additive. Until confirmed otherwise, it is reasonable to assume that the effects of liveweight change during pregnancy on the birth weights and weaning weights of progeny from Merino and Maternal Composite ewe lambs will be similar to that observed for Romneys.

(d) The birth weight of progeny born to Merino, Maternal Composite and Romney ewe lambs was significantly related to their survival to weaning. The optimum birth-weight for maximum survival was between 4.5 and 6.0 kg for single and twin born lambs, but this varied between ewe-types. The average birth weight for single and twin born progeny from Merino ewe lambs was 4.7 and 3.9 kg, and for single, twin and triple born progeny from Maternal Composite ewes was 5.0. 4.2 and 3.6 kg. The average birth weight for single and twin born progeny from Romney ewe lambs was 4.3 and 3.3 kg, and this data set also suggested an increased risk of dystocia and mortality of progeny at heavier birth weight. The effects of liveweight profile of ewe lambs on the survival of their progeny appears to be up to 50% larger than those attributed to changes in birth weight alone, so the higher survival of progeny from well grown ewe lambs is more than likely a reflection that they also have less lambing issues and they have improved mothering ability.

(e) Liveweight at the start of joining was also a determinant of the reproductive success of Merino and Maternal Composite ewes mated a second time at 19-20 months of age. The average reproductive rate of hogget ewes varied between flocks and years from 0.7 to 2.3% but if anything maybe less than the typical response observed in adult ewes of 2.0% extra foetuses scanned per kg per 100 ewes joined. At the same liveweight at hogget joining, there was no significant difference in the reproductive rate or weaning rate of Merino or Maternal Composite ewe lambs that were born as a single, twin or triple. However, at the same liveweight at hogget joining, Maternal composites that were twin and triple bearing as ewe lambs had a significantly higher reproductive rate and weaning rate than those which had a single lamb or were dry when mated at 7-9 months of age. The differences in reproductive rate and weaning rate between each of these cohorts was 10-12% across the range in liveweights at joining. These effects of ewe lamb performance on subsequent reproductive performance were not evident in the Merino, but this is likely to reflect inadequate data rather than genuine differences in biology between ewe types.

(f) Progeny from Merino and Maternal Composite ewe lambs grow slower to weaning and produce less wool during their life. Progeny from ewe lambs were 3 to 4 kg lighter at weaning than those from hogget and adult ewes. As ewe lambs were often joined later and their lambs weaned younger, this comparison is difficult but, nevertheless, is it reasonable to expect that progeny from ewe lambs will grow slower. As expected, progeny from ewe lambs produced 0.2 to 0.4 kg less wool than those from older ewes. The effects of dam age on the fibre diameter of wool produced by Merino progeny was unexpected, in that nutritional penalties *in utero* would be expected to increase fibre diameter of wool produced but instead progeny from ewe lambs produced significantly finer wool at both hogget and adult age. However, as twin born lambs produced broader wool than single lambs at both hogget (18.1 *vs* 17.9 um) and adult age (18.4 *vs* 18.2 um), as expected, there is reason to believe that whilst the effects of dam age were not expected they are probably real.

(g) Progeny from Merino and Maternal Composite ewe lambs had a lower reproductive performance than those from adult ewes when bred as a ewe lamb. Whilst this was partly because the progeny born to ewe lambs were lighter at joining at 7 to 9 months of age, the effects of dam age were still significant when liveweight at joining was included in the statistical model. The poorer performance of progeny born to ewe lambs versus older ewes at their ewe lamb breeding probably also reflects difference in age, as those from ewes lambs would often be one to two months younger. This indicates progeny born to ewe lambs may be less suitable to be bred at a young age. There were no significant effects of dam age on reproductive potential of their progeny at their hogget or adult joining's in either Merino of Maternal Composites when adjusted for differences in liveweight at joining.

The project used the outputs from this metanalysis to inform economic modelling using MIDAS to developed management guidelines to cost-effectively improve the reproductive performance from ewe lambs. In some cases where there was insufficient data it was necessary to assumed that similar production responses would apply across sheep types. Based on these assumptions, and the now recognised limitations of the economic modelling, this modelling suggested that joining maternal ewes to have their first lamb at yearling age was profitable in all the scenarios examined in the long growing season environment in south west Victoria. Extrapolating the results to a shorter growing season indicates that it will be profitable if lambing is occurring earlier than the normal spring Merino lambing. This earlier lambing of the Maternal flock is the most common production system so mating maternals for a yearling lamb could have widespread applicability. By contrast, the profitability of mating Merinos was much lower and if all the young ewes are mated then there was insufficient profit to make it a practice that would warrant widespread extension and adoption. However, only mating a proportion of the younger ewes, selected at weaning as the heavier animals, increased the profitability of mating young Merino ewes and further investigation of this strategy is warranted. This practice reduces the cost of feeding the weaners to achieve a reasonable joining liveweight and selecting the heaviest 40-50% of the weaners to target for mating increases the profitability from breakeven up to achieving a profit of $20 to $40 per ewe lamb joined. However, the trade-off is that there are fewer ewe lambs being mated.

The determination of the management guidelines with respect to liveweight profiles from weaning to joining, during joining and pregnancy and between weaning and the 2 year old mating to maximise the profitability from joining ewe lambs were not clear from the economic modelling completed. This was in part due to the limited number of scenarios modelled and known short comings in the prediction equations for energy requirement or intake capacity of maternal sheep. Additional analysis of Maternal production systems across environments and for different lambing times, plus lambing yearling ewes 1-2 months later that the adult flock, is still needed to formulate more robust guidelines that optimise profitability. This additional analysis, also using refined intake and energy equations for Maternals derived from L.LSM.0008, is currently in progress within L.LSM.0007. This additional analysis will then inform the creation of a decision support tool to inform on-farm decision making regarding joining ewe lambs and their optimum management.

Table of contents

1 Background

Increasing the number of ewes mated to lamb as yearling at 12 to 15 months could be an effective avenue to rapidly build ewe numbers and increase lamb supply, and industry-level analysis that underpinned the National Sheep Reproduction RD&E strategy indicated that the second most important area for future research was improving the reproductive performance from ewe lambs mated at 7 to 9 months of age. However, the reproductive performance of ewe lambs is much lower and more variable than that achieved by adult ewes. A lack of information on the longer term impacts of mating ewe lambs, both on the young ewe and her offspring, plus the financial ramifications of joining ewe lambs has also contributed to relatively poor adoption of the practice.

To this end, MLA-funded projects (B.LSM.0038 and B.PDS.0903) made significant progress towards development of management guidelines to improve their reproductive performance and more specifically identified the importance of using teasers, live weight at joining, growth rate during joining and sire genetics on fertility and reproductive rate. However, the overall extension package is also dependent on developing management guidelines for pregnancy as it appears that birth weights may be highly sensitive to ewe nutrition during pregnancy and there is limited data on peri natal mortality in lambs born from ewe lambs. Furthermore, most producers remain reluctant to mate ewe lambs because of a lack of information on the longer term impacts, both on the young ewe and her progeny, and the financial ramifications of mating ewe lambs.

The current project aimed to extend this earlier work and complete a metanalysis of datasets relating to the reproductive performance of ewe lambs from Australia and New Zealand, including the effects of: (i) liveweight profile of ewe lambs on the birth weight, survival and growth of their offspring to weaning; (ii) carryover effects of ewe lamb reproductive performance on their hogget reproductive performance and (iii) growth, wool production and reproductive performance of offspring born to ewe lambs compared to progeny born to adult ewes. Outputs from this metanalysis would then inform a desktop study using whole farm bio-economic modelling to develop optimum management guidelines to improve the reproductive performance from ewe lambs and develop a decision support tool to inform on-farm decision making regarding joining ewe lambs.

2 Project objectives

By 30th June 2016:

1. Completed a metanalysis of datasets relating to the reproductive performance of ewe lambs from Australia and New Zealand to provide inputs into the MIDAS modelling.

2. Determined the critical control points and developed management guidelines to improve the reproductive performance from ewe lambs. Outputs will be published in a refereed journal similar to that for the More Lamb Quality Pastures project and the National Reproduction RD&E Strategy.

3. Consolidate key messages from this and other projects relating to improving the reproductive performance of ewe lambs, update the MLA Tip and Tool relating to reproductive e performance of ewe lambs and provide these key messages in a format suitable for incorporation into extension products such as Bred Well Fed Well

4. Developed and tested a decision support tool prototype that provides consultants and farmers information on the profitability of mating ewe lambs for their particular situation.

3 Metanalysis of data relating to ewe lamb reproduction

3.1 Methodology

3.1.1 Data sets

Data relating to the reproductive performance of ewe lambs was compiled from multiple sources, including; (a) Projects B.LSM.0038 and b.pds.0903; (b) Sheep CRC Nucleus Flock; (c) Maternal Efficiency flock in WA, (d) Commercial Maternal ram breeders (e.g. LambPro, Cashmore/Oaklea and Mount Ronan); and (e) Massey University research flocks in New Zealand. The most suitable data for the Merino analysis was from the Maternal Efficiency flock, albeit limited in size, and the Cashmore/Oaklea and Massey University data sets were most suitable for the Maternal analysis (Table 1).

Table 1. Average characteristics of key data sets.

	Maternal Efficiency (Merino)	Cashmore/Oaklea (Maternals)	Massey University (Maternals)
Live weight at joining (kg)	42.3 (*n* = 1,471)	40.0 (n = 7,437)	43.4 (*n* = 15,445)
Number of lambs born (%)	52	112	128
Birth weight (kg)	4.5 (*n* = 760)	4.4 (*n* = 4,529)	4.4 (*n* = 2,481)
Number of lambs weaned (%)	37	77	-
Survival to weaning (%)	71	69	78
Weaning weight (kg)	22.8 (*n* = 541)	26.6 (*n* = 5,368)	23.6 (*n* = 1,944)

3.1.2 Statistical Analysis

All statistical analyses were performed using GENSTAT (GENSTAT Committee 2008) and the Merino and Maternal data sets (Cashmore/Oaklea or NZ) were analysed separately. Reproductive rate and weaning rate were analysed using a Generalized Linear Model with a multinomial distribution and logit link function as a function of different variables, including year, joining weight, age at joining, liveweight change during joining and sire breeding values for NLW, own birth type or birth type/rear type as a ewe lambs as appropriate. For the various liveweights quadratic effects were also examined.

Estimates of lamb survival were assessed by fitting General Linear Mixed Models (GLMM; Genstat 2018). The approach used a logit transformation and binomial distribution. Using additive models, logits were predicted as a function of lamb birth weight (quadratic effect) and birth type as fixed effects while year and sire (nested within year) were fitted as random effects.

The method of restricted maximum likelihood (REML) was used to fit progeny birth or weaning weight data with liveweight of the ewe at joining, birth type and sex of progeny fitted as fixed effects where appropriate, while year and sire (nested within year) were fitted as random effects. All possible models were examined with statistical significance of terms and interactions thereof accepted at $P < 0.05$.

For the NZ data the method of restricted maximum likelihood (REML; Genstat 2018) was used to fit progeny birth or weaning weight data with liveweight of the ewe at joining, change in liveweight of the ewe between joining and Day 100 of pregnancy, and change in liveweight of the ewe from Day 100 of pregnancy until lambing, birth type and sex of progeny fitted as fixed effects where appropriate, while site, replicate (nested within site) and plot (nested within replicate) were fitted as random effects. All possible models were examined with statistical significance of terms and interactions thereof accepted at $P < 0.05$.

All weight, and fleece traits was assessed using the method of restricted maximum likelihood (Genstat, 2018). Birth-type-rear-type (BTRT: 11=single born and reared; 21=twin born, single reared or; 22=twin born and reared) and ewe class (ewe lambs, hogget ewes and adult ewes) were fitted as fixed effects. Year and sire (nested within year) were fitted as random terms.

3.2 Results and Discussion

3.2.1 The impact of liveweight at joining on reproductive rate and weaning rate of ewe lambs

Liveweight at the start of joining was a major determinant of the reproductive success of ewes lambs joined at 7 to 9 months of age in all data sets analysed. Reproductive rate and weaning rate increased linearly (P<0.001) in response to increasing liveweight at joining in Merino ewe lambs, and there was no evidence of a threshold response for either trait at least up to 50 kg (Fig. 1). Reproductive rate and weaning rate increased by 3.4% and 2.6% per extra kg of liveweight at joining and the responses were not influenced by the ewe lambs own birth or rear type or their age at joining (average 7.5 months). The reproductive rate response to increasing liveweight at joining was comparable to what we have previously reported in other Merino flocks (3.4%, Rosales Nieto *et al.* 2015 and 4.0 to 4.5%, Thompson *et al.* 2018, submitted).

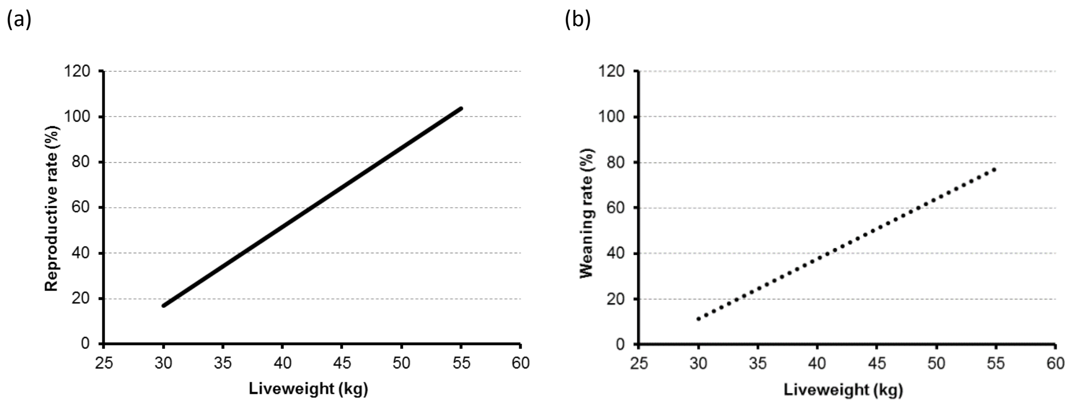

Figure 1. Effects of liveweight at joining at 7.5 months of age on the reproductive rate (foetuses/100 ewes joined) (a) and weaning rate (lambs weaned/100 ewes joined) (b) for Merino ewe lambs. Data from Maternal Efficiency Flock in Western Australia (Thompson, unpublished data).

By contrast, the reproductive rate and weaning rate responses of Maternal Composite ewe lambs were curvilinear and there was a significant effect of their own birth type (Fig. 2) and age at joining (Fig. 3). When birth type of the ewe lamb was included in the model, if ewe lambs achieved 45 kg at joining their reproductive rate and weaning rate were within 2 to 3% of their maximum. On average, at the same joining liveweight the reproductive rate and weaning rate of Maternal Composite lambs that were born as triples was about 17% and 11% greater than twin born lambs which were in turn 14% and 7% better than that achieved by single born lambs.

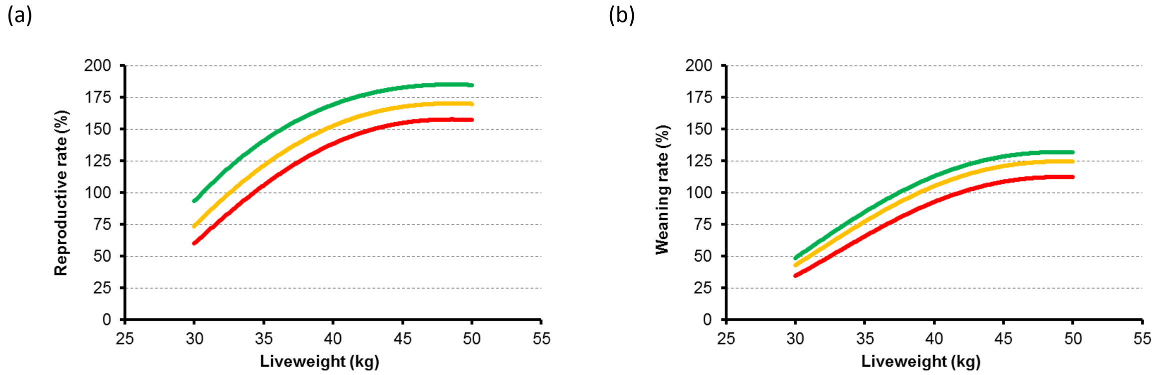

Figure 2. Effects of live weight at joining at 7.5 months of age on the reproductive rate (foetuses/100 ewes joined) (a) and weaning rate (lambs weaned per 100 ewes joined) (b) for Maternal Composite ewe lambs born a single (red), twin (orange) or triple (green). Data from Cashmore/Oaklea (Thompson unpubl. data).

For Maternal composite ewe lambs, the age effects was also quadratic and for reproductive rate there was a significant interaction with birth type. On average, the difference in reproductive rate and weaning rate between ewe lambs joined at 6.5 *vs*. 7.5 months of age was 38% and 26% whereas only 6% and 8% between those joined at 7.5 *vs*. 8.5 months of age.

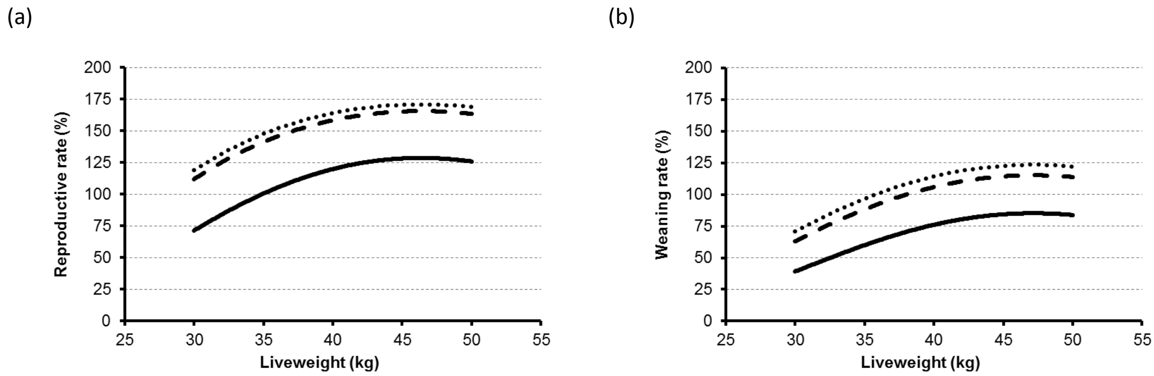

Figure 3. Effects of liveweight at joining on the reproductive rate (foetuses/100 ewes joined) (a) and weaning rate (lambs weaned per 100 ewes joined) (b) for Maternal Composite ewe lambs joined at 6.5 (solid), 7.5 (dashed) or 8.5 months of age (dots). Data from Cashmore/Oaklea (Thompson unpubl. data).

When neither birth type or age at joining were included in the model, a scenario which would most closely represent typical commercial farms, the reproductive rate and weaning rate for ewe lambs that achieved 45 kg at joining were within 1.5% of their maximum. Furthermore, whilst the responses were curvilinear, the increase in reproductive rate and weaning rate between 35 and 45 kg was 44% and 42% respectively. The corresponding increase in reproductive rate across this range in liveweight at joining in the final report for B.LSM.0038 was 33% for Maternal Composites. An analysis of over 15,000 records from Massey University in New Zealand also indicated a quadratic relationship between liveweight at joining and reproductive rate. In that data set the maximum reproductive rate was achieved at a liveweight at joining of 55 kg, 90% of this maximum was achieved at liveweight at joining of 45 kg and the increase in reproductive rate between a liveweight at joining of 35 kg and 45 kg was 30%.

The responses in reproductive rate and weaning rate suggest the overall survival of lambs from Merino ewes joined at 7.5 months of age was 71% if joined at 30 kg and 74% if joined at 50 kg, despite the proportion of ewes with twins increasing from 4 to 18%. In comparison, the estimated survival of lambs from Maternal Composite ewes joined at 7.5 months of age was about 57% if joined at 30 kg and 74% if joined at 55 kg, despite the proportion of ewes with multiples increasing from 22% to 70%. In the NZ data the overall survival of lambs from Romney ewes joined at 7 to 9 months was 78%.

3.2.2 Variation in liveweight at joining versus reproductive rate relationships with genotype, pre-joining weight change and improved joining management

There was considerable variation in the reproductive rate responses to liveweight at joining between experiments, indicating that other factors also influence the reproductive success of joining ewe lambs. The liveweight profile from birth to joining at 7 to 9 months of age does not appear to significantly influence the reproductive performance of ewe lambs over and above the impacts due to differences in liveweight at joining, including number of lambs born, lamb survival or number of lambs weaned. The current project and other work indicates that the reproductive success of ewe lambs is influenced by their sires ASBVS for number of lambs born, number of lambs weaned (Fig. 4), post-weaning weight, post-weaning fat and post weaning muscle, plus phenotypic condition score, but importantly there is no consistent evidence that these factors influence the slope of the relationships between liveweight at joining and either reproductive rate or weaning rate. Therefore the variability in responses to liveweight at joining will be best handled in the MIDAS modelling by a sensitivity analysis.

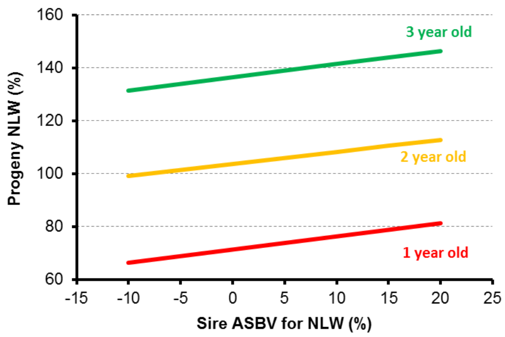

Figure 4. Effects of sire ASBV for number of lambs weaned on the weaning rate of their Maternal Composite daughters when joined as ewe lambs (red; 0.52 lambs weaned per %), hoggets (orange; 0.46 lambs weaned per %) and adults (green; 0.50 lambs weaned per %). Data from Cashmore/Oaklea (Thompson unpubl. data).

As described in the final report for B.LSM.0038, improving the nutrition of Merino ewe lambs during joining significantly increases their reproductive rate when mated at 7 to 9 months of age. The effects of nutrition and therefore growth rate during joining on reproductive rate are evident regardless of liveweight at the start of joining. In other words, the effects of liveweight at joining and growth rate during joining are additive. For every 100 g/day increase in growth rate during the joining period reproductive rate in Merino ewe lambs increased by 20% (Fig. 5), and most of the effect of growing faster during joining on reproductive rate is in addition to the fact that faster growing lambs are also heavier at the time of conception. Growing an extra 100 g/day during joining had a similar impact on reproductive rate as an extra 5 kg of live weight at the start of joining. In other words, ewe lambs that weighed 40 kg at the start of joining and grew at 200 g/day during joining achieved similar reproductive performance to those that weighed 45 kg at the start of joining and grew at 100 g/day or weighed 50 kg at the start of joining and maintained weight during joining.

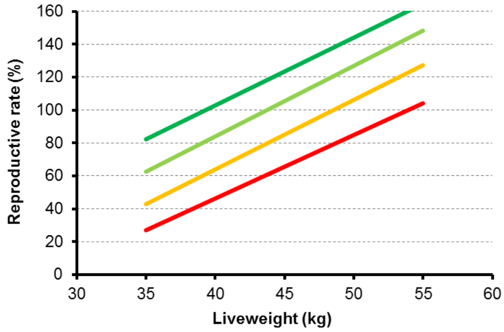

Figure 5. Effects of live weight at joining and growth rate during joining [maintenance (red); 100 g/day (orange); 200 g/day (light green) and 300 g/day (dark green)] on the reproductive rate of Merino ewe lambs mated at 7 to 9 months old in Western Australia (Thompson *et al*. submitted).

The effects of growth rate during joining on reproductive rate have not been quantified for non-Merino ewe lambs, and the data sets compiled for this project were not suitable for this analysis as all Maternal Composite (or NZ Romney) ewe lambs were managed together during joining within a site and year. It is reasonable to expect that the effects of growth rate during joining will be similar for Merino and Maternal ewe lambs, and this assumption will be adopted in the MIDAS modelling, however the effects of growth rate during joining on reproductive rate need to be quantified for Maternal Composites given the magnitude of the effect. It is also reasonable to expect that ewe lambs fed to grow faster during joining could increase the birth weight, survival and weaning weight of their progeny, but this too is yet to be quantified.

3.2.3 Relationship between reproductive rate and the proportion of dry, single, twin and triplet ewe lambs

All pregnancy scanning data from Cashmore/Oaklea for 2007 onwards was used to relate the proportion of dry, single, twin and triplet bearing ewes to reproductive rate. This database included approximately 11,000 ewe lambs, 8,000 ewe hoggets and 4,000 adult ewes (2.5 to 6 years old). The data available was the proportion of ewes scanned dry, single, twin or triplet by age group by Sire ASBV for NLW. All the data points were analysed together because there was no indication that age or Sire ASBV for NLW altered the relationship. A multiple regression analysis related the proportion of ewes of each birth type to scanning percentage, (scanning percentage)^2, (scanning percentage)^3 and the inverse of scanning percentage (Fig. 6). The range of scanning percentage in the data was from 45% up to 171% so this is the range that the equations are valid over, however sensible results are achieved up to 195% scanning, although at this level the equations may be underestimating the proportion of triplet bearing ewes.

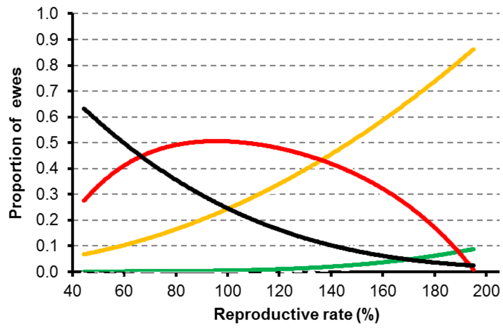

Figure 6. Data points from Cashmore/Oaklea used for the multiple regression and the fitted relationships between reproductive rate and the proportion of ewes scanned dry (black), single (red), twin (orange) and triplet (green). Data from Cashmore/Oaklea.

3.2.4 Impact of liveweight at joining and liveweight change during pregnancy on birth weight and weaning weight

Liveweight at the start of joining has a positive effect on the birth weight and weaning weight of the progeny born from Merino ewes mated at 7 to 9 months of age. On average, the progeny from Merino ewe lambs which were 10 kg heavier at joining were 0.17 kg heavier at birth (Fig. 7a) and 1.3 kg heavier at weaning (Fig. 7b). Single born progeny from Merino ewe lambs were 0.8 kg heavier at birth and 4 kg heavier at weaning than twin born progeny, however the birth weight and weaning weight responses to increasing live weight at joining were similar for single and twin born lambs.

(a) (b)

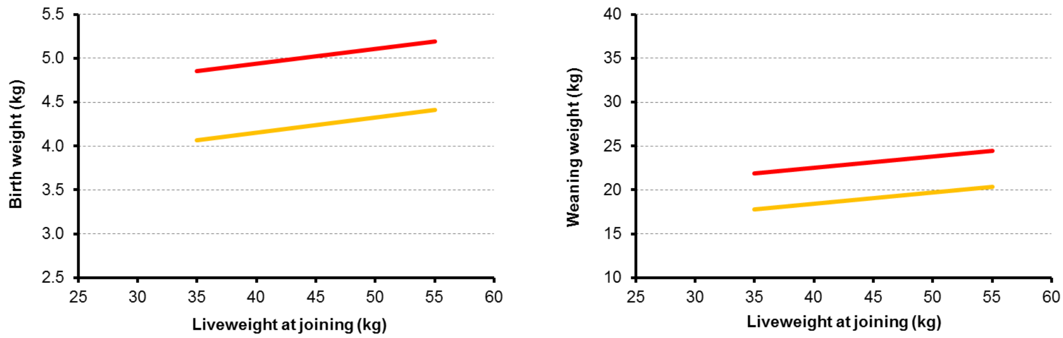

Figure 7. Effect of liveweight of ewe lambs at joining on the birth weight (a) and weaning weight (b) of single (red) and twin (orange) born progeny from Merino ewe lambs mated at 7-9 months of age. Data from Maternal Efficiency Flock in Western Australia (Thompson, unpubl. data).

On average, the progeny from Maternal Composite ewe lambs which were 10 kg heavier at joining were 0.25 kg heavier at birth (Fig. 8a) and 2.9 kg heavier at weaning (Fig. 8b). Single born progeny from Maternal composite ewe lambs were 0.8 kg heavier at birth and 5.1 kg heavier at weaning than twin born progeny. Twin born lambs were also about 0.7 kg heavier at birth than triple born lambs but only 1.7 kg heavier at weaning, probably because most triplets were reared as twins. Like Merinos, the birth weight and weaning weight responses to increasing live weight at joining were similar regardless of birth type.

(a) (b)

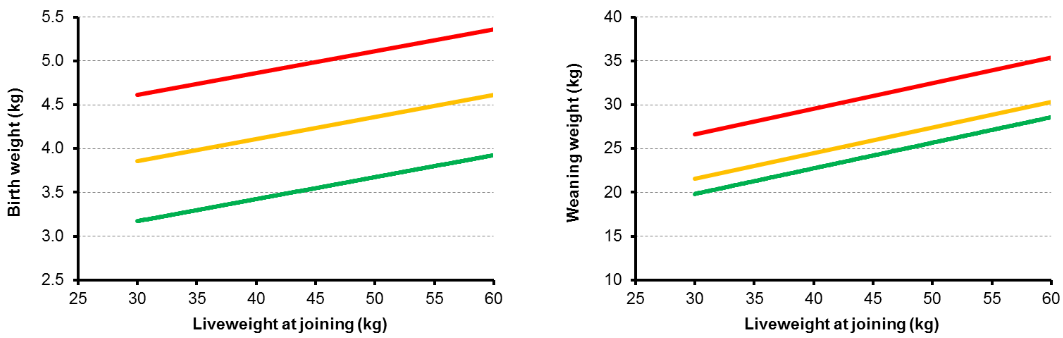

Figure 8. Effect of live weight at joining on the birth weight (a) and weaning weight (b) of single (red), twin (orange) and triplet (green) born progeny from Maternal Composite ewe lambs mated at 7-9 months of age. Data from Cashmore/Oaklea (Thompson, unpubl. data).

The data sets compiled for Merinos and Maternal composites were both unsuitable for quantifying the relationships between changes in liveweight between joining and Day 100 of pregnancy or Day 100 of pregnancy and lambing on either the birth weight or weaning weight of their progeny, due either to inadequate numbers of records, that ewe lambs in most data sets were managed in common during pregnancy and/or a lack of liveweight data especially during late pregnancy and pre-lambing. Suitable data was available from multiple research projects using NZ Romneys, and given the birth weight and weaning weight responses are similar across breeds in adult ewes, it is reasonable to expect that this will apply in ewe lambs and hence the Romney coefficients reported below will be adopted in the MIDAS modelling.

Increasing liveweight of Romney ewe lambs during pregnancy increased the birth weights and or weaning weight of their single and twin born progeny. A 10 kg gain in liveweight between Day 90 of pregnancy and lambing increased the birth weights of their progeny by about 0.6 kg (Fig. 9a), but increasing liveweight between joining and Day 90 of pregnancy had no significant effect on birth weights. A 10 kg gain in live weight between joining and Day 90 of pregnancy or between Day 90 of pregnancy and lambing increased the weaning weight of their progeny by 0.8 kg and 3.2 kg respectively (Fig. 9b). The effects of live weight gain in the different periods was additive.

(a) (b)

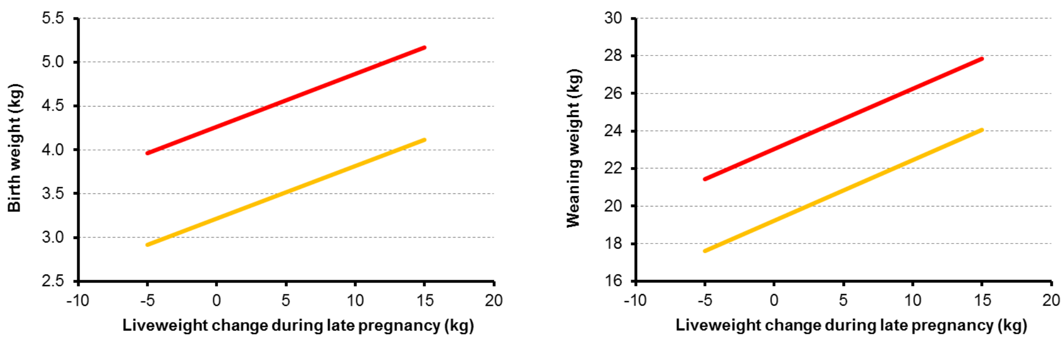

Figure 9. Effect of liveweight change between Day 90 of pregnancy and lambing on the birth weight (a) and weaning weight (b) of single and twin born progeny from Romney ewe lambs mated at 7-9 months of age. Data from 10 experiments in New Zealand (Kenyon, Paganoni and Thompson, unpubl. data).

3.2.5 Relationship between birth weight and survival for lambs born to ewe lambs

The birth weight of lambs born to Merino, Maternal composite and Romney ewes mated at 7 to 9 months of ages was significantly related to their survival, which is similar to the case in adult ewes (Fig. 10). The optimum birth-weight for maximum lamb survival was between 4.5 and 6.0 kg for single and twin born lambs, but varies between ewe-type. The average birth weight for single and twin born lambs from Merino ewe lamb was 4.7 and 3.9 kg, and for single, twin and triple born lambs from Maternal Composite ewes was 5.0. 4.2 and 3.6 kg. The average birth weight for single and twin born lambs from Romney ewes was 4.3 and 3.3 kg (data not shown), and this data set suggested an increased risk of dystocia and mortality in heavy birth weight lambs. The variability in lamb survival responses to birth weight will be best handled in the MIDAS modelling by a sensitivity analysis.

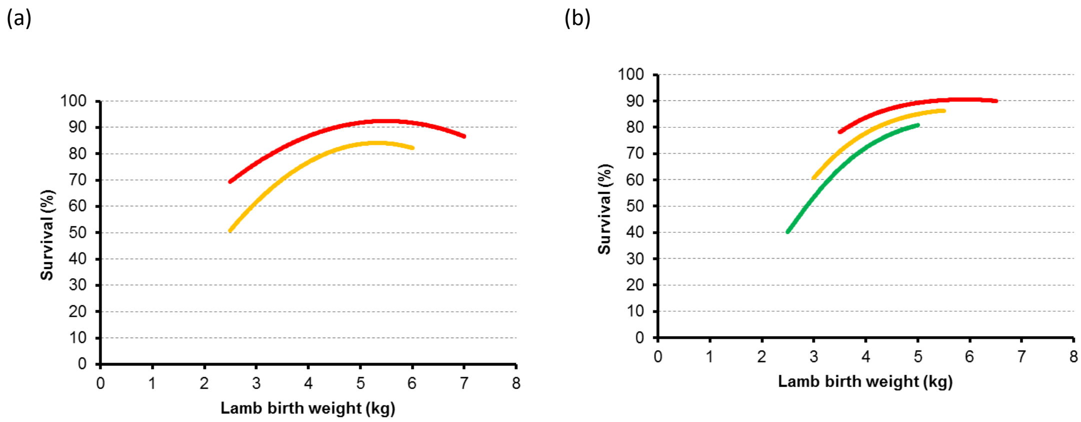

Figure 10. Effect of birth weight on the survival to weaning of single (red), twin (orange) and triple (green) born lambs from Merino (a) and Maternal composite (b) ewes mated at 7 to 9 months of age. Data from Maternal Efficiency Flock in WA and from Cashmore/Oaklea (Thompson and Paganoni, unpubl. data).

Furthermore, the effects of ewe liveweight profile on survival of progeny from ewe lambs appears to be up to 50% larger than those attributed to changes in birth weight alone, so higher survival of progeny from well grown ewe lambs more than likely reflects that they have less lambing issues and their better mothering ability. For example, for Maternal Composites an extra 1 kg in liveweight at joining between 35 and 45 kg improved lamb survival within birth types and overall weaning rate by 4.2%, whereas the increase in weaning rate predicted from the changes in birth weight alone were only 2.7% per kg. This effect on progeny survival over and above the impacts of birth weight is still being explored. In a farmer survey in New Zealand lamb survival increased by about 3% per kg gain in liveweight of ewe lambs during pregnancy.

3.2.6 Relationship between $CS_{lambing}$ and mortality of the ewe lamb

There is limited data on mortality of ewe lambs during late pregnancy and lambing. Data from the Maternal Efficiency Flock in WA indicated that the average mortality of Merino ewe lambs over 5 years was 4.3%. About two-thirds of these deaths were attributed to dystocia and one-third to prolapse, and whilst caution is needed due to low numbers of deaths, there was no apparent effect of condition score in late pregnancy on likelihood of death as most ewes were in excess of CS 3 at lambing. A farmer survey in New Zealand indicated that 7% of ewe lambs required assistance during lambing, but in that study there was no direct comparison to the levels of lambing assistance required in adults. Work in NZ is currently quantifying the relationships between condition score at lambing and the mortality of ewe lambs (Paul Kenyon, pers. comm), however, in the meantime this lack of robust data on mortality of young ewes will be best handled in the MIDAS modelling by a sensitivity analysis.

3.2.7 Impact of joining as ewe lambs on the subsequent reproductive performance

Liveweight at the start of joining is also a determinant of the reproductive success of Merino and Maternal Composite ewes mated a second time at 19-20 months of age. The average NLB response of hogget ewes varied between flocks and between years from 0.7 to 2.3%, and if anything maybe less than the typical response observed in adult ewes of 2.0% extra foetuses scanned per kg per 100 ewes joined. Interestingly, these relationship were linear unlike the responses for Maternal Composite ewe lambs which were curvilinear. Further work is need to quantify these relationship across a wider range of Merino and Maternal ewe types, including quantifying the effects of liveweight at hogget joining on their subsequent reproductive performance. At the same liveweight at their hogget joining, there was no significant difference in the reproductive rate or weaning rate of Merino or Maternal Composite ewes that were born as a single, twin or triple.

Birth type as a ewe lamb influenced the subsequent reproductive performance of Maternal Composites at hogget age. At the same liveweight at hogget joining, Maternal composite ewes that had twin or triple lambs as ewes lambs had a significantly higher reproductive rate and weaning rate than those which had a single lamb or were dry when mated at 7-9 months of age (Fig. 11). The difference in reproductive rate and weaning rate between each of these cohorts was 10-12% across the range in liveweights at joining. These effects of ewe lambs performance on subsequent reproductive performance were not evident in the Merino, but this may reflect inadequate data rather than genuine differences in biology between ewe types.

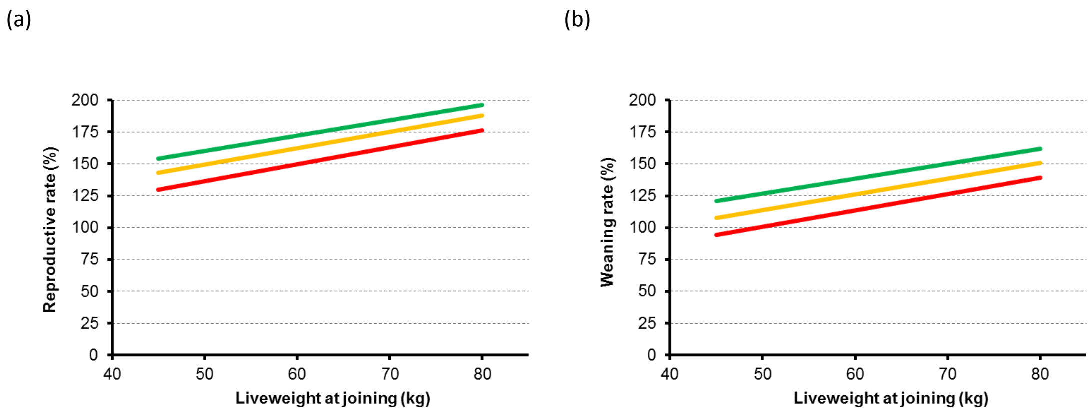

Figure 11. Effect of liveweight at joining at 19-20 months of age on the reproductive rete (a) and weaning rate (b) of hogget ewes that were dry (black), or had a single (red), twin (orange) or triple (green) lamb when joined as a ewe lamb. Data from Cashmore/Oaklea (Thompson, unpubl. data).

3.2.8 Lifetime productivity of lambs born to ewe lambs

Lambs from Merino or Maternal Composite ewes joined at 7 to 9 months of age were 3 to 4 kg lighter at weaning than those from hogget and adult ewes. As ewe lambs were often joined later and their lambs weaned younger, this comparison is difficult but, nevertheless, is it reasonable to expect that progeny from ewe lambs will grow slower. For the purposes of the MIDAS modelling, it will be assumed that lambs from ewe lambs growth 30-40 g/day slower than those from older ewes.

As expected, progeny from ewe lambs produced 0.2 to 0.4 kg less wool than those from older ewes. The effects of dam age on the fibre diameter of wool produced by Merino progeny was unexpected, in that nutritional penalties *in utero* would be expected to increase fibre diameter of wool produced but instead progeny from ewe lambs produced significantly finer wool at both hogget and adult age. As twin born lambs produced broader wool than single lambs at both hogget (18.1 *vs* 17.9 um) and adult age (18.4 *vs* 18.2 um), as expected, there is reason to believe that whilst the effects of dam age were not expected they are probably real. In any case, the impacts on the outcomes from the MIDAS modelling will be minimal due to absence of premiums for finer wool.

Merino and Maternal Composite ewe lambs that were born to ewe lambs had a lower reproductive performance themselves than those from adult ewes when bred as a ewe lamb (Table 2). Whilst this was partly due to the ewe lambs born to ewe lambs being lighter at joining at 7 to 9 months of age, the effects of dam age were still significant when live weight at joining was included in the statistical model. The poorer performance of ewe lambs born to ewe lambs versus older ewes at their ewe lamb breeding probably also reflects difference in age, as those from ewes lambs would often be one month younger. This indicates progeny born to ewe lambs may be less suitable to be bred at a young age. There were no significant effects of dam age on reproductive potential of their progeny at their hogget or adult joining's in either Merino of Maternal Composites when adjusted for differences in live weight at joining.

Table 2. Productivity of lambs born from ewe lambs compared to hogget and adult ewes. The effects of dam age on weaning rates do not include adjustments for live weight at joining.

	Dam age			Significance
	Ewe lambs	Hogget ewes	Adult ewes	of dam age
	Merino ewes			
Weaning weight (kg)	21.1[a]	25.2[b]	26.3[c]	P<0.001
Growth rate to weaning (g/day)	200[a]	235[b]	234[b]	P<0.001
Hogget greasy fleece weight (kg)	2.88[a]	3.37[b]	3.57[c]	P<0.001
Adult greasy fleece weight (kg)	3.96[a]	4.34[b]	4.40[b]	P<0.001
Hogget Fibre diameter (um)	17.8	18.0	18.1	n.s.
Adult fibre diameter (um)	17.8[a]	18.4[b]	18.6[b]	P<0.001
Weaning rate (%)				
- Ewe lamb	32.5	33.3	44.6	P<0.05
- Hogget	100.0	99.2	100.0	n.s.
- 3 year old	109.9	109.7	119.5	n.s.
- 4 year old	102.4	118.1	111.5	n.s.
- Average over 4 years	86.2	90.1	94.0	-
	Maternal ewes			
Weaning weight (kg)	28.0[a]	31.1[b]	32.2[c]	P<0.001
Growth rate to weaning	-	-	-	-
Hogget greasy fleece weight (kg)	2.31[a]	2.53[b]	2.60[c]	P<0.001
Adult greasy fleece weight (kg)	-	-	-	-
Reproductive rate (%)				
- Ewe lamb	23.1	57.0	61.3	P<0.001
- Hogget	106.7	119.8	113.2	P<0.05
- 3 year old	135.9	128.3	131.0	n.s.
- 4 year old	146.0	151.1	147.7	n.s.
- Average over 4 years	102.8	112.0	113.2	-

4 Whole-farm bio-economic modelling

4.1 Methodology

The analysis was carried out with the MIDAS suite of whole farm optimisation models (Young *et al.* 2011). Two regional versions were used and different combinations of times of lambing and genotypes were evaluated in each region (Table 3).

Table 3. Regional models used and breed and time of lambing evaluated in each region.

Region	Breed	Time of Lambing
South West Victoria	Merino	August
	Maternal	July
Great Southern WA	Merino	July
	Merino	May

The economic analysis was to address a number of strategic questions and generate information for the decision support tool.

1. In which scenarios is it profitable to mate ewe lambs? The scenarios examined were to include:
    a. Genotypes - Merinos and Maternals
    b. Time of lambing
    c. Different regions
    d. Meat, wool and grain prices

2. What is the optimum management of ewe lambs if they are to be mated?
    a. Growth path weaning to yearling joining
    b. Nutrition during pregnancy
    c. Fate of ewes lambs scanned as dry
    d. Growth path after the progeny are weaned through to the two year old joining.

3. What proportion of the weaners should be targeted for joining at 7 to 9 months of age?

4.1.1 Prices

Standard prices for meat, wool and grain were used in the analysis and sensitivity analysis was conducted on the prices to determine the impact of variation (Table 4).

Table 4. Standard prices used in the analysis and the ranges examined in the sensitivity analysis.

Commodity	Unit	Standard price	Sensitivity Levels
Meat Prices			+/- 20%, 40%
Finished lamb	$/kg DW	5	
CFA Ewe 5.5yo	$/hd	85	
4.5yo		95	
Ewe hogget	$/hd	125	
Wether hogget	$/hd	105	
Wool price			+/- 20%, 60%
20µ	$/kg clean	12.50	
27µ	$/kg clean	9.50	
Supplementary feed price			+/- 20%, 40%

Lupins	$1t	300
Barley	$1t	250

4.1.2 Genotype and flock management

The Merino enterprise evaluated was based on a 'modern Merino' genotype with high weaning rates and a self-replacing flock with all ewes mated to Merino rams. Young surplus ewes and the wethers were sold as either store lambs at 5.5 months old, prime lambs at 7 month old or after shearing as a hogget (17.5 months old). Cast-for-age ewes were sold at either 5.5 or 6.5 years of age, depending on which was more profitable. See Table 5 for typical productivity levels for the Merino genotype. The Victorian Merino genotype has a slightly lower weaning rate and a heavier wool cut than the WA genotype. The Victorian genotype is based on productivity data from the top 20% in the Livestock Monitor farms project (Tocker *et al.* 2014) and the WA genotype is based on productivity data from the top 20% of the Icon Agriculture benchmarking database (Ritchie *pers. comm.*).

The Maternal enterprise evaluated was a Romney based composite genotype. It was a self-replacing flock with all ewes mated to composite rams. All wethers and the surplus ewes were sold as finished lambs and cast-for-age ewes were sold at 5.5 or 6.5 years of age, depending on which was more profitable. See Table 5 for typical productivity levels for the Maternal genotype. The genotype is based on productivity data from the top 20% in the Livestock Monitor farms project (Tocker *et al.* 2014).

Table 5. Typical productivity of adults (average of ewes 2-5yo) and progeny of adults for the genotypes represented in the analysis.

	Units	Merino WA	Merino Vic	Maternal Vic
Standard Reference Weight	(kg)	55	55	60
Adult ewe CFW	(kg)	3.2	3.5	2.8
Adult ewe FD	(μ)	20	18.0	27
Scanning rate	(%)	135	120	145
Lamb survival – Single	(%)	88	85	93
– Twin	(%)	60	55	75
Weaning rate	(%)	90	85	110
Weaning weight[1]	(kg)	26	25	28

[1] Weaning weight of adult's progeny if the ewes follow the standard nutrition profile.

The progeny from ewe lambs have a lower wool growth potential than progeny from adult ewes so the sale age of these progeny was optimised separately in the model. These animals could be sold as ewe lambs, ewe hoggets, 5.5 year old or 6.5 year old. This allows selling the ewe progeny from ewe lambs at a younger age if this is profitable.

Typical husbandry was carried out and the management calendar is outlined in Table 6. The difference in husbandry costs between the mated and non-mated ewe lambs is the cost of scanning for litter size. The young ewes were mated with 2.5% rams and rams were purchased for $750 per head and used for 3 years.

Table 6. Management calendar and husbandry costs ($/hd) for the flocks in each region.

	Great Southern		South West Victoria	
	Early	Late	Merino	Maternal
Calendar				
Rams in	29Nov	20Feb	26Mar	19Feb
Scanning (for litter size)	27Feb	21May	24Jun	20May
Lambing	28Apr-1Jun	30Jul-24Aug	23Aug-26Sep	19Jul-22Aug
Shearing & surplus sheep sales	30Oct	22Jan	25Feb	25Feb
Finished lambs sales	27Nov	12Mar	1Jun	15Apr
Husbandry cost ($/hd)				
Ewe	9.11	9.48	9.47	9.02
Mated yearling	9.96	10.42	10.04	9.94
Non-mated yearling	9.12	9.58	9.20	9.11
Wether Hogget	9.12	9.58	9.20	9.11
Lamb	7.66	7.87	7.87	7.49

The nutritional management of the adult ewes followed the updated LTEM guidelines for flocks that are scanning ewes for litter size. Twin bearing ewes were managed during pregnancy to lamb 3-4kg heavier than single bearing ewes. For the spring lambing flocks ewes had moderate weight loss in early pregnancy and gained weight in late pregnancy. In the autumn lambing flock the ewes maintained weight from joining to lambing. Dry ewes lost weight through pregnancy.

4.1.3 Analysis specific data

The following is a summary of the relationships as they have been implemented in this analysis. It should be noted that when this economic analysis was completed the relationships between liveweight at joining and reproductive rate and weaning rate for Maternal Composites was thought to be linear rather than curvilinear, and the analyses including age at joining had not been completed.

4.1.3.1 Reproductive rate

The reproductive rate of ewe lambs was linearly related to liveweight at joining and the following relationship (Equation 1) was developed. It is a similar form to the relationship for adults although the slope is greater than for adults being 4% per kg of liveweight for both Merinos and Maternals, compared with adults at 2%. The slope of the line is not affected by the birth type of the animal but reproductive rate at 45 kg was affected by genotype, the birth type/rear type of the animals (Table 7) and liveweight change during joining.

$RR = RR45 + Slope\ (LW_J - 45)$ ………. Equation 1, where RR45 is Reproductive rate achieved at 45 kg

Lambs born and reared as multiples had a higher reproductive rate at the same joining liveweight but they are lighter and the result is a similar reproductive rate. These effects are important when examining not joining (or not feeding) the lightest animals because the animals excluded will be biased towards the multiple born animals and the impact on reproductive rate will be less than expected. In this analysis if animals were selected for fattening or joining then the slope was reduced to 2%. Changes in the slope of the reproductive rate relationship have been measured on farm, but the source of the variation is not well understood. A sensitivity analysis has been done to examine if this variation alters the optimum liveweight at joining. The slope of the adult relationship was held at 2% during this sensitivity analysis on the ewe lamb slope.

RR45 is effected by:

1. Genotype (sire ASBV for NLW, PWT, PFAT, PEMD),
2. Nutrition during the joining period. If the yearlings are gaining weight during joining this increases RR45 by 20% for every 100 g/hd/d being gained during the joining period. The analysis of the Lifetimewool dataset did not show a similar effect for adults.
3. Age of the ewe lamb at joining. Later joining is likely to increase RR45 because more of the ewes will be sexually mature, however the effect was not quantified in the metanalysis and has not been included in this analysis.
4. Date of joining. Later joining's which coincide with the breeding season are likely to increase RR45.

The effect of liveweight gain during joining has been examined separately and the other factors have been covered by the sensitivity analysis carried out on RR45.

Table 7. Coefficients used that relate the reproductive rate of the flock to the liveweight at joining (LW_J). Note: RR45 is the reproductive rate if LW_J is 45kg and actual RR = RR45 + Slope * (LW – 45).

	Merino		Maternal		Sensitivity
	Retain drys	Sell drys	Retain drys	Sell drys	analysis range
RR 45	70	72.7	100	102.7	+/- 20% points.
Increase in RR45 for each 100g/d LWG during joining	20		20		-
Slope of relationship	4		4		2.5% to 4.5%
Slope if unknown BTRT	2		2		-

This analysis includes the option of selling the ewe lambs 'scanned dry' and this increases their reproductive rate in subsequent years. Based on the differences observed in the metanalysis, culling the dry ewe lambs will lift subsequent reproductive rate by 2.7% (Table 8).

Table 8. Derivation of improvement in subsequent weaning rate if dry yearling ewes are culled.

BT as a Yearling	Typical proportion (%)	Weaning rate at 2yo (%)
Dry	30	108
Single	50	113.5
Twin	18	125
Triplet	2	135.5
Overall with Drys retained		114.4
Overall with Drys culled		117.1
Increase from culling Drys		2.7

It is assumed that this increase of 2.7% in subsequent weaning rate is achieved whatever the proportion of dry ewe lambs that are culled, i.e. if there are 10% drys in the flock or 50% drys in the flock, the response in weaning rate is the same. This appears unrealistic because increased selection pressure would be expected to increase the response. However, insufficient data is available to calculate the response more precisely.

4.1.3.2 Proportion of dry, singles, twins and triplets at different reproduction rates

To calculate weaning percentage from scanning percentage and lamb survival requires estimating the proportion of ewes that are dry, single, twin and triplet bearing at different scanning percentages and this was done using the coefficients in Table 9.

Three adjustments were made to the predictions from the equations:

1. The proportion of single bearing ewes was calculated from the estimated proportions of dry, twin and triplets, rather than using the equation. This was to ensure that the proportion of ewes always added to 100%.
2. The proportion of triplet bearing ewes was constrained to a minimum of 0 (the estimated proportion was less than zero if scanning percentage was at or below 45%)
3. The proportion of dry ewes was constrained to a minimum of 4% (this was shown in the data and the constraint came into effect with scanning % above 165%)

Table 9. Multiple regression coefficients relating proportion of dry, single, twin and triplet bearing ewes to the scanning percentage.

	Dry	Single	Twin	Triplet
Constant	14.9831	-12.438	2.5274	-1.711
Scan %	-0.1631	1.214	-2.875×10^{-3}	0.0685
(Scan %)^2		-5.869×10^{-3}	2.216×10^{-3}	-8.74×10^{-4}
(Scan %)^3				4.105×10^{-6}
1 / Scan %	2588.2			

4.1.3.3 Birth weight and weaning weight

The coefficients used to calculate birth weight and weaning weight from ewe liveweight at joining, day 90 and lambing are provided in Table 10 and 11 and these are from the statistical analysis of the Cashmore/Oaklea data. When calculating birth weight and weaning weight, the resulting weight was scaled by the SRW of the animal (Merino 55 kg, Maternal 60 kg) relative to the Cashmore /Oaklea genotype (66 kg).

Table 10. C oefficients used to estimate birth weight of progeny from the liveweight profile of ewe lambs. The coeffients for adult progeny are also presented as a comparison. Source of coefficients for ewe lambs: Cashmore. Note: the coefficients have been scaled by the SRW of the target genotype relative to the source genotype (66 kg).

		Ewe lamb progeny		Adults progeny	
		Merino	Maternal	Merino	Maternal
Constant		2.88	3.15	3.67	3.70
LW	Joining	0.023	0.025	0.027	0.031
LWC	Join-90	0.023	0.025	0.033	0.031
	90-Lamb	0.102	0.108	0.045	0.047
Sex	Male	0	0	0	0.288
	Female	-0.21	-0.23	-0.192	0
BT	1	0	0	0	0
	2	-1.05	-1.11	-1.12	-1.41
	3	-1.56	-1.65		-2.63

Table 11. Coefficients used to estimate weaning weight of progeny from the liveweight profile of ewe lambs. The coeffients for adult progeny are also presented as a comparison. Source of coefficients for ewe lambs: Cashmore. Note: the coefficients have been scaled by the SRW of the target genotype relative to the source genotype (66 kg).

		Yearlings Progeny		Adults Progeny	
		Merino	Maternal	Merino	Maternal
Constant		18.5	19.6	11.8	21.8
LW	Joining	0.15	0.16	0.18	0.14
LWC	Join-90	0.05	0.05	0.24	0.18
	90-Lamb	0.12	0.13	0.19	0.07
	Lamb-Wean			0.08	
Sex	Male	0	0	0	1.0
	Female	-1.2	-1.3	0	0
BT.RT	11	0	0	0	0
	21	-1.4	-1.6	-1.7	-3.5
	22	-5.7	-6.1	-4.8	-8.2
	31	-2.1	-2.2		-7.9
	32	-7.5	-8.0		-11.6
	33	-11.5	-12.2		-14.1

Variation in birth weight is predominantly due to genotype and nutrition during pregnancy, and both of these are captured in the sensitivity analysis on lamb survival. Weaning weight is affected by genotype and by feed on offer during lactation. The variation due to these two effects is also captured in the sensitivity analysis on weaning weight.

4.1.3.4 Lamb survival

Single, twin and triplet lamb survival is estimated using a relationship with birth weight. The coefficients for the quadratic equations are in Table 12, and the equation is in the form specified in Equation 2.

Lamb survival = Constant + a (BW) + b(BW)^2 ………………. Equation 2

Other factors that affect lamb survival include genotypes, management (mob size at lambing) and environment (chill factor). These factors are captured in the sensitivity analysis on lamb survival that has been carried out, -25% and +50% mortality.

Table 12. Coefficients use to predict survival of progeny born to ewe lambs from birth weight (BW).

		Constant	BW (a)	BW^2 (b)
Merino	Single	-2.57	28.23	14.92
	Twin	-4.16	44.26	-33.70
Maternal	Single	-2.80	30.63	7.90
	Twin	-3.83	44.06	-39.31
	Triplet	-3.44	42.38	-44.35

4.1.3.5 Mortality of ewe lambs at lambing

Little data was collected on the impact of condition score or liveweight at lambing on the mortality of ewe lambs during lambing because most ewes were lambing at condition score 3 or above. However, some of the scenarios and nutrition profiles examined in this analysis involve low liveweight at joining and the mortality of the ewe lambs has been estimated using the relationship estimated in the Lifetime Wool project for adult ewes (Equation 3). The condition score of the pregnant ewe lambs was calculated from liveweight using Equation 4.

Adult Ewe mortality = $28.48 + 4.324\ CS_L + 47.79 / CS_L$ + Adjustment ……Equation 3; the adjustment was 0 Single, + 2.25 Multiple

Ewe lamb $CS_L = 3 + (LW_L - 0.75\ SRW) / 10$…………………………………………..Equation 4

The resulting relationship is in Fig. 12. Mortality of the ewe lamb is also likely to be impacted by the genotype and this has been captured in the sensitivity analysis.

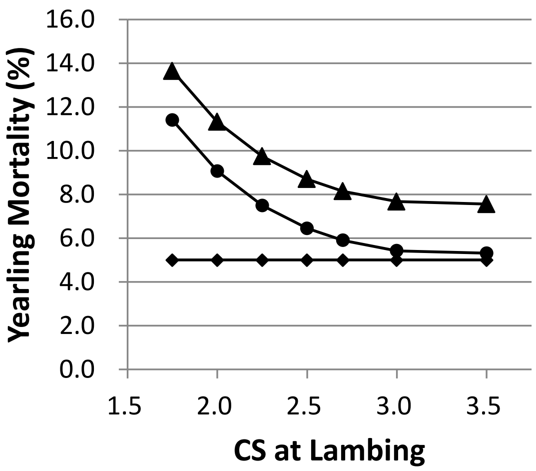

Figure 12. Mortality of dry (diamonds), single (circles) and twin (triangle) bearing ewe lambs and the impact of variation in the condition score (CS) at lambing.

4.1.3.6 Impact of joining as a ewe lamb on lifetime production of the ewe

It was assumed that mating the ewe to have a lamb as a yearling has no impact on her future productivity other than through the impact on her liveweight. If liveweight is similar, which depends on the feed offered in the post-weaning period through to the next joining, the reproduction at the 2 year old lambing will be similar, however, if the yearling ewes are not allowed to recover then reproduction at the 2 year old lambing will be lower. The importance of this impact has been quantified by the range of nutrition profiles examined for the period from weaning to the 2 year old joining. It is a common perception that the maiden joining has a poor result in terms of number of lambs weaned. There is a perception that this is due to the yearling ewe being inexperienced, and that therefore mating as a ewe lamb will increase experience and therefore improve the 2 year old reproduction result. However, there was no evidence from the Lifetime Wool project that the poorer 2 year old performance was due to anything except liveweight at joining.

4.1.3.7 Productivity of the progeny from ewe lambs

The progeny from ewe lambs grow more slowly to weaning, the growth rate is 30-40 g/hd/d slower than progeny from adults. Weaning weight of the progeny from ewe lambs is estimated from the coefficients presented in Table 11. It is assumed that this lower growth rate is the result of lower milk production from the ewe lambs so the milk yield and energy requirement for the ewe lamb lactation has been reduced by 15% compared to the adult milk yield. The progeny of ewe lambs cut less wool that is of a similar fibre diameter to progeny of adults. This was represented in the modelling as the progeny from ewe lambs having a 12% lower wool growth efficiency with a similar expected fibre diameter (at the lower CFW). The progeny of ewe lambs, compared with the progeny from adult ewes have reduced reproductive rate as ewe lambs. This reduction in reproduction may be due to the progeny of ewe lambs being younger because joining of the ewe lambs was delayed in some of the experiments. Due to this reduced productivity and the analytical complexity of representing animals of different ages, mating the progeny from ewe lambs as 7 to 9 months of age was not included in the analysis. However, the data suggests that at subsequent lambing opportunities the progeny of yearlings have the same weaning rate as progeny of adults.

4.1.4 Analysis

To calculate the profitability of mating ewe lambs, firstly the optimum nutrition profile was identified to ensure the profitability was reflecting well managed ewe lambs. The nutrition analysis evaluated a range of nutrition profiles for the young ewes through five periods. These were:

1. From when they were weaned through to when they were joined as a yearling
2. During the joining period
3. Early pregnancy
4. Late pregnancy
5. From lambing through to joining for their 2 year old lambing

In each period a number of nutrition options were evaluated (Table 13 and Fig. 13). The approach used was different to the liveweight profile approach used in the Lifetime Wool (Young *et al.* 2011) and Lifetime Maternals projects. Those projects evaluated specific ewe liveweight profiles whereas in this project different feed supplies in each period were evaluated. This allowed any feed supply profile to be followed by any other feed supply profile in the next period. This allowed more options to be examined without expanding the workload that would have been involved if this number of specific profiles had to be generated. The difference is that the results are not as readily presented as liveweight targets in the way they can be with a liveweight profile approach, i.e. the results are based on level of feeding rather than the rate of liveweight change.

Table 13. The different feed supply profiles in each of the periods and the MEI and LWC for animals that start at the weight they would have attained if they had followed the standard feed profile to that point, ie. the dark line in Figure 13. Note: LW is calculated for SRW = 55 kg.

	Start	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Weaning to yearling Joining								
LWC		30	85	110	**140**	170	200	225
LW	25	30	33	35.7	**38.5**	41.2	44	46.8
% of SRW		55	60	65	**70**	75	80	85
During Joining								
LWC		**0**	100	200				
LW	38.5	**38.5**	42	45.5				
% of SRW		**70**	75	82				
Early Pregnancy								
LWC		-55	**0**	55				
LW	38.5	34.5	**38.5**	42.5				
% of SRW		62	**70**	78				
Late Pregnancy								
LWC		0	**50**	100				
LW	38.5	38.5	**41.5**	44.5				
% of SRW		70	**75**	80				
Lambing to 2yo Joining								
LWC								
LW	41.5	41.5	44	**48**	52	55	58	61.5
% of SRW		75	80	**87.5**	95	100	105	110

.Note: the standard nutrition option is bold.

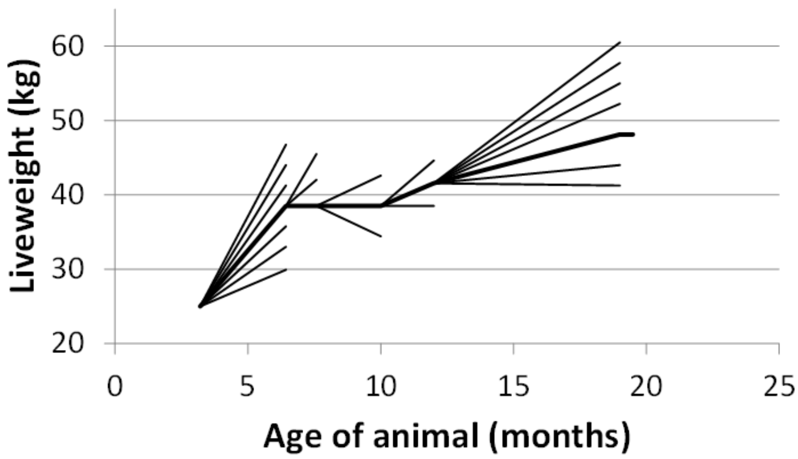

Figure 13. Nutrition options examined for the animals mated as yearlings. Note: each of the nutrition options was continued with the same feed supply options as for the standard profile. They are not presented so that the graph remains legible.

The identification of the optimum nutrition profile was carried out in two steps:

1. Nutrition from joining at 7 month through to joining at 19 months. This included three levels of nutrition in early pregnancy, three levels of nutrition in late pregnancy and five levels of nutrition in the recovery to the following joining. Combinations of these options were evaluated during pregnancy for the dry, single, twin and triplet bearing ewes with the constraint that the drys wouldn't be gaining more weight than the singles, the singles would not be gaining more weight than the twins and the triplets follow the same profile as the twins. All these profiles started at joining weight achieved from the predicted weaning weight

and the standard feed profile from weaning to joining. During the recovery, drys, singles, twins and triplets were managed together and were offered the same five levels of nutrition.

2. Nutrition from weaning to joining at 7 months of age. This included five levels of nutrition weaning to joining and three levels of nutrition during joining. Each combination was followed by the best nutrition option for the period from the 7 month old joining through to the 19 month old joining. This analysis was carried out for the predicted weaning weight with a sensitivity analysis on:

    a. +/-5kg and +/-10kg from the predicted weaning weight.
    b. Slope of the reproduction rate to liveweight at joining relationship
    c. Proportion of the ewes mated, and
    d. Meat price

The above two analyses quantified the importance of achieving the specified growth path from weaning to joining, through joining, during pregnancy and during the recovery phase post weaning. It also quantified the impact of starting at different weaning weights.

Having identified the optimum nutrition the other strategic questions were addressed by subjecting the system to sensitivity analyses to determine the change in profitability for a range of scenarios. The scenarios examined are noted below and the levels of the sensitivity analysis are either outlined below or in the previous table with the standard values.

a. Ewe lambs reproduction rate
b. Survival of progeny from ewe lambs (-20% and -40% mortality)
c. Ewe lamb mortality (-50% and +50% mortality)
d. The management of the dry ewe lamb – retained or sold as a prime lamb at scanning
e. Lifetime productivity of progeny from ewe lambs
    i. weaning weight
    ii. weaning rate and
    iii. clean fleece weight
f. Meat price
g. Wool price
h. Proportion of ewe weaners fed from weaning to joining (20, 40, 60, 80 and 100%)

4.2 Results and Discussion

4.2.1 The Base case farm

The farm with the early lambing flock in the Great Southern of WA has a profit of $150/ha, 48% of the farm is cropped and the stocking rate on the pasture area is 8.8 DSE/ha with 9,750 DSE carried. There is a high level of grain feeding (50 kg/DSE) which is required to maintain the ewes during pregnancy which is all occurring in summer/autumn on dry feed. It is a ewe dominant flock with 81% of the DSE being ewes with all young ewes retained to hogget age before a proportion are sold, and all wethers are sold as prime lamb. The weaning rate achieved is 93% which reflects the high joining condition that can be achieved because there is abundant green feed available post weaning.

The late lambing farm in the Great Southern has a higher profitability of $212/ha with 38% of the farm cropped and 15,500 DSE carried at 11.8 DSE/WG ha. The flock structure is 70% of the DSEs as ewes with wethers being retained for sale after shearing as a hogget. The reproduction rate is lower, reflecting lower joining weights due to a shorter period of green feed in the post weaning period. For example the maiden ewes are 14.6 kg lighter at joining than for the early lambing flock (Table 14).

The SW Victorian farms do not include a cropping option. The later lambing Merino flock is carrying a slightly higher stocking rate with a slightly lower level of supplementary feeding per DSE. Both flocks are ewe dominant, with the only non-reproducing animals not sold as lambs being the replacement ewe hoggets. The Merino flock is achieving a lambing percentage of 86% and the Maternal flock 107%.

Table 14. Profitability and optimum management for the base case farm (without mating ewe lambs). Note: Each farm has the optimum level of feeding for the ewe hoggets in the spring/summer prior to joining at 19 months old.

		Great Southern		South West Victoria	
		Early	Late	Merino	Maternal
Whole farm Profit	$/ha	150	212	538	426
	$/DSE	-[1]	-[1]	27.44	23.72
Farm Parameters					
Crop Area	%	48%	38%	-	-
Total Stock Numbers	DSE	9758	15553	19609	17971
	DSE/WG[2] ha	8.8	11.8	19.6	18.0
No. of ewes	Hd	4438	6516	10192	8445
No. of ewe hoggets	Hd	1240	1872	2308	1928
Pasture production	t/ha	5.4	7.6	9.8	10.0
Grain Feeding	T	484.8	147	387	371
	kg/DSE	49.7	9.5	19.8	20.7
Sale age of CFA ewes	Yrs	5.5	5.5	6.5	6.5
% of young ewes sold	%	18%	11%	29%	39%
Proportion of ewes	% of DSE	81%	70%	89%	89%
Weaning rate	%[3]	93%	79%	86%	107%
Lambs/ha	hd/WG ha	3.7	3.9	8.8	9.1
2yo Reproduction					
LW_{J2yo}	Kg	54.9	40.3	60.1	57.3
	% SRW	100%	73%	109%	96%
RR_{2yo}	%	145	116	140	145
WR_{2yo}	%	85	75	88	99

1. Whole farm profit per DSE is not a relevant measure on these farms because they include crop.
2. WG ha = winter grazed hectare
3. Lambs weaned per ewe mated

4.2.2. Profitability and optimum management if ewe lambs were not mated

If ewe lambs were not mated, the nutrition of the weaner through the period to the first joining at 19 months of age impacts profitability. The optimum management of the dry weaners is to grow at a slow rate over the first summer and break of the season, then to gain liveweight quickly during the spring in the lead up to joining at 19 months of age, with higher joining weight being more profitable in most scenarios. However, the increase in profit varies with the path followed to create the higher joining weight. The options to achieve higher joining weight are:

1. Higher weaning weight. Increasing weaning weight increases profitability in SW Victoria, but has little impact in the Great Southern of WA (Fig. 14). In South West Victoria the value of an extra kilogram of liveweight at weaning varies between $0.60 and $0.80/hd/kg. In the shorter growing season environment of the Great Southern of WA the value of the higher weaning weight is offset by the extra feed consumption of the larger weaner.

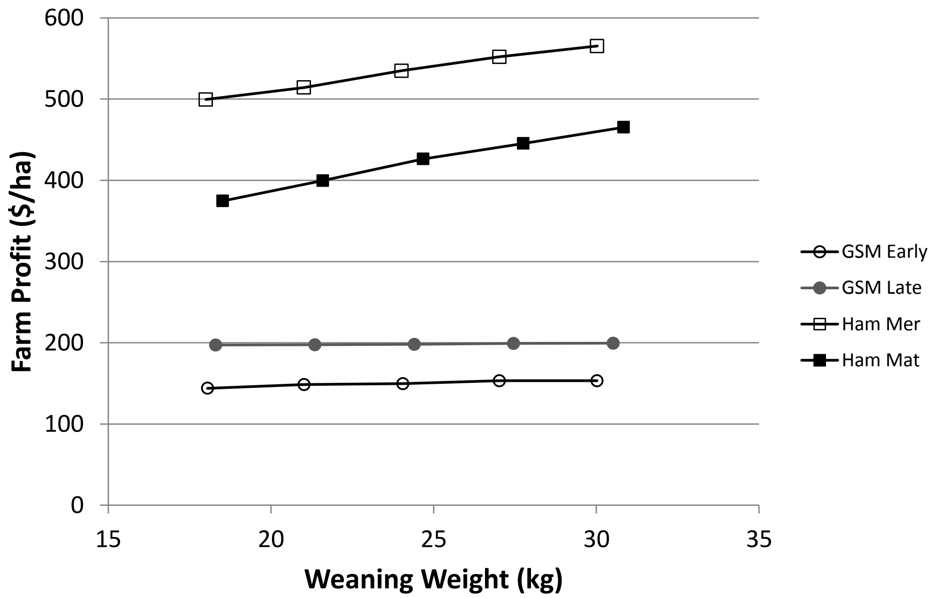

Figure 14. Impact of weaning weight on profitability if ewe lambs are not joined for each region, genotype and time of lambing. Note: the nutrition profile from weaning to joining at 19 months old is optimised for each weaning weight.

2. Extra feeding post weaning. Increasing liveweight at joining by feeding the weaner more during the first spring/summer reduces profitability in three of the four scenarios (Fig. 15). For these scenarios the cost of the feed is not recouped from the extra wool and higher liveweight at joining, and the animal has a higher maintenance requirement through the winter feed gap. The fourth scenario, Great Southern with May lambing, profitability is not affected or increases slightly. In this scenario, weaning is occurring during the spring flush so green feed is available to achieve liveweight gain at low cost. However, profit is not increased greatly by providing the extra feed to the weaners because the heavier weaners have a higher maintenance requirement during the following winter when feed is limited.

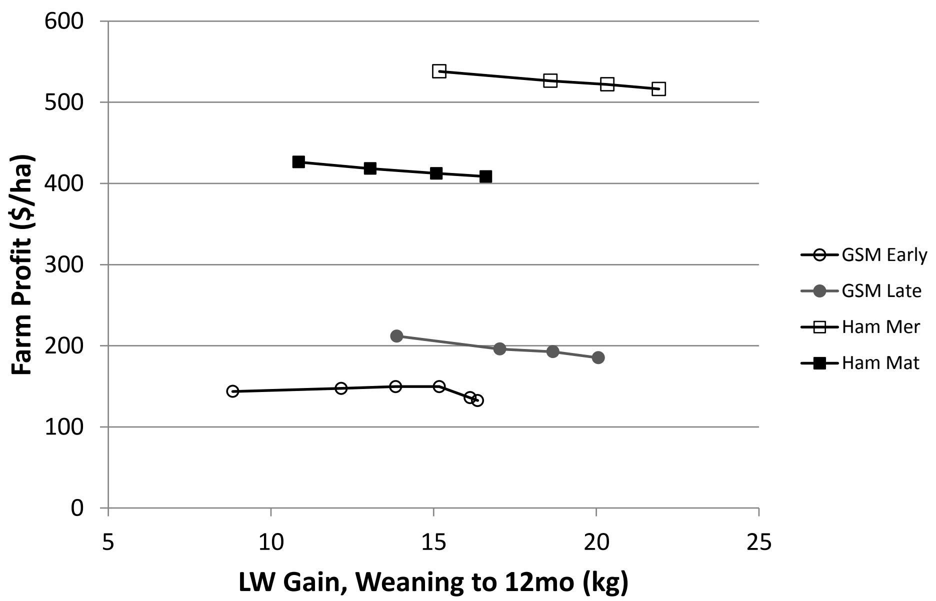

Figure 15. Impact of gaining more liveweight between weaning and 12 months old on profitability if ewe lambs are not joined for each region, genotype and time of lambing. Note: the nutrition profile from 12 months old to joining at 19 months old is optimised for each level of weight at 12 months old.

3. Feeding extra during the spring/summer in the lead up to joining. For South West Victoria and the May lambing in the Great Southern of WA profit increases by between $0.25 and $0.45 per kg up to a maximum at 90-100% of the SRW of the genotype (Fig. 16). This is much higher than is standard practice on farm for wool producers. With August lambing in the Great Southern profitability is reduced by $0.35 per kg if liveweight at joining is above 75% of SRW. The different result is because with late lambing in this short season environment weaning is occurring at the end of the spring flush and therefore weight gain has to be achieved predominantly with supplementary feeding and this is unprofitable.

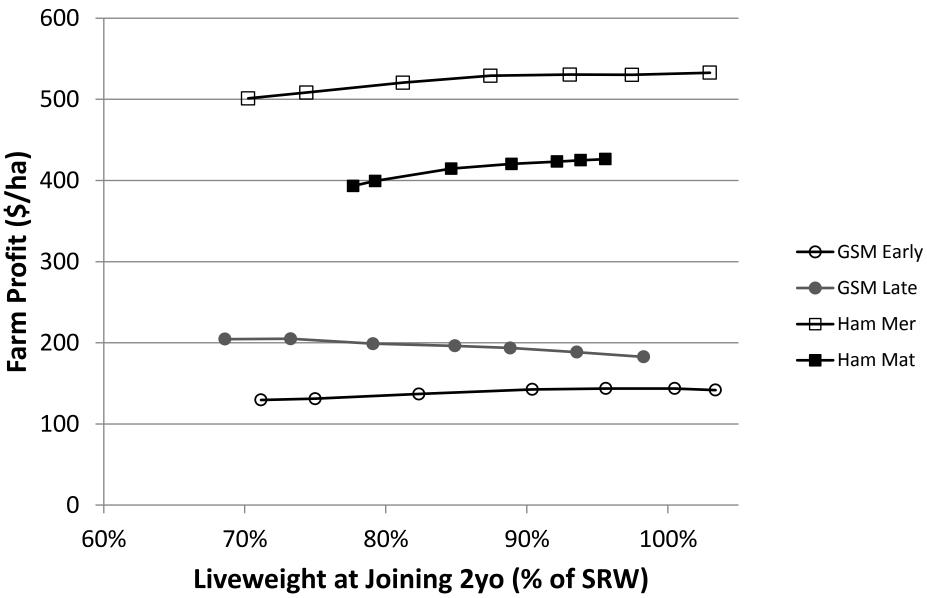

Figure 16. Impact of nutrition in spring/summer prior to joining (2 year old lambing) on profitability if ewe lambs are not joined for each region, genotype and time of lambing.

4.2.3. Profitability of mating ewe lambs if all ewe lambs are mated.

The profitability of mating ewe lambs was compared with the profitability of an unmated flock with the optimum nutrition from weaning to joining at 19 months old.

4.2.3.1. Standard assumptions

Mating ewes to have a lamb at yearling age was profitable for maternal producers in South West Victoria. Mating increased profit by $20.79 per ewe mated or $33.05 per ewe lambing. The typical farm was running about 2000 yearlings so the increase in profit from mating yearlings was $40,000/year for a Maternal producer (Table 15). Mating ewe lambs was less profitable for the Merino producers in South West Victoria and this is a combination of the Merino having a lower reproductive rate and the Merino lambing later. The benefit for the Merino producer if all ewe weaners are joined was less than $1/ewe lamb/year.

In the Great Southern of WA, with the later lambing time (July/Aug) profit was reduced by about $10 per ewe lamb if all the ewes were joined to lamb as yearlings. This compares with an increase of about $3/ewe lamb if lambing in May. When compared to the long season Victorian results this indicates that the shorter season reduces the profitability of mating ewe lambs unless lambing is occurring early in the season so there is green feed to grow the ewe prior to joining at 7 months of age.

Table 15. Profit and production levels achieved with optimum management for ewe lambs in each region, genotype and time of lambing scenario.

		Great Southern		South West Victoria	
		Early	Late	Merino	Maternal
Profit	$/ha	152	199	536	466
	$/DSE	32.44	30.86	26.48	26.32
Change due to mating	$/ha	2.73	-9.64	1.66	39.40
	$/yearling	3.17	-13.28	0.72	20.79
Farm Parameters					
Stock numbers	DSE	10000	13715	20258	18 400
	DSE/WG ha	9.0	11.3	20.3	18.4
Adult Ewes	hd	4133	5402	10137	8257
Ewe lambs	hd	1831	1546	2300	1895
Weaning rate	%	73%	68%	78%	98%
Lambs/ha	hd/WG ha	3.9	3.9	9.7	9.9
Production associated with ewe lambs					
Weaning weight[1]	kg	24.0	24.4	24.0	24.7
Liveweight at joining	kg	38.4	32.3	37.8	36.8
	% of SRW	70%	59%	69%	61%
LWG during joining	g/hd/d	0	200	200	100
Reproductive rate)	%	41.1	36.5	58.8	79.9
Birth weight Singles	kg	3.1	3.6	3.5	3.9
Twins	kg	2.7	2.7	2.6	2.9
Triplets	kg	2.2	2.2	2.1	2.4
Prog. survival Single	%	71.9	78.3	77.0	81.0
Twin	%	44.0	43.9	41.3	45.3
Triplet	%	30.5	30.3	27.4	22.0
Weaning rate)	%	26.2	24.9	38.0	52.7
Ewe lamb mortality	%	5.5	5.2	5.1	5.6
Ewe lamb supplement	kg/hd	13.9	53.0	20.8	12.0
2 year old reproduction					
Liveweight at joining	kg	57.0	43.5	62.2	59.5
	% SRW	104%	79%	113%	99%
Reproductive rate	%	149	122	144	149
Weaning rate	%	86	78	90	102

[1] Wean weight of the ewe lamb (not the progeny of the ewe lamb) - controlled by nutritional management of the adult ewes.

There was no detrimental effect on the lambing at 2 years of age if ewes lamb as yearlings. In each scenario it was profitable to feed the yearlings to join at the same or slightly heavier weights than if the ewes were not mated.

4.2.3.2. Sensitivity Analyses

Lambing environment and genotype

The profitability of joining young ewes increases with increasing weaning rate achieved (Fig. 17) provided the improvement is associated with genotype or lambing environment (as distinct from nutrition). The gains equate to an increase in profit of between $27 and $55 per extra lamb weaned from the ewe lambs (Table 16). Improving conception is more valuable in young ewes than mature ewes because the majority of the improvement for ewe lambs is converting dry ewes to single bearing ewes whereas for mature ewes it is converting single bearing to twin bearing. This is also the explanation for the lower value for increased conception for the maternal ewe lambs because they are scanning about 80% lambs in utero and this is the level at which the proportion of singles are reaching their maximum.

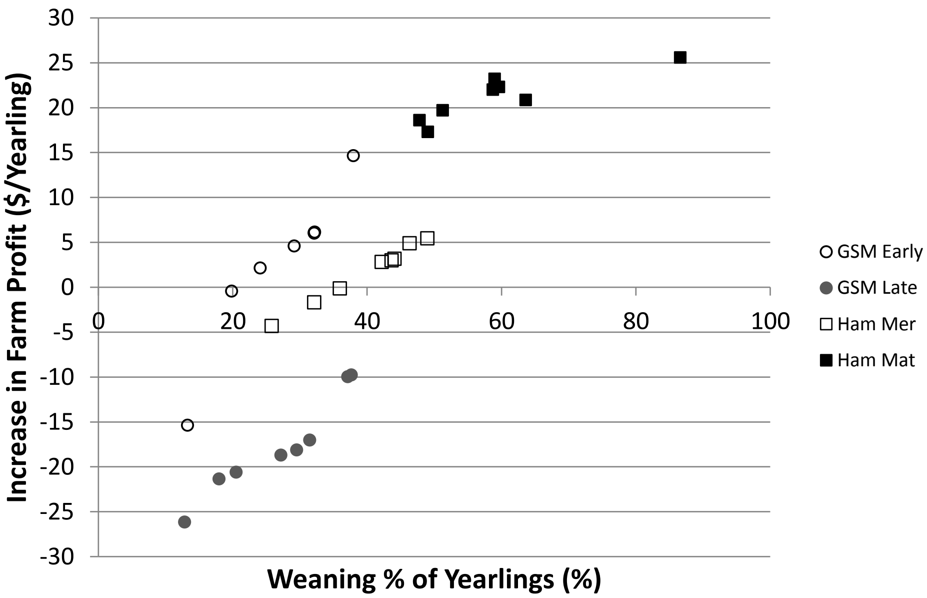

Figure 17. Increase in profit from mating ewe lambs and the impact of varying the weaning rate achieved. Note: the variation in weaning rate is due to altering RR45 or lamb survival. That is, it is from altering environmental conditions or genotype and not due to varying nutrition.

Table 16. Value of an extra lamb weaned from ewe lambs ($/lamb) if the extra lamb is achieved by increasing reproductive rate or increasing survival.

	Great Southern		South West Victoria	
	Early	Late	Merino	Maternal
Reproductive Rate	55	41	40	27
Survival	46	34	52	48

Weaning weight

Achieving higher weaning weights increases the profitability of mating ewe lambs in three of the four scenarios and this increase is over and above the increase profitability of higher weaning weights when yearlings are not mated. In the long growing season Victorian scenarios the increased weaning weight is worth between $0.60 and $0.90/kg/ewe lamb joined. In the shorter season WA scenarios, increasing weaning weight is less valuable and in the late lambing scenario increasing weaning weight reduces profitability.

In the Victorian Maternal scenario, in which lambing the yearlings is highly profitable these results demonstrate the importance of producers managing the adult ewes to achieve high weaning weights of the animals that will be joined. Weaning weight is controlled predominantly by FOO during lactation and is also impacted by the genotype and nutrition of the ewe during pregnancy.

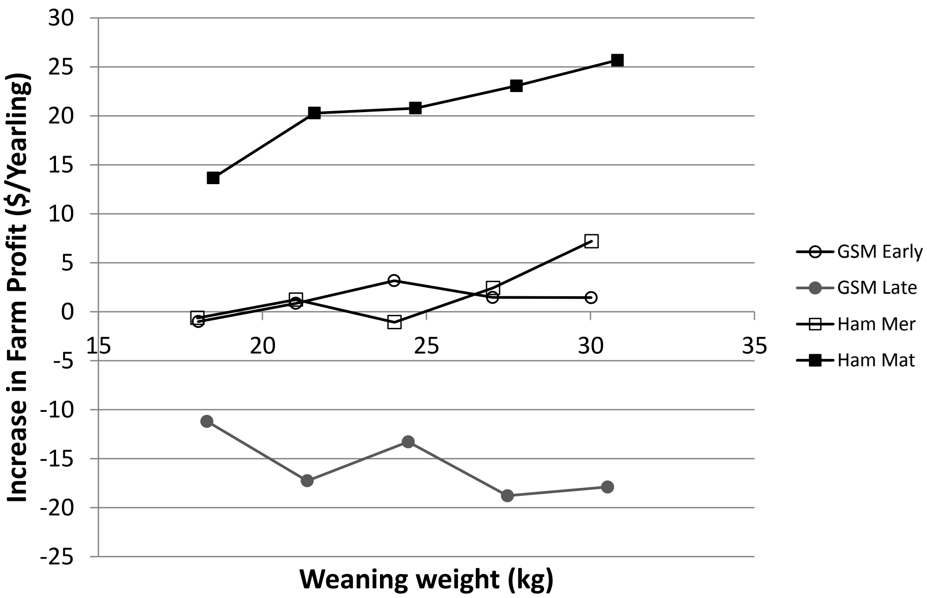

Figure 18. Change in profit from mating ewe lambs if different weaning weights are expected from that which is predicted from the nutrition profile of the (adult) ewes.

Lamb, wool and grain prices

The price scenario also alters the profitability of mating ewe lambs, with high meat prices, low wool prices and low grain prices increasing the profitability of joining ewe lambs (Table 17). For the maternal producer, it was profitable to mate ewe lambs in all the price scenarios examined. However, for the Merino producer the breakeven prices are very close to the standard prices used for the analysis.

Table 17. Profit increase ($/ha and $/ewe lamb) for different price scenarios from mating ewe lambs using the optimum nutrition profile and optimum management of the dry ewe lambs and the progeny.

		Great Southern				South West Victoria			
		Early		Late		Merino		Maternal	
		$/ha	($/ewe)	$/ha	($/ewe)	$/ha	($/ewe)	$/ha	($/ewe)
Standard Prices		2.7	(3.2)	-9.6	-(13.3)	-2.5	-(1.1)	39.4	(20.8)
Lamb price	$3/kg	0.0	(0.0)	-11.5	-(26.6)	-29.5	-(13.4)	18.6	(10.4)
	$4/kg	1.8	(3.3)	-7.8	-(13.9)	-18.4	-(7.2)	28.2	(14.4)
	$6/kg	13.0	(10.8)	-5.4	-(7.0)	10.0	(4.1)	60.5	(30.9)
	$7/kg	9.7	(8.0)	3.6	(4.4)	32.1	(13.1)	64.9	(33.0)
Wool price	-40%	3.6	(10.0)	-3.9	-(9.9)	19.1	(9.4)	44.2	(26.5)
	-20%	7.6	(10.5)	-3.6	-(7.4)	11.3	(5.1)	42.6	(24.3)
	+20%	1.3	(1.4)	-8.7	-(10.3)	-11.7	-(4.8)	35.6	(18.8)
	+40%	2.1	(2.0)	-3.5	-(3.5)	-21.6	-(9.1)	32.2	(15.1)
Grain price	-40%	4.1	(4.5)	1.0	(1.2)	13.5	(5.6)	48.8	(25.5)
	-20%	6.7	(8.0)	-4.3	-(5.4)	5.2	(2.2)	38.4	(20.2)
	+20%	1.4	(3.3)	-9.4	-(20.8)	-0.7	-(0.3)	39.5	(22.5)
	+40%	1.0	(2.7)	-5.1	-(14.4)	-8.9	-(4.0)	37.7	(20.4)

4.2.4. Optimum management if mating ewe lambs

4.2.4.1. Growth path from weaning to ewe lamb joining

The results indicate that there is an optimum level of feeding in the post weaning period rather than an optimum target for liveweight at joining, with the optimum joining liveweight varying with the weaning weight. The optimum level of nutrition is associated with a growth rate of the weaners of approximately 100 g/hd/d from weaning to joining but it is lower for the late lambing Great Southern scenario. Achieving higher post weaning growth rates increases the number of lambs conceived however beyond the optimum liveweight the cost of the extra grain is greater than the extra lambs conceived. Each kilogram of liveweight gain above a threshold requires about 8 to 10 kg of grain and the threshold is higher with earlier lambing or a longer growing season (Fig. 19). Gaining weight prior to joining has the greatest pay-off for the early lambing system in the Great Southern. This is because the weight can be gained on green feed prior to pasture senescence and therefore comes at low cost.

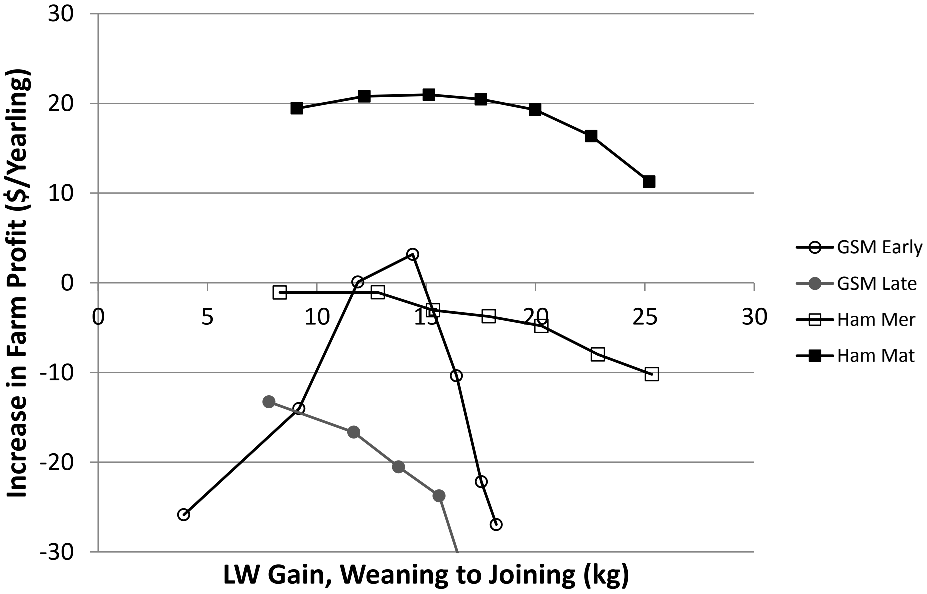

Figure 19. Difference in profit between joining at the different post weaning nutrition levels and not joining with optimum post weaning nutrition.

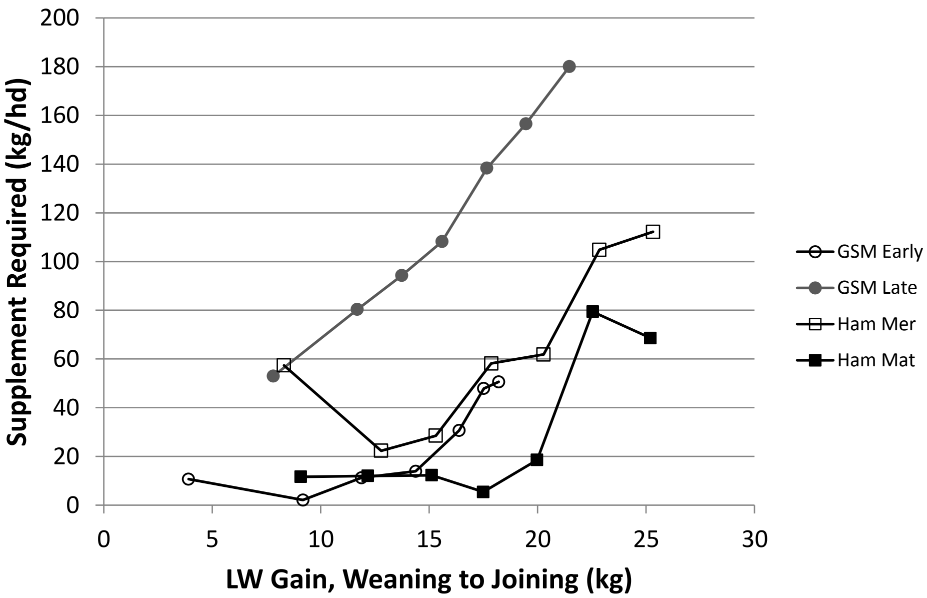

Figure 20. Impact of altering the post weaning nutrition on supplementary feeding required

4.2.4.2. Nutrition during ewe lamb joining

The optimum nutrition during joining varies for each scenario. The response in reproduction achieved by feeding during joining is more cost effective than feeding to gain weight prior to joining (unless that weight gain can be achieved on green feed). However, at $5/kg for lamb it is only a marginal response if the weight gain is achieved by grain feeding. The profitability of the response may be improved if grain feeding was targeted to the period when the majority of the ewes are conceiving.

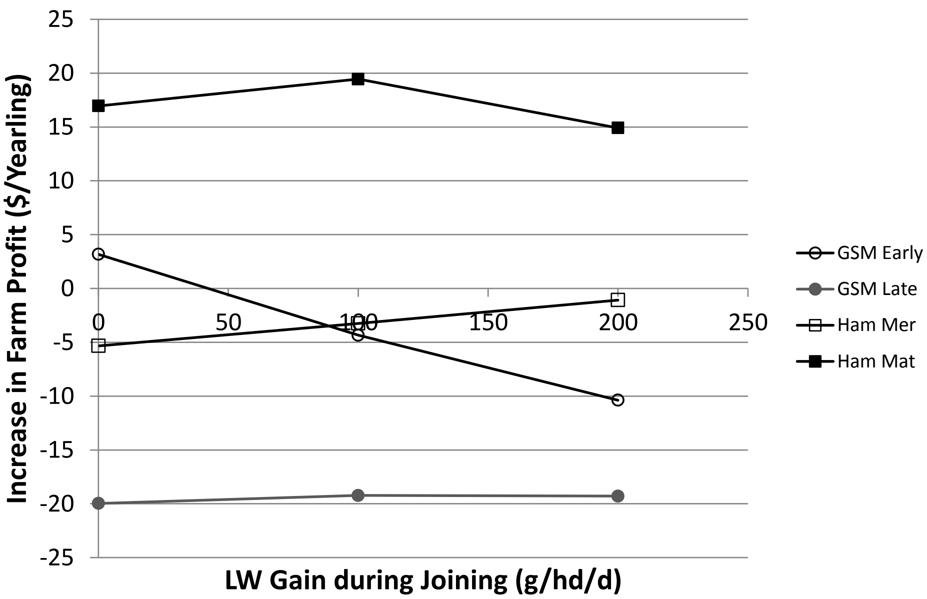

Figure 21. Impact of rate of liveweight gain during pregnancy on the increase in profit from mating ewe lambs.

4.2.4.3. Nutrition during pregnancy

The optimum nutrition profile during pregnancy for ewe lambs is similar to the recommended profile for adult ewes. The optimum profile was to allow the ewes that will lamb on green feed to have slow weight loss in early pregnancy and weight gain in late pregnancy to lamb above their joining weight. For the early lambing scenario without green feed the optimum is to maintain from joining to lambing. Similar to adult ewes, the twin bearing ewes are the most important and the cost of missing the target for the twins is $0.25-$3.65/kg compared to -$3.32 to $1.94/kg for single bearing ewes (Table 18 and 19). As for adult ewes the dry ewes can lose weight during pregnancy and having them gaining weight reduces profitability by $0.12-$3.10/kg.

Table 18. Example of calculation of variation in profit due to altering nutrition during pregnancy for a Merino wool producing flock in South West Victoria.

	Profit	Ewe lambs	Difference in profit	
	$/ha	Hd	$/ha	$/hd/kg
Optimum	532	2482		
Early pregnancy				
Reduce weight loss	529	2482	-2.70	-0.78
Late Pregnancy				
Increase dry nutrition	531	1701	-1.70	-0.20
Reduce single nutrition	527	648	-4.10	+1.94
Reduce Twin & Triplet nutrition	525	133	-1.6	+3.65

Table 19. Variation in profit due to nutrition during pregnancy ($/hd/kg) for each flock. Note: a positive number indicates that profit increases as liveweight increases, a negative number indicates that profit reduces as liveweight increases.

	Great Southern		South West Victoria	
	Early	Late	Merino	Maternal
Early pregnancy				
Reduce weight loss	-1.82	-0.28	-0.78	-0.12
Late Pregnancy				
Increase dry nutrition	-3.10	-2.75	-0.20	-0.55
Reduce single nutrition	-3.32	+1.06	+1.94	+1.42
Reduce Twin & Triplet nutrition	+.025	+1.60	+3.65	+2.08

4.2.4.4. Nutrition of the yearling from weaning to 2 year old Joining

The amount of weight gained by the yearling ewe in the period after their lamb is weaned through to the next joining has an impact on profitability (Fig. 22). Extra liveweight at joining increases the number of lambs weaned from 2 year old ewes and this increases income. In the long growing season environment and the early lambing scenario in the Great Southern there is green feed available for cheap weight gain. In the late lambing scenarios in the Great Southern the optimum joining weight for the 2 year old lambing is 75-80% of the SRW which is much lower than the other scenarios.

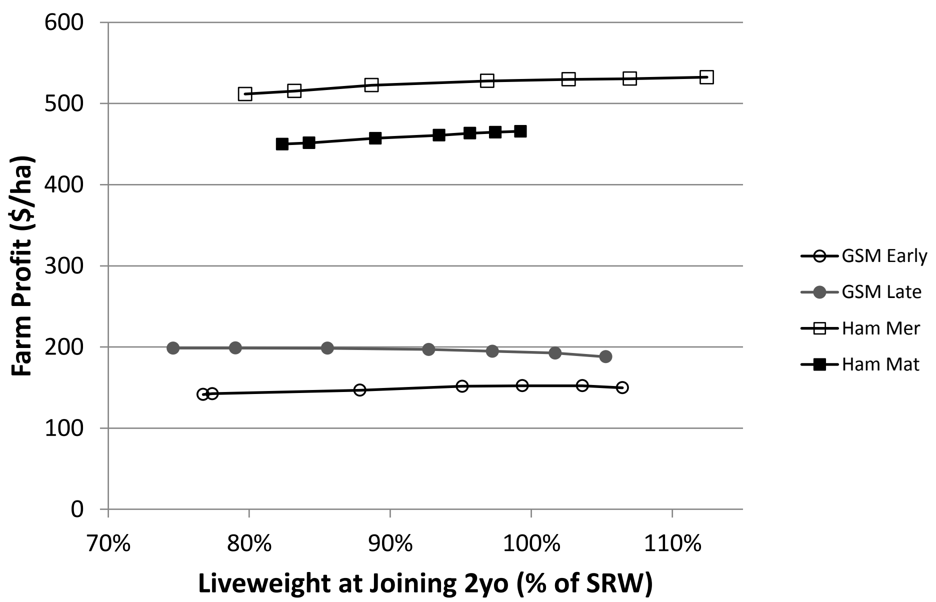

Figure 22. Impact of nutrition in spring/summer prior to joining (2 year old lambing) on profitability when ewe lambs are mated.

The optimum joining weight for the 2 year old lambing is higher when ewe lambs are joined and this is because the ewes are heavier at the start of the spring growth period. However, the increase in profit for the increase in weight is similar whether the ewe lambs are or are not mated.

4.2.4.5. Retaining or Selling Dry Yearlings

The optimum management of the dry ewe lambs in the Maternal flock in South West Victoria is for them to be sold at scanning and this is $9,300 more profitable (Table 20). Selling the dry ewe lambs at scanning is a way to achieve a return on the supplementary feed given to the animals that do not get pregnant and it is profitable provided that sufficient yearlings are retained to replace the flock. In the Merino scenarios it was more profitable to retain the dry ewe lambs and this is a reflection of the number of dry ewe lambs in these flocks.

Table 20. Optimum management for the ewe lambs and their progeny, and the impact on profitability ($).

Region	System	Dry ewe lambs Retain or Sell	Yearling's ewe progeny Propn sold young (%)	Adults's ewe progeny Propn sold young (%)
Great Southern	Early	Retain (7320)	100	26
	Late	Retain (9810)	100	20
SW Victoria	Merino	Retain (5360)	100	29
	Maternal	Sell (9300)	100	39

4.2.4.6. Management of the progeny from ewe lambs

The optimum management of the progeny of the ewe lambs is to sell all the progeny as finished prime lamb at 6 to 8 months of age or as hoggets after shearing, and retain a higher proportion of the adult's progeny as replacements. This management reflects the lifetime wool production penalty of progeny born to ewe lambs and is optimal even though the progeny from ewe lambs have a lower weaning weight and grow more slowly post weaning which makes them less valuable at sale. Selling the progeny from ewe lambs and retaining extra progeny of adult ewes would increase the genetic interval and reduce the rate of genetic gain, however, given the difference in productivity of the progeny from ewe lambs it is unlikely that that the improvement in genetic gain would compensate.

4.2.4.7. Proportion of the weaners to target to join as ewe lambs

Selecting the heaviest weaners to target for feeding and joining to have a lamb as a yearling increases the benefit achieved from mating younger ewes (Fig. 23). Targeting the heaviest weaners reduces the cost of feeding and increases the profit achieved per weaner by up to $50 per weaner if only 20% of weaners are mated. Although mating a small proportion of the weaners is best if measured by increase in profit per weaner, the total profitability is not maximised because of the trade-off with the number of weaners (Fig. 24). The optimum level to target is between 40% and 60% of the weaners.

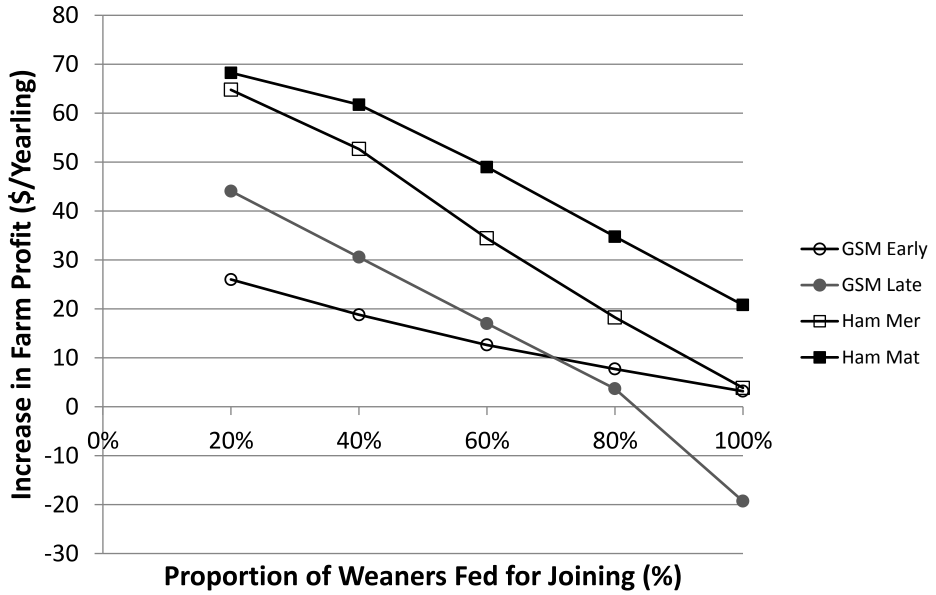

Figure 23. Increase in profit from mating ewe lambs expressed as increase in profit per ewe lamb mated.

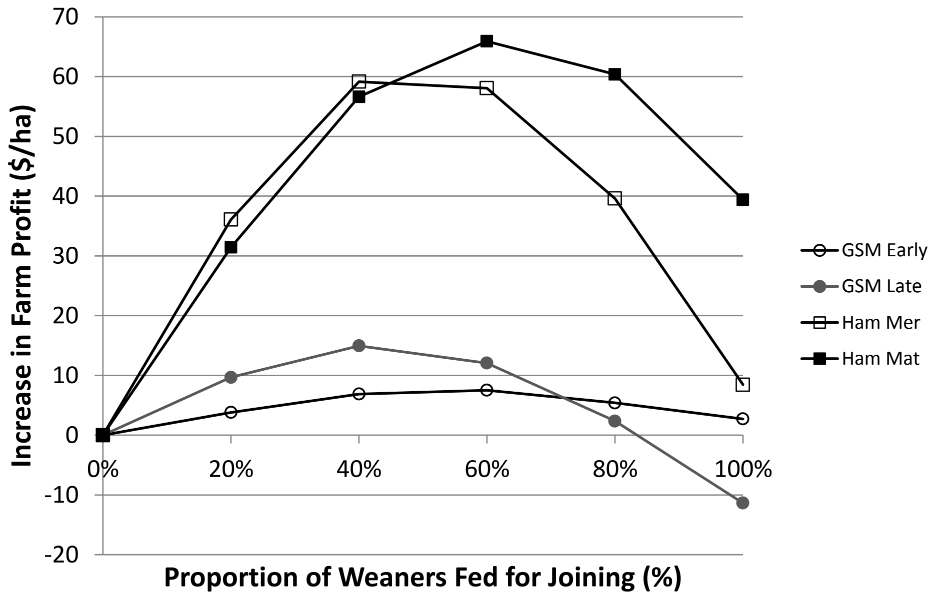

Figure 24. Increase in profit from mating ewe lambs expressed as increase in profit per hectare.

When the heaviest weaners are targeted all the flock scenarios examined are profitable. The increase in profit per hectare is much higher in the Victorian scenarios and the increase in profit per farm is between $60,000 and $70,000 per farm per year. The increase in less in the Great Southern scenarios and the increase in profit is between $20,000 and $30,000 per farm per year.

4.2.4.8. Cut-off weight for joining

Analysis was carried out varying the proportion of the ewes that were joined when all animals had been fed from weaning. The decision to join or not was made at rams-in and the heaviest animals were selected for mating. This provides a range of joining weights and these can be compared with the increase in profit per ewe lamb joined. Extrapolating the line to the x-axis provides an estimate of the liveweight at joining at which mating is breakeven (Fig. 25). An interpretation of this figure is that it is the cut-off below which it is not profitable to mate the ewe lamb. For the Maternal flock the cut-off is about 50% of the SRW and for the Merino flocks it is between 60% and 70% of the SRW.

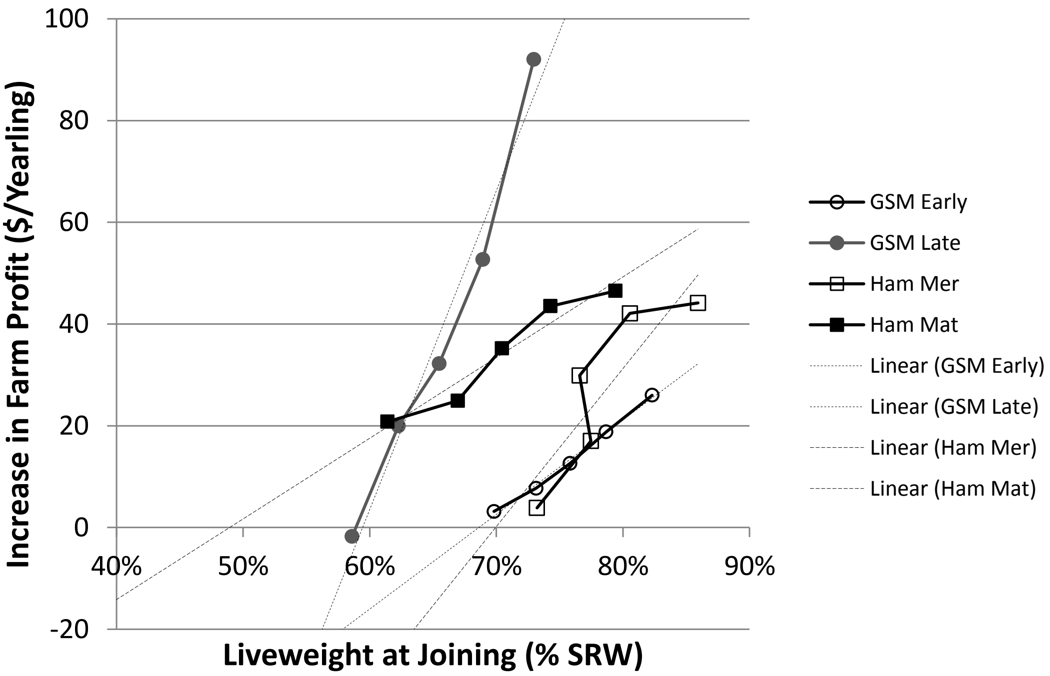

Figure 25. Increase in profit per yearling when the proportion of the yearlings joined is varied, which varies the average weight of those joined.

This analysis was carried out to provide information for the decision support tool and to determine whether the concept of a cut-off for joining was sensible. The concept appears sensible and will be followed up in the decision support tool.

4.2.5. Analysis challenges and shortcomings

There were several challenges and shortcoming associated with the current analysis and these limitations are being address in the current modelling within L.LSM.0007. The advantages of selecting the heavier weaners for feeding to be joined is likely to be understated in this analysis. The standard equations to predict intake include a factor for relative condition which is calculated as a function of current weight relative to the expected weight of the animal at that age. When the heaviest animals are selected for feeding the equations treat them as being higher 'relative condition' and this penalises intake. However, the selected animals are most likely bigger frame sheep and intake may actually be higher. A similar impact will also be occurring with the sensitivity analysis on weaning weight. The impact of this depends on the reasoning for the heavier weaning weight. If it is due to a faster growing genotype then the error will be active, however, it is due to improved feeding of the mother then the predictions might be correct.

The analysis of the proportion of ewe lambs joined was not well represented. There is likely to be an impact of selecting only the heaviest weaners to target for feeding on the variance of liveweight at joining and therefore affect the scope for selecting only the heaviest to mate. This impact was not accounted for. This is likely to overstate the profitability of selecting only a portion of the heavier ewe lambs to mate. Secondly, the accounting for the extra wool growth of the weaners that are targeted but not subsequently mated was not accounted for. This is likely to understate the value of selecting the heavier ewe lambs to mate. Thirdly, accounting for the energy intake of the animals that were targeted but not mated was poorly constructed and this would overestimate the profitability of mating a smaller proportion of the ewe lambs. Overall, this is likely to have overestimated the cut-off weight for joining the yearlings. Given the importance of the benefits of selecting only a proportion of the animals to target for mating, this highlights the importance of the assumptions about the increase in reproductive rate that will be achieved if the heavier animals are selected. The trade-off with selecting the heavier animals that hasn't been well handled is that selecting the heavier animals will bias toward single born animals and it is known that these ewes have a lower reproductive rate than multiple born animals. This is an area that needs further investigation and these limitations are being addressed in the modelling within L.LSM.0007.

This analysis was carried out representing both Merino and Maternal Composite ewe lambs. The Lifetime Maternals Project (B.LSM.0064) has demonstrated that our ability to model the mature age Maternal ewe is limited because of short comings in the prediction equations for energy requirement or intake capacity. The same equations are being utilised to in this analysis and therefore it is possible that the Maternal component of this analysis could be incorrect. The impact of the error will be to underestimate the profitability of joining maternal ewe lambs and underestimate the optimum liveweight at joining. The additional analysis in L.LSM.0007 will use refined intake and energy equations for Maternals derived from L.LSM.0008. This additional analysis will then inform the creation of a decision support tool to inform on-farm decision making regarding joining ewe lambs and their optimum management.

5. Conclusions and recommendations

Joining maternals to have their first lamb at yearling age was profitable in all the scenarios examined in the long growing season environment in SW Victoria. Extrapolating the results to a shorter growing season indicates that it will be profitable if lambing is occurring earlier than the normal spring merino lambing. This earlier lambing of the maternal flock is the most common production system so it indicates that mating maternals for a yearling lamb will have widespread applicability. These conclusions will be verified after additional modelling to address some shortcoming associated with the current analysis.

The profitability of mating Merinos is much lower and if all the young ewes are mated then there is insufficient profit to make it a practice that would warrant widespread extension. However, only mating a proportion of the younger ewes, selected at weaning as the heavier animals, increases the profitability of mating young Merino ewes. This practice reduces the cost of feeding the weaners to achieve a reasonable joining weight and selecting the heaviest 40-50% of the weaners to target for mating increases the profitability from breakeven up to achieving a profit of $20-$40 per ewe lamb joined. However, the trade-off is that there are fewer ewe lambs being mated.

A base set of skills are assumed that are necessary in order to implement the management that is implicit in this analysis. The results of this analysis are only relevant to that group of producers that are already:

- Monitoring ewe condition
- Managing ewes to LTEM guidelines and achieving the targets
- Scanning ewes and differentially managing twin bearing ewes
- The difference in weaning rate between the 2 year old lambing and adult ewes is less than 5%
- Managing a genotype in a system that is delivering greater than 100% weaning for adult ewes.

If any of the above aren't being done then concentrating on these areas first is likely to generate greater returns than mating ewes lambs. On-going work in project L.LSM.0007, which is an extension of the current project, will develop a Decision Support Tool (DST) to be used by consultants and farmers to address both strategic and tactical questions about mating ewe lambs for their particular situation. This will lead to improved decision making about in which situations lambs should be joined and the targets for post weaning growth rate and the proportion of ewe lambs to mate. The DST will be tested with producers and consultants to ensure it's usability and answers the questions they want to know. Key messages from this, and other projects relating to improving the reproductive performance of ewe lambs, will also be consolidated and provided in a format suitable for incorporation into extension products such as Bred Well Fed Well, and the MLA Tip and Tool relating to reproductive performance of ewe lambs will be updated.

6. Bibliography

Rosales Nieto CA, Ferguson MB, Macleay CA, Briegel JR, Wood DA, Martin GB, Thompson AN (2013) Ewe lambs with higher breeding values for growth achieve higher reproductive performance when mated at age 8 months. *Theriogenology* 80(5), 427-435. doi:10.1016/j.theriogenology.2013.05.004

Rosales Nieto CA, Ferguson MB, Macleay CA, Briegel JR, Martin GB, Thompson AN (2013) Selection for superior growth advances the onset of puberty and increases reproductive performance in ewe lambs. *Animal* 7, 990-997. doi:10.1017/S1751731113000074

Rosales Nieto CA, Ferguson MB, Thompson H, Macleay CA, Briegel JR, Martin GB, and Thompson AN (2015). Relationships between puberty and phenotypic values for muscle and fat in female sheep: role of liveweight gain during mating. *Reproduction in Domestic Animals* 50; 637-642.

Tocker et al (2014) Livestock Monitor Farms Project. Victorian Department of Primary Industries. Victoria.

Young JM, Thompson AN, Curnow M, Oldham CM (2011) Whole farm profit and the optimum maternal liveweight profile of Merino ewe flocks lambing in winter and spring are influenced by the effects of ewe nutrition on the progeny's survival and lifetime wool production. *Animal Production Science* 51, 821-833. doi:10.1071/AN10078