Final report

More lambs from ewe lambs through developing and extending best practice

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Abstract

Mating ewes to lamb at 12 to 15 months is an effective avenue to rapidly build maternal (including shedding breeds) and merino ewe numbers and increase lamb supply. This project aimed to build understanding to improve the performance of a cohort of ewes in the Australian flock that is currently both under utilised and underperforming, by investigating a set of research priorities established via consultation with advisors, producers and a detailed gap analysis process.

The findings of the research undertaken provide the basis for changing the current rules of engagement for mating ewe lambs in the Australian sheep industry. Currently a maximum of 34% of Australian producers mate ewe lambs with varying results. The industry focus has been to encourage the adoption of mating ewe lambs to lift lamb production, especially whilst the national flock has struggled to sustain itself or the turn-off of sheep meat demanded globally or both. However, the findings of this project clearly show that the attention to detail when mating ewe lambs must improve for the production, profit and welfare outcomes from ewe lambs to be improved simultaneously. Especially in the aspect of lamb survival from ewe lambs, where on-farm trial data collected in this project, shows that only two-thirds of the lambs conceived by ewe lambs make it alive to lamb marking. This wastage is compromising ewe lamb performance and is the primary limitation to yield (lamb marking) increases from this cohort of ewes. The key is employing much more stringent policies prior to mating ewe lambs, where it appears from the biological research undertaken that minimum joining weights of 45kg are required, along with at least 15kg of total pregnancy weight gain. Together this ensures the ewe lamb is adequately grown to bear a lamb of sufficient birth weight to survive and the ewe subsequently produces enough colostrum and milk to grow her progeny. This development of the ewe lamb and her progeny, coupled with smaller mob sizes at lambing has potential to profoundly increase the performance of Australian ewe lambs.

Executive summary

Background

Mating ewes to lamb at 12 to 15 months is an effective avenue to rapidly build maternal (including shedding breeds) and merino ewe numbers and increase lamb supply. However, the reproductive performance of ewe lambs is much lower than that achieved by mature ewes and highly variable. This variation in performance and lack of information on the financial ramifications of joining ewe lambs has contributed to relatively poor adoption, which is estimated to be 30% of Maternal and 5% of Merino sheep producers.

This National project aims to increase both the number of ewe lambs being mated and their reproductive performance by developing and validating a best practice guide with supportive tools to deliver reproductive success. This project findings will incorporate understanding from producer consultation and on-farm trials that quantify the full impacts of management and husbandry practices during their first two years of a ewe's life. This project will also incorporate and build upon previous research work, particularly liveweight targets for joining ewe lambs and recent economic modelling of optimum management systems for ewe lambs. A best-practice guide for producers, to improve the reproductive performance of their ewe lambs, covering joining, pregnancy and lambing management, will be developed.

Ultimately this project aims to improve performance of a cohort of ewes in the Australian flock that is currently both under utilised and underperforming, that can contribute substantially to addressing the challenge of sustaining breeding ewe numbers and increasing lamb supply.

Objectives

The following objectives were achieved:

- Identify the range in current industry recommendations and suggested best practice for mating ewe lambs to lamb at 12 to 15 months, from consultants, leading sheep advisors and producers, and the key barriers to adoption.
- Have compiled national baseline data from producers identified by working with pregnancy scanners on; (i) the current numbers of ewe lambs mated to lamb at 12 to 15 months, (ii) the reproductive rate achieved when mating ewe lambs, (iii) the mortality rates of mated ewe lambs and their lambs, and resultant marking rate.
- Have identified the suite of management practices that impact the reproductive performance of ewe lambs on commercial farms, in particular reducing the mortality rates of ewe lambs and their lambs, assess their apparent effectiveness and prioritised key gaps that require further validation on participatory research sites.
- Have tested the effectiveness of these practices at commercial scale, as single or multiple factor comparisons, on a network of participatory research sites across Australia, to provide new understanding on how to improve the improve the performance of ewe lambs and their lambs.
- Have quantified the carryover impacts of management of ewe lambs during their first pregnancy and lactation on their subsequent reproductive rate.
- Have completed economic modelling and cost benefit analysis to confirm the value of various management practices and the most economic pathways to improve ewe lamb reproductive success for Maternal and Merino enterprises.
- Have developed a standalone best practice guide and decision tools for reproductive success from ewe lambs, including impacts of critical success factors such as nutrition/weight profile, genetics/breed, timing, husbandry practices such as the use of melatonin in late-pregnancy and smaller mobs for lambing and economics.
- Published a peer reviewed journal publication on improving the number of live lambs born from ewe lambs, from research undertaken (to be available open access).

Methodology

- Market research with sheep consultants/advisors and producers to identify the range in current industry recommendations and practices for mating ewe lambs to lamb at 12 to 15 months, and the barriers to adoption,
- Baseline of the prevalence and performance of ewe lambs, and associated management practices among producers that mate ewe lambs to lamb at 12-15 months, and the barriers to adoption,
- Gap analysis - to prioritise the key gaps in understanding that require further investigation and/or validation,
- Participatory on-farm research and demonstration of best practice management of ewe lambs to determine the impact of management strategies identified as gaps in joining, pregnancy and lambing management, to improve the reproductive success of ewe lambs,
- Economic modelling and cost benefit analysis to determine optimum management systems for improving the reproductive performance of ewe lambs, and
- Develop a best practice guide and decision tools for improving the reproductive performance of ewe lambs.
- Draft, refine and publish a peer reviewed journal publication on improving the number of live lambs born from ewe lambs, from research undertaken.

Results/key findings

The project commenced with consultation with advisors and leading producers to identifying their research priorities, which include;

- impact of growth rate and flushing with green fed or lupins during joining on ewe lamb reproductive rate,
- pregnancy weight/condition score profile management and its impacts of ewe and lamb survival and lamb growth rates,
- impact of mob size at lambing on lamb survival from ewe lambs, and
- management guidelines for ewe lambs on their first lactation and recovery period to enhance subsequent reproduction rates.

Subsequently a national survey was conducted on Australian producers to baseline the performance, practices, attitudes and barriers to adoption of ewe lambs on commercial farms. From the survey of 500 producers, it was found that 23% of producers had joined ewe lambs in 2019. In addition, there were a further 10% of producers that join ewe lambs when conditions are suitable and another 1% of the producers who had never joined ewe lambs, intend to do it from now on. Hence, in a year with suitable conditions, the estimate of the maximum number of Australian sheep producers currently mating ewe lambs would be 34%.

Almost three quarters of the ewes joined by the producers interviewed were Merino, but two thirds of the ewe lambs joined were Maternal/Cross-bred/Meat breeds. Hence, joining ewe lambs is a lot more prevalent with Maternals, crossbreds, meat breeds and shedding sheep, than in Merinos.

The average lamb marking rate from ewe lambs was 76% marked to ewe lambs joined and the average ewe lamb mortality annually was 5.9%. The indicative estimate of overall lamb survival rates out of ewe lambs was 77% (76% lambs marked out of 98% overall scanning rate). However gathering accurate lamb survival data was compromised by the fact that only one-third of the producers that mate ewe lambs scanned for multiples, around one-quarter scan wet-dry only and 40% of producers who mate ewe lambs don't scan at all. Furthermore, only 71% of producers run ewe lambs separately from other age groups of ewes.

The barriers to mating ewe lambs were also documented. These include; ewe lambs not being big enough or mature enough to join successfully, it is not economically viable and/or not suitable in their region, they will have too many lambing difficulties, be poor mothers and there will be high losses of ewe lambs themselves. Also, the potential negative aspects associated with joining ewe lambs including the long-term impact on their reproductive performance and longevity, outweighed by limited benefits by mating them as ewe lambs to only achieve low lambing percentages.

In conjunction with the understanding from consultation with leading producers and sheep advisors and the national survey of 500 producers, a review of the literature was undertaken by Professor Paul Kenyon from Massey University, as a gap analysis on what's known and not known with breeding ewe lambs, to ultimately determine the highest research priorities for ewe lambs. The summary of the research priorities identified through this process are in Table 1 below.

Table 1. Research priorities for ewe lambs.

	Stage of ewe lamb reproduction cycle			
	Joining	**Pregnancy**	**Lambing**	**Lactation/recovery**
Research priority 1	Impact of growth rate during joining on reproductive rate	Impact of live-weight change in late pregnancy on lamb survival and lamb growth rate	Impact of mob size during lambing on the survival of lambs from ewe lambs	Impact of weaning age during first lactation on subsequent reproductive rate
Research priority 2	Impact of short-term flushing on lupins and/or Lucerne on reproductive rate	Impact of live-weight change in late pregnancy on ewe survival and subsequent reproductive rate	Examine the impact of ewe lamb joining weight on ewe and lamb survival rates	Examine the impact of ewe lamb joining weight on subsequent reproductive rate and longevity
Research priority 3	Identifying the relationship between live weight and BCS at joining and reproductive rate			
Research priority 4	Identifying relationship between percentage of mature weight at joining and reproductive rate			

Research priorities 1 and 2 are to be addressed by interventions/treatments imposed in this project during the relevant stages of the ewe lamb reproduction cycle. Whereas Research priority 3 will be addressed by connective analysis of data across numerous data sets that have recorded ewe lamb live-weight and condition score at joining and subsequent conception and reproductive rate. The priority of 'identifying the relationship between percentage of mature weight and reproductive performance' was beyond the scope/time-frame of this current project as waiting for the ewes to mature takes years- this has been detailed as future research opportunities to follow on from this project.

Key results from the experimental work undertaken in this project showed that;

- For Maternal ewe lambs the response to weight gain during joining, where increasing weight gain by 100 g/day, equates to around an 8% lift in reproductive rate ($p<0.001$),
- Flushing ewe lambs with Lupins, fed at a rate of 500g/day for 14 days, had no significant impact on their conception or reproductive rate ($p>0.05$) and the breed of the ewe lamb had no significant bearing on the response to flushing,
- The effect of the late-pregnancy growth treatment (+156 g/day between low and high growth) on lamb survival was around 8% ($P<0.001$) with low and high growth treatments having a lamb survival of 66.5% and 74.6%, respectively. The effect on ewe mortality was around 2% ($P<0.001$) with low and high growth treatments having ewe mortality rates of 3.58% and 1.46%, respectively. Both singles and twins had similar effect.
- For ewe lambs, their joining weight had a significant quadratic effect on the mortality of single and twin bearing ewes and their lambs, while liveweight change during pregnancy had a linear effect on the mortality of single and twin bearing ewes and their lambs ($P<0.001$, $P<0.05$, highest P given for any term fitted).
- Treatment of pregnant ewe lambs with Regulin (melatonin) post-pregnancy scanning, had no discernible influence on lamb survival ($P=0.974$) or ewe mortality ($P=0.530$) of either single or twin bearing ewe lambs,
- Mob size at lambing has a significant effect on lamb survival from both single and twin bearing ewe lambs but there was no effect of breed (Merinos, Maternals or Shedders), which is consistent with research done on adult ewes. For single bearing ewe lambs, every 100 less ewes in the mob at lambing, lamb survival increases by around 3.9%, while for twin bearing ewe lambs, lamb survival improved by around 6.3% per 100 less ewes at lambing,
- Significantly more ewe lambs have lambing difficulties at lighter joining weights than ewe lambs with heavier joining weights ($P=0.014$),
- Lambing difficulties have direct consequences on lamb survival, with a much greater proportion (10-fold increase) of the ewe lambs that have lambed and lost experiencing lambing difficulties than ewes that have reared a lamb(s),
- There were significant curvilinear relationships between liveweight ($p < 0.001$) or condition score ($p < 0.001$) prior to breeding and reproductive rate for both Merino and non-Merino ewe lambs. It was concluded that liveweight is a more effective method than condition score for selecting ewe lambs for breeding,

- The relationship between hogget joining weight and hogget reproductive rate appears to differ, in that for Maternals it's a quadratic relationship, whereas for Merinos its linear, where for every 1 kilogram of Merino hogget joining weight, reproductive rate increases by 1.84% ($p<0.001$). For Maternals between 45 and 65 kg at hogget joining every 1 kilogram of Maternal hogget joining weight, increases reproductive rate increases by almost 2%, whereas between 65 and 85 kg at hogget joining every 1 kilogram of Maternal hogget joining weight, increases reproductive rate increases by less than 1%.
- Examination of the impact of parity as a ewe lamb on reproductive rate on the subsequent hogget joining, shows that for Maternals, conceiving twins as a ewe lamb results in about a 14-17% increase in reproductive rate as a hogget over and above single bearing or dry ewe lambs, whereas for Merinos, conceiving twins as a ewe lamb, results in about a 9% increase in reproductive rate as a hogget over and above single bearing and dry ewe lambs.

The benefit-cost analysis of management strategies when mating ewe lambs revealed that;

- Based on an increase in reproductive rate of 8% for a flock gaining an extra 100 g/hd/d for the duration of joining (35 days), it only pays to feed the extra grain to ewe lambs to drive this increase in weight during joining to increase reproductive rate and weaning rate, if the price of lamb was at least $9/kg and the cost of supplement was no greater than $200/t.
- A flock of ewe lambs that gain 100 g/hd/d for a 35-day period prior to the start of joining will be 3.5kg heavier at the start of joining, the predicted increase in reproduction rate averages 14% (at 4% per kg LW). This is 6% greater than the increase in reproduction rate predicted for a flock that starts the joining period lighter but utilises the feed saved to gain 100 g/hd/d during joining. As such temporal reallocation of feed to boost the rate of liveweight gain during joining is not expected to improve flock profitability.
- Updated ewe mortality relationships discovered in this project predict high mortality for ewes that are mated at light weights and gain little weight during pregnancy. The increased mortality reduces the profitability of mating the lighter ewe lambs and the optimal management will be to implement a higher LW for joining and leave a greater proportion unmated. This is likely to be combined with increasing the nutrition of the ewe lambs during either pre-joining or pregnancy. To some extent the increased mortality predicted from joining light ewe lambs can be mitigated if the ewes gain weight during pregnancy. However, to compensate for being 5 kg lighter at joining requires gaining an extra 10 to 15kg during pregnancy, so this is only likely to be feasible for flocks that are lambing in spring rather in autumn or winter, so that there is sufficient green feed available for liveweight gain.
- Updated lamb survival relationships are – similar as for the ewe lamb dam mortality – much more sensitive to ewe LW at joining than the previous research. The increased sensitivity compared to the relationships measured in adults is up to 8 times the impact on survival for a given change in ewe liveweight at joining and 2 to 3 times the impact of LW change during pregnancy. The increased sensitivity increases the financial importance of achieving the target liveweight change during pregnancy and is also likely to increase the target LW gain during pregnancy.
- The most economic pathway to increasing reproductive success in ewe lambs is through focusing on improving lamb survival, indicating that emphasis should be placed on improved pregnancy nutrition prior to emphasising the benefits of better pre-joining nutrition.

- If is increasing LW at joining is achieved by feeding extra supplementary feed the increased cost of increasing LW at joining by 1kg is between $2.00 and $3.60/ewe. This cost is partly offset by the increased reproductive rate achieved by joining at a heavier weight. The net value of the supplement cost versus the extra lambs weaned due to the higher reproductive rate for the Merino ewe lambs is a cost of between $0 and $3/ewe lamb and for Maternals is between a cost of $2.50 and a benefit of $1/ewe lamb, with the range dependent on the price of grain and the lamb value.
- Increasing LW at joining is most valuable for ewes that are joined at lighter weights and have a lower growth expectation during pregnancy. The benefits of higher joining targets are greater for the portion of the flock that conceive twins because the twin bearing ewes are more sensitive for both ewe mortality and lamb survival than the singles, furthermore the benefit of the improved survival is achieved for 2 lambs, although each lamb is less valuable.
- For a flock in which 80% of the pregnant ewe lambs have conceived singles (approx. reproductive rate 110%) it will be profitable to feed grain to increase LW at joining if the expected LW of the ewes is less than 42kg, and to feed to reduce weight loss if less than 47kg. This indicates that the target for minimum LW at joining is 42kg and that the ewes joined in the range 42 to 47kg should be fed extra grain during pregnancy to increase pregnancy weight gain. This aligns with acceptable levels of reproductive success if the single bearing ewes are gaining at least 10kg during pregnancy and the twins are gaining at least 15kg.
- If increasing LW during pregnancy is achieved by feeding extra supplementary feed the increased cost of gaining extra weight during pregnancy by 1kg is between $1.75 and $3.20/ewe depending on the cost of supplementary feed.
- Increasing LW gain during pregnancy is most valuable for ewes that are joined at lighter weights and for twin-bearing ewes rather than single-bearing ewes. If ewes are joined at 40kg or less, then it will be profitable to feed grain to increase LW gain during pregnancy. If joining at 50kg or more then it is unlikely to be profitable to feed grain to increase LW gain. In the range 40 to 50kg then it will be profitable to feed the multiple bearing ewe lambs but not the single-bearing ewe lambs.
- Ewe lambs give a bigger return on subdivision and have smaller optimum mob size than adults. The optimum mob size for ewe lambs is approximately 50% of the optimum mob size for adults. Therefore, allocate the reproducing ewe lambs to the smaller paddocks.
- The optimum mob size for ewe lambs when using permanent fencing is between 40 and 60 head for twins and 80 to 125 head for singles, with he optimum mob size for Merinos is 10 to 20% larger than the corresponding mob size for maternal/shedding breeds.

Future extension and research opportunities

Future extension endeavours should target;

- Changing extension messages and producer mindset to adopt and focus on a minimum critical mating weight for ewe lambs, not a target weight, which has been misconstrued as a mob average by industry over recent years,
- Current knowledge, skills and confidence of producers to achieve satisfactory ewe and lamb survival outcomes out of ewe lambs is much lower than the knowledge, skills and confidence of producers to achieve satisfactory scanning rates,
- Changing the mindset of producers from focussing on pregnancy scanning rates as the measure of success when mating ewe lambs to focussing on improving ewe and lamb survival rates to lift weaning rates by adopting more proactive weight profile management from prior to joining through to lambing- where currently the weighing of ewe lambs throughout pregnancy to monitor growth rates and hit growth targets is almost non-existent,
- Changing producers' mindset and understanding that optimum mob size targets for single and twin bearing ewe lambs are 50% of that of adults due to being much more influenced by the need for privacy and the subsequent risks of miss-mothering when mob sizes are elevated,
- Prioritise investment in extension campaigns that extend best practice to improve lamb survival from ewe lambs as a matter of urgency given that survival rates from pregnancy scanning to lamb marking in ewe lambs are consistently around 66%, hence one in every three lambs conceived is lost, which concerning from a production, profit and welfare perspective.

Further research that needs to be conducted on ewe lambs, includes;

- Identifying for Merino, Maternal and Shedding genotypes the relationship between percentage of mature weight and reproductive performance of ewe lambs. If the joining and lambing weight targets for ewe lambs could be as expressed as a percent of mature weight, as has been done with heifers in the beef industry for many years, this would improve the universal extension and interpretation of the information being extended. An opportunity exists in the short term (2024/2025) to re-engage with flocks that participated in this project to capture mature weight data on ewes that were part of the ewe lamb trials in recent years and evaluate the robustness of the weight targets as a percent of adult weight. This would be a very efficient approach to value add to thousands of records already collected in this project.
- Evaluating the impact of feed-on-offer (FOO) in the lambing paddock on lamb survival from ewe lambs. This research has been undertaken in the Lifetime Wool and Lifetime Maternal projects for adult ewes and has revealed differing outcomes, where Merino ewe maternal behaviour and resultant lamb survival was found to be much more sensitive to FOO in the lambing paddock. This is a further gap in understanding with ewe lambs that may contribute to reducing lamb loss from ewe lambs.
- Evaluating the impact of grain feed in late-pregnancy on ewe and lamb survival from ewe lambs. This research has been undertaken recently with adult triplet bearing ewes and revealed significant improvements in survival outcomes. This is a gap in understanding with ewe lambs that may contribute to reducing ewe and lamb loss from ewe lambs.
- Research into the optimum genotypes to mate ewe lambs to, for evaluating the impact of direct sire effects on lamb survival from ewe lambs. Currently many producers select low birth weight sires to mate ewe lambs and this may be exacerbating the loss of ewe lamb's progeny due to too low birth weight. Birth weight, lambing ease and body composition have been found to directly affect lamb survivability but have never been evaluated in ewe lamb dams.

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1. Background

Mating ewes to lamb at 12 to 15 months is an effective avenue to rapidly build maternal (including shedding breeds) and merino ewe numbers and increase lamb supply. However, the reproductive performance of ewe lambs is much lower than that achieved by mature ewes and highly variable. This variation in performance and lack of information on the financial ramifications of joining ewe lambs has contributed to relatively poor adoption, which is estimated to be 30% of Maternal and 5% of Merino sheep producers.

This National project aims to increase both the number of ewe lambs being mated and their reproductive performance by developing and validating a best practice guide with supportive tools to deliver reproductive success. This project findings will incorporate understanding from producer consultation and on-farm trials that quantify the full impacts of management and husbandry practices during their first two years of a ewe's life. This project will also incorporate and build upon previous research work, particularly liveweight targets for joining ewe lambs and recent economic modelling of optimum management systems for ewe lambs. A best-practice guide for producers, to improve the reproductive performance of their ewe lambs, covering joining, pregnancy and lambing management, will be developed.

Ultimately this project aims to improve performance of a cohort of ewes in the Australian flock that is currently both underutilised and underperforming, that can contribute substantially to addressing the challenge of sustaining breeding ewe numbers and increasing lamb supply. Ewe lambs are a challenging cohort of ewes and are renowned for typically lower and more variable outcomes than traditional 2-year maidens. Industry emphasis with ewe lambs over recent years has been on improving conception rates and reproductive rates from ewe lambs through interventions such as increasing weights and age at joining (Thompson *et al.* 2021) and genetic selection for traits like growth and carcass and early onset of puberty (Rosales Nieto et al. 2013a and b, 2015 and 2018). However, the aim of this project is to now shift the industry emphasis to more live lambs weaned from ewe lambs as the end game, particularly via improved ewe and lamb survival rates. The outcomes from this research project intends to drive production and profit from this cohort while significantly reducing wastage and improving welfare outcomes, with a series of new rules for engagement with ewe lambs.

2. Objectives

The following objectives were achieved:

- Identify the range in current industry recommendations and suggested best practice for mating ewe lambs to lamb at 12 to 15 months, from consultants, leading sheep advisors and producers, and the key barriers to adoption.
- Have compiled national baseline data from producers identified by working with pregnancy scanners on; (i) the current numbers of ewe lambs mated to lamb at 12 to 15 months, (ii) the reproductive rate achieved when mating ewe lambs, (iii) the mortality rates of mated ewe lambs and their lambs, and resultant marking rate.
- Have identified the suite of management practices that impact the reproductive performance of ewe lambs on commercial farms, in particular reducing the mortality rates of ewe lambs and their lambs, assess their apparent effectiveness and prioritised key gaps that require further validation on participatory research sites.
- Have tested the effectiveness of these practices at commercial scale, as single or multiple factor comparisons, on a network of participatory research sites across Australia, to provide new understanding on how to improve the improve the performance of ewe lambs and their lambs.
- Have quantified the carryover impacts of management of ewe lambs during their first pregnancy and lactation on their subsequent reproductive rate.
- Have completed economic modelling and cost benefit analysis to confirm the value of various management practices and the most economic pathways to improve ewe lamb reproductive success for Maternal and Merino enterprises.
- Have developed a standalone best practice guide and decision tools for reproductive success from ewe lambs, including impacts of critical success factors such as nutrition/weight profile, genetics/breed, timing, husbandry practices such as the use of melatonin in late-pregnancy and smaller mobs for lambing and economics.
- Published a peer reviewed journal publication on improving the number of live lambs born from ewe lambs, from research undertaken (to be available open access).

3. Industry consultation

This project commenced with industry consultation to identify the range in current industry recommendations and suggested best practice for mating ewe lambs to lamb at 12 to 15 months, from consultants, leading sheep advisors and producers, and the key barriers to adoption. The consultation was primarily undertaken using phone surveying, with a small portion complete face-to-face.

3.1 Methods

This report forms part of the initial phase of the More Lambs from Ewe Lambs Project that is using a series of consultative approaches to involve sheep consultants/advisors, researchers and sheep producers to review and ultimately improve the reproductive performance of ewe lambs lambing at 12-15 months. The initial consultation has involved;

- Market research with consultants and producers to identify the range in recommendations and practices for mating ewe lambs to lamb at 12 to 15 months, and the barriers to adoption.

This activity has undertaken consultative analysis with leading sheep industry consultants, extension specialists and producers that mate maternal, shedding or merino ewe lambs in both Australia and New Zealand to determine the range in current industry recommendations and suggested best practice for managing ewe lambs to lamb at 12-15 months. A total of 120 stakeholders were surveyed either over the phone or face-to-face, using a questionnaire as the basis for the interview that is attached as Appendix 1, comprising of 98 producers and 22 sheep advisors/consultants. The approach taken highlights the variation in recommendation and practice for ewe lambs around key management decisions such as joining weight/condition score, growth path to and during joining, growth path during pregnancy, vaccination, weight/condition score targets at lambing, feed-on-offer targets at lambing, paddock allocation and mob size for lambing, weaning age and weight/condition score targets for second joining, and genetic selection strategies. Also, some insight to the barriers to adoption were gained.

3.2 Results

Mate ewe lambs or not

A summary of the 98 producers interviewed, their sheep type and whether or not they mate ewe lambs is outlined in Table 3.1. The table outlines the number of producers and in brackets are the percentages this represents. Fifty percent of the producers interviewed were Merino producers, 37% Maternal producers and 13% had shedding breeds.

Table 3.1. Summary of the producers interviewed and whether or not they mate ewe lambs

Sheep type	Yes-mate ewe lambs	No- mate ewe lambs	Total
Merino	9 (18%)	40 (82%)	49 (50%)
Maternal	19 (53%)	17 (47%)	36 (37%)
Shedders	1 (8%)	12 (92%)	13 (13%)
			98

Proportion mated

The proportion of the ewe lambs that are mated to lamb at 12-15 months of age, out of the ewe lambs available to be retained (ie. not including ewe lambs sired by terminal rams), varied widely from 10 to 90%.

Basis for selection of ewe lambs mated

The basis for selecting the ewe lambs to be mated also varied widely among producers (Table 3.2).

Table 3.2. Basis for selecting ewe lambs to be mated

Selection approach	Percent of producers using each approach
Visual draft	25%
Weight	19%
Weight and condition	33%
Born early	7%
Born as a multiple	5%
Other	11%

Minimum mating weight policy

The strategy producers employed regarding minimum joining weights for mating ewe lambs differed substantially (Table 3.3). One-third of the producers mating ewe lambs did not have a minimum mating weight, they just mated all the ewe lambs that they bred to be retained, whereas the other two-thirds of producers have a minimum mating weight policy but it varied from 35 to 50 kg.

Table 3.3. Minimum mating weight policy employed

Minimum mating weight policy	Percent of producers using each approach
No minimum weight	33%
35.0 kg	3%
37.5 kg	7%
40.0 kg	17%
42.5 kg	7%
45.0 kg	23%
47.5 kg	7%
50.0 kg	3%

Age of ewe lambs at mating

The age of the ewe lambs at the start of their mating also varied substantially among producers, basically from 6-12 months of age (Table 3.4).

Table 3.4. Age of ewe lambs at the start of mating

Age of ewe lambs at start of their mating	Percent of producers using each approach
6 months	3%
7 months	13%
8 months	37%
9 months	20%
10 months	3%
>10 months	23%

Density of rams for mating ewe lambs

For mating ewe lambs, the strategy producers employed regarding the density of rams also varied substantially (Table 3.5), basically from between 1 to 5% rams to ewe lambs mated.

Table 3.5. Percent of rams used to mate ewe lambs

Ram % when mating ewe lambs	Percent of producers using each approach
1%	0%
1.5%	8%
2%	25%
2.5%	8%
3%	25%
3.5	8%
4%	18%
>4%	8%

Length of mating for ewe lambs

The length of mating for ewe lambs also varied widely across producers (Table 3.6), from as short as 4 weeks mating to over 8 weeks.

Table 3.6. The length of mating for ewe lambs

Length of joining for ewe lambs (weeks)	Percent of producers using each approach
4 weeks	7%
5 weeks	19%
6 weeks	41%
7 weeks	4%
8 weeks	19%
>8 weeks	11%

Use of suggested practices- teasers, campylobacter vaccination, low birth weight rams and scanning

The practices implemented by producers in relation to using teasers prior to mating, vaccinated against campylobacter prior to mating, sue of low-birth-weight rams and pregnancy scanning practices also varied greatly (Table 3.7). For instance, one-third of producers were using teasers prior to mating and two-thirds were not, the vast majority (84%) of producers weren't vaccinating for campylobacter prior to mating, basically half used low birth weight rams and half didn't, and two-thirds pregnancy scanned for multiples and one-third didn't.

Table 3.7. Use of suggested practices for mating ewe lambs

Suggested practice for mating ewe lambs	Yes	No
Use teasers prior to mating	33%	66%
Vaccinate against campy-lobacter prior to mating	16%	84%
Use low birth weight rams over ewe lambs	52%	48%
Pregnancy scan ewe lambs for multiples (0, 1, multiple)	66%	33%

Strategy with empty ewe lambs- keep or sell

The strategy regarding the ewe lambs that scanned dry varied among producers, with 40% of the producers interviewed selling them as lambs and the remaining 60% of producers keeping them to be re-mated as part of their flock.

Typical conception rates and overall scanning rates for ewe lambs mated

The typical percentage of ewe lambs getting pregnant achieved by each producer varied widely, from 40-90% of ewe lambs mated (Table 3.8).

Table 3.8. Typical conception rates for ewe lambs mated

Typical percent of ewe lambs that conceive	Percent of producers achieving that result typically
30%	10%
40%	23%
50%	3%
60%	7%
70%	17%
80%	7%
85%	23%
90%	7%

The typical overall scanning percentage (foetuses to ewe lambs mated) varied from 60-130%, with an average of 93%. Similarly, the marking rate to ewe lambs mated varied widely from 30-100%, with an average of 70% and no-one interviewed typically marked > 100% lambs to ewe lambs mated.

Biggest challenge with mating ewe lambs to lamb at 12-15 months

The ‘biggest challenge’ producers nominated for mating ewe lambs to lamb at 12-15 months differed among producers (Table 3.9), with one-third of producers nominating poor lamb survival out of ewe lambs as the biggest challenge, while low conception rates (25% of producers) and poor overall scanning rates (19%) were other significant challenges for producers.

Table 3.9. Biggest challenge with mating ewe lambs

Biggest challenge with mating ewe lambs	Percent of producers with that challenge
Low conception rates	25%
Poor overall scanning rates	19%
Poor lamb survival out of ewe lambs	33%
Getting ewe lambs to recover for next mating	7%
Poor scanning rates on 2nd joining	5%
Other	11%

Research priorities for ewe lambs

The priority for research of the different aspects of mating ewe lambs to lamb at 12-15 months that the producers would like investigated (Table 3.10) was quite interesting and will help inform the gaps/priorities that are examined in years 2 and 3 of this project.

Table 3.10. Producer priorities for research for mating ewe lambs

Aspects of mating ewe lambs that require further research	Percentage of producers surveyed	Producer priority
Pregnancy weight/condition score profile management and its impacts of ewe and lamb survival	72%	1
Impact of growth rate during joining on scanning rates	56%	2
Impact of mob size at lambing on lamb survival from ewe lambs	44%	3
Impact of feed-of-offer during lambing on lamb survival and lamb growth rate from ewe lambs	22%	4
Impact of sire birth weight and lambing ease ASBVs on survival rates of ewe lambs & their lambs	12%	5

Barriers to adopting mating ewe lambs

The key barriers to producers adopting mating of ewe lambs to lamb at 12-15 (Table 3.11) included having no room for mating ewe lambs because already have too many other sheep, the perception that ewe lambs are poor mothers and will achieve poor lamb survival, and my current sheep type doesn't suit lambing as a ewe lamb. These perceived barriers will also help inform the gaps/priorities that are examined in years 2 and 3 of this project. There was a very even spread of producers nominating the different barriers to adoption, so at this point there seems to be a range of things holding producers back.

Table 3.11. Barriers to adopting mating of ewe lambs to lamb at 12-15 months

Barrier to adopting mating of ewe lambs to lamb at 12-15 months	Percent of producers nominating each barrier
Already have too many other sheep, don't have room for more lambing ewes	23%
Ewe lambs will make poor mothers and have poor lamb survival rates	19%
My current sheep type doesn't suit lambing at 12-15 months	16%
Question the profitability of mating ewe lambs to lamb at 12-15 months	13%
Reproduction rates need improving in other age ewes first	10%
Poor scanning rates achieved when mating ewe lambs	10%
Concerned about impacts on 2 year old scanning and lamb marking results	10%

Consultant feedback

Consultants feedback as to what the optimal package for improving the performance of ewe lambs that lamb at 12-15 months varied markedly (Table 3.12). Basically, this process verified the need for clarity around the best practice guidelines for mating ewe lambs and to managing their pregnancy, lambing, weaning and recovery. Consultants had a lot of thoughts for the stages- ewe lamb selection, pre-mating and mating practices/targets but their recommendations varied a lot. Whereas for pregnancy, lambing/lactation and weaning/recovery the consultants had few recommendations that were specific to ewe lambs, just guiding clients to manage pregnant ewe lambs similar to their adult ewes.

Table 3.12. Suggested best practice for mating ewe lambs to lamb at 12-15 months

Stage	Practice	Consultant recommendations
Selection strategies for mating	Proportion of ewe lambs that should be mated	30-100% of drop
	Based on weight	85% Yes 15% No
	Based on born as multiple	20% Yes 80% No
	Base on born early in the drop (increase age at mating)	30% Yes 70% No
	Minimum mating weight for ewe lambs	38-50 kg
Pre-mating	Vaccinate for campylobacter prior to mating	60% Yes 40% No
	Use of teasers prior to mating	70% Yes 30% No
	Flushing on lupins or beans or green feed prior to mating	30% Yes 70% No
Mating	Recommended growth rate during mating	100-250 g/day
	Recommended age for mating ewe lambs	7-11 months
	Recommended ram density for mating ewe lambs (ram %)	2-4%
	Recommended joining length (weeks)	4-7 weeks
	Use low birth weight rams for mating ewe lambs	65% Yes 35% No
Pregnancy	Pregnancy scan for multiples (0, 1, multiple) in ewe lambs	100% Yes
	Recommend to keep or sell empty ewe lambs	Keep all to sell all
	Growth rate target for ewe lambs from mating to scanning	Nothing specific
	Growth rate target for singles from scanning to day 130	Nothing specific
	Growth rate target for twin from scanning to day 130	Nothing specific
Lambing and lactation	Condition score target for singles at lambing	Nothing specific
	Condition score target for twins at lambing	Nothing specific
	Feed-on-offer target for lambing singles	Nothing specific
	Feed-on-offer target for lambing twins	Nothing specific
	Mob size target for lambing singles	Nothing specific
	Mob size target for lambing twins	Nothing specific
	Lamb survival targets for singles and twins from ewe lambs	Nothing specific
	Lamb growth targets for singles and twins from ewe lambs	Nothing specific
Weaning /recovery	Weaning age of lambs	Nothing specific
	Weight gain target post weaning for ewe	Nothing specific
	Value of splitting heavy and lite ewes at weaning	Nothing specific
	Condition score target for next mating	Nothing specific

The biggest challenges that consultants consistently nominated with ewe lambs were;

- highly variable results in scanning and marking rates,
- impact if not managed well on 2-year old performance,
- getting the ewe lamb back in condition for the next mating.

The research priorities that consultants consistently nominated with ewe lambs were;

- understanding the causes of the gap between scanning rates and marking rates,
- improving lamb survival out of ewe lambs by developing pregnancy profile management guidelines and lambing guidelines for factors such as mob size and feed-on-offer,
- ways to lift lamb birth weight without increasing dystocia problems,
- impact of growth rates and/or green fed during joining on reproductive rate, and
- understanding the impact of growth path, rather than just weight at mating, on reproductive performance.

The primary barriers to adoption that consultants consistently nominated with ewe lambs were;

- if producers try ewe lambs and achieve poor results they don't go back again for a long time,
- not informed how to do it, so don't try it at all,
- not set up to manage ewe lambs, both infrastructure (eg. scales) and mindset/skills to manage the complication of ewe lambs in their system,
- don't manage ewe weaners well enough because focused on finishing other lambs (ie. not a priority).

The discussions held with consultants and producers based in New Zealand revealed that again there is much more information provided and followed for mating ewe lambs compared to pregnancy and lambing management specific to ewe lambs. One difference to Australia was there did appeared to be more consensus among consultants and leading producers as to the protocol to follow for mating ewe lambs such as; minimum a mating weight of 40 kg, compulsory vaccination for campylobacter and toxoplasmosis prior to mating, use of teasers prior to mating, higher ram density for ewe lambs compared to adults of 3-3.5%. An additional practice that is recommended in New Zealand for ewe lambs is to shear pre-mating. This has been shown to have a definite impact on conception rates by increasing the appetite of ewe lambs post-shearing and is widely recommended. Regarding pregnancy management the guidelines in New Zealand are to have the ewe lambs as heavy as possible when allocated to lambing paddocks, preferably 60kg, this is linked to higher lamb marking rates. The scanning of ewe lambs to manage singles and twin separately in late pregnancy, lambing and lactation is unanimously recommended in New Zealand.

3.3 Conclusions

The consultation undertaken in this milestone has highlighted the huge opportunity and need for this project to develop and validate guidelines for managing ewe lambs through their entire growth path from their own weaning through to the second mating as a rising two-year old. There is more information available to inform mating strategies and this must be consolidated and gaps such as the impact of weight gain during mating and the role of flushing with green feed evaluated, whereas with pregnancy and lambing management there is little known and is the primary void to be address. The subsequent milestone in this project will further add to the understanding gleaned, providing more information on the practices and performance associated with ewe lambs and will pinpoint the most critical gaps in understanding to be investigated in trials in subsequent years of this project.

4. The national baseline for ewe lambs on-farm

This section provides a national baseline for ewe lambs on-farm for the prevalence, performance, practices and attitudes associated with ewe lambs.

4.1 Methods

4.1.1 Justification for approach taken

In the original methodology for this project it was intended to that objective 2 ('the national baseline data of current ewe lamb matings, reproductive rate rates, mortality rates of the ewe lambs and their lambs, marking rate, practices and barriers to adoption), would be achieved by engaging with pregnancy scanners to identify and work with producers that mate maternal, shedding or merino ewe lambs to lamb at 12-15 months.

Having reviewed the intended approach and the critical aim of being able to provide a baseline for the mating of ewe lambs nationally, and on reflection the approach of targeting producers through pregnancy scanners would result in significant bias and limit the ability to extrapolate the findings to the whole industry. Also, from speaking to Elise Bowen who is undertaking a similar approach, of targeting producers who mate ewes (via both pregnancy scanners and ram breeders), she has discovered it was causing significant bias in data collected. This was exacerbated by very few producers meeting additional qualifiers to be surveyed, that they must scan for multiples and lamb ewe lambs separately to other age groups of ewes. Therefore, it was pointless following a similar vein in this project and having results that couldn't be related to whole industry, so it was decided to undertake a random national survey of sheep producers in all states.

There were two considerations in determining the size of the sample for the national survey (in addition to cost and time). These were;

1. What accuracy is needed on the estimate of the "proportion of producers that join ewe lambs",
2. Will enough producers be reached who join ewe lambs to get a wide range of views.

To solve the first query, an estimate of what the proportion of producers' mate ewe lambs has to be made. A previous study from the mid-1990s gave an estimate of 3%. Given the rise in importance of lamb production, it was expected this may have risen to 10%, although no one has a definitive answer and that is why this study is being undertaken.

Given an estimate of 10% of producers mating ewe lambs then for a 95% confidence interval of +/-3%, 385 producers would need to be surveyed. Under the assumption that 10% of producers currently mate ewe lambs, approximately 38 producers from this group would need to be interviewed. It was concluded that this is far too few to get thorough feedback on the issues pertaining to joining ewe lambs. Previous work suggested we should interview at least 100 producers, half who did and half who didn't join ewe lambs. Thus, to interview 50 ewe lamb joining producers, where 10% conduct the practice, you need to survey 500 producers. As shown in Table 4.1, a survey of 500 producers with an estimate of 10% joining ewe lambs would give a 95% confidence interval of +/- 2.6% (i.e. 7.4% to 12.6%).

If our 10% estimate was wrong and the estimate should have been 5%, then the 95% confidence interval would be +/-1.9% (i.e.3.1% to 6.9%). If we were too low, and the estimate should be 20%, then a sample of 500 gives a confidence interval of +/-3.5% (i.e. 16.5% to 23.5%), but the bonus would be 100 producers who joined ewe lambs would be surveyed (Table 4.1).

Table 4.1. Basis to surveying 500 producers to determine national baseline data

Confidence level 95%

Sample

		Half interval			
		2.0%	3.0%	4.0%	500
	5%	457	203	115	1.9%
	10%	865	385	217	2.6%
	15%	1225	545	307	3.1%
Estimate	20%	1537	683	385	3.5%

Interpretation:
If we expect 10% of producers join ewe lambs, then to get a 95% confidence interval of +/- 3%, we should survey 385 producers
Alternatively, with an estimate of 10%, a survey of 500 porducers gives a 95% confidence interval of +/- 2.6%

Producers joining ewe lambs that we would surveu

		Half interval			
		2.0%	3.0%	4.0%	500
	5%	23	10	6	25
	10%	87	39	22	50
	15%	184	82	46	75
Estimate	20%	307	137	77	100

To achieve an even tighter confidence interval beyond this survey, then it is suggested to get a question into the AWI/MLA sheepmeat and wool survey. They get a response from between 1500 and 2000 producers. This would give a confidence interval of +/- 2.0%, (down from 3.5%), but of an opt-in sample, so potential bias must be recognsised. To convert the data being collected in this survey into a population estimate, it would be good to get an independent estimate of how many producers join ewes of different breeds. This is known from ABS for Merino producers but is not available from ABS for the other breeds. Estimates of how many producers are running Maternal or Shedding ewes from the sheepmeat and wool surveys would be useful. This could be done when working with Toby Pitt (MLA) to include a ewe lamb question in MLA/AWI survey in February 2020.

4.1.2 Survey methodology

The survey was conducted by telephone using a prepared questionnaire and Computer Aided Telephone Interview (CATI) software. A list of producers (the 'sample') was purchased from a commercial list provider. The provider indicated their list of sheep producers (wool, meat and stud) contained over 32,000 contacts. The sample purchased contained 4,000 contacts drawn from the list and stratified by state in proportion to the number of sheep producers joining ewes as reported by ABS from their 2015-16 agricultural census (Table 4.2).

Table 4.2. Number of sheep businesses (farms) that reported joining ewes in the 2015-16 ABS agricultural census

State	Sheep businesses joining ewes	Share of Australian total (%)	Survey quota limit
NSW (including ACT)	9,915	38	200
Qld.	897	3	20
SA	4,466	17	90
Tas.	751	3	20
Vic.	6,432	24	130
WA	3,971	15	80
Australia	26,432	100	

A total of 500 responses was requested. Maximum quotas were set for responses from each state to reduce the risk of geographical bias.

To ensure only commercial sheep producers were interviewed, each contact from the sample was asked if they had joined 500 or more ewes this year (2019) or in their last normal year. Only those who answered yes were invited to complete the survey.

Survey outline

A copy of the questionnaire is attached as Appendix 1 at end of this report. The survey questionnaire was structured to gather information from both those producers who do join ewe lambs (or have in the past) and from those who have never joined ewe lambs.

All producers were asked (Q1) how many ewes (of all ages) they joined this year or in the last normal year[1]. The number of ewes was recorded by three breed categories – Merino, Maternal/Cross-bred/Meat and Shedding.

All were asked (Q2) if they joined ewe lambs.
If they joined ewe lambs, they were asked (Q3) how many they joined, and this was recorded by the same breed categories. In addition (Q4), they were asked how they decided which ewe lambs to join, and (Q5-Q11) about reproductive performance (scanning rates, marking rates and ewe lamb mortality). Finally, they were asked (Q14) to rate a series of statements on the practice of joining ewe lambs.

Producers who did not join ewe lambs this year were asked (Q12) if they had previously, and whether they might in the future.

Those that had previously joined ewe lambs were asked (Q13) about their approach to joining ewe lambs and then asked (Q14) to rate a series of statements on the practice.

[1] "last normal year" was included because of the drought conditions experienced in 2019 in many sheep producing areas.

Those that said they have never joined ewe lambs were asked (Q15) for the key reasons they don't join ewe lambs and then asked (Q16) to rate a series of statements about not joining ewe lambs.

4.2 Results

A total of 500 producers who joined 1.14 million ewes completed a telephone interview. The distribution of those producers and of the number of ewes joined between states is compared to that reported by ABS in Figure 4.1 and Figure 4.2 respectively.

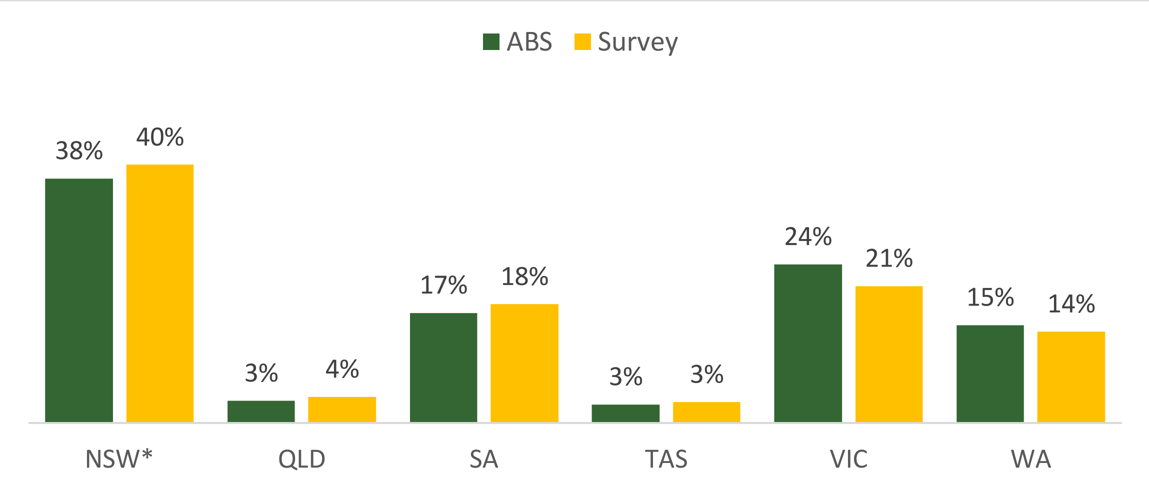


Figure 4.1. Comparison of the proportion of sheep producers joining ewes by state as reported by ABS (2015-16 Agricultural Census) with those surveyed for this study.

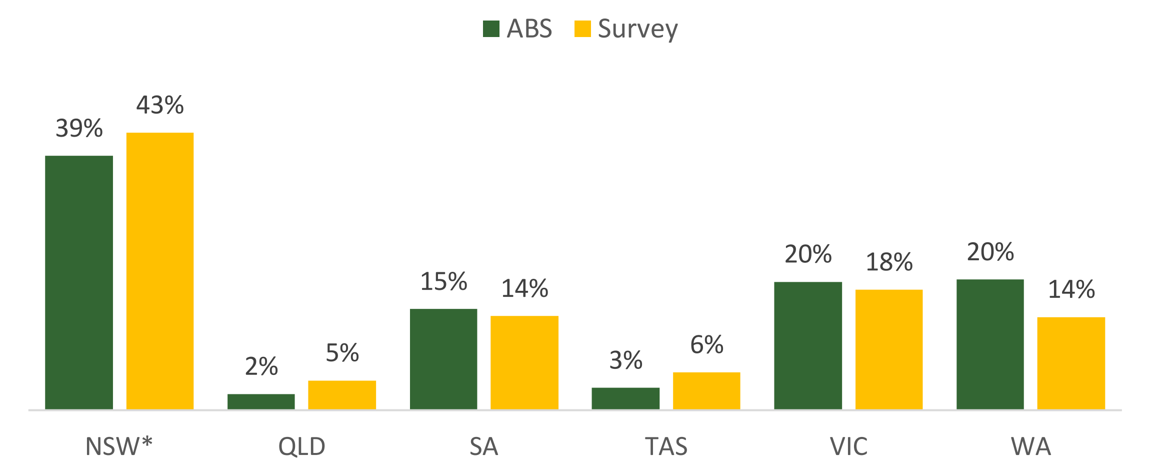


Figure 4.2. Comparison of the proportion of ewes joined by state as reported by ABS (2015-16 Agricultural Census) with those reported in this study.

Breed mix

Almost three quarters of the ewes joined by the producers interviewed were Merino, but two thirds of the ewe lambs joined were Maternal/Cross-bred/Meat breeds (Figure 4.3). Hence, joining ewe lambs is a lot more prevalent with Maternals, Cross-breds, meat breeds and shedding sheep, than in Merinos.

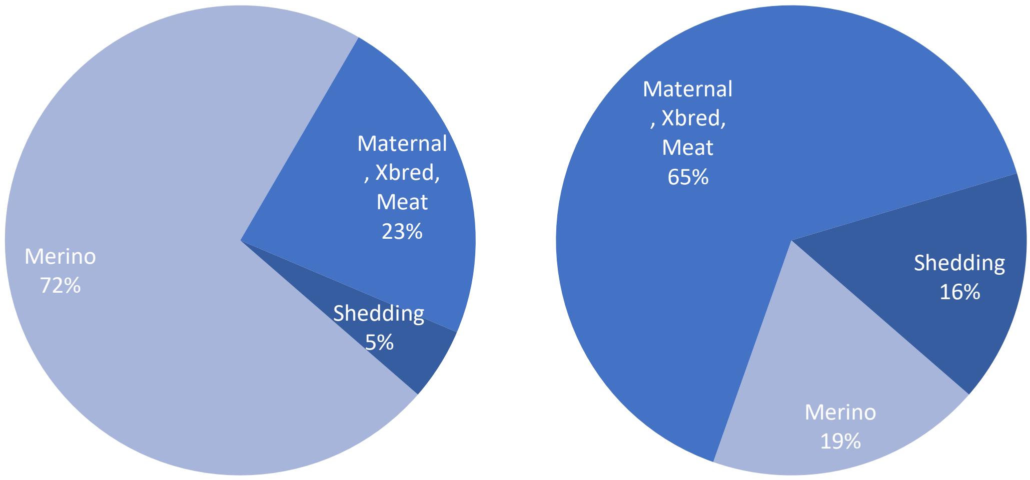


Figure 4.3. Proportion of ewes joined by breed type – all ewes (lambs, maidens and adults) (left-side) and ewe lambs (right side).

Joining ewe lambs

Of the 500 producers interviewed;

- 117 (23%) had joined ewe lambs in 2019[2],
- 107 (21%) had previously joined ewe lambs but didn't in 2019[2], and
- 276 (55%) had never joined ewe lambs.

The standard error of the percent of producers who joined ewe lambs is 1.9% giving a 95% confidence interval of 19.7% to 27.1%. From the survey of 500 producers who joined ewe lambs in 2019 (or in the most recent normal year), the following table shows the proportion that reported joining ewe lambs (Table 4.3).

Table 4.3. The proportion of producers that mated ewe lambs in 2019

Group	Count	% joining ewe lambs	S.E of % joining ewe lambs	95% confidence interval
NSW	198	21	2.9	15.5 – 26.9
QLD	20	30	10.2	9.9 – 50.1
SA	91	27	4.7	18.3 – 36.6
TAS	16	44	12.4	19.4 – 68.1
Vic	105	26	4.3	17.4 – 34.1
WA	70	14	4.2	6.1 – 22.5
Australia	500	23	1.9	19.7 – 27.1
Breed differences:				
Merino	388	7.5	1.3	4.9 – 10.1
Maternal / Xbred / Meat	216	35	3.2	28.4 – 41.1
Shedding	26	77	8.3	60.7 – 93.1
Non-Merino (aggregate of Maternal/ Xbred/Meat and Shedding)	242	39	3.1	33.1 – 45.4

[2] "or in the most recent normal season"

Those 107 producers who had not joined ewe lambs this year but had done so previously were asked about their approach to joining ewe lambs;

- 36 (34%) chose "I usually join ewe lambs but didn't because of the season."
- 15 (14%) chose "I usually join ewe lambs, but I didn't think they were in good enough condition this year."
- 28 (26%) chose "I have tried joining ewe lambs, but the results were too poor or too variable."
- 10 (9%) chose "I have tried joining ewe lambs, but they required too much effort for the reward."
- 18 (17%) chose "I have tried joining ewe lambs, but it was not economically viable."

This indicates that an additional 51 producers or 10% of the producers surveyed join ewe lambs when conditions are suitable. Hence, in a year with suitable conditions, it could result in approximately one-third of producers mating ewe lambs (23% that joined ewe lambs in 2019, plus 10% that mate ewe lambs when conditions are suitable, totalling 33%).

Of the 276 producers who said they have never joined ewe lambs;

- 207 (75%) indicated they "would never consider it",
- 64 (23%) indicated they "might consider it in the future", and
- 5 (2%) indicated they "intend to do it from now on".

Choosing ewe lambs to join

The 117 producers who joined ewe lambs in 2019 were asked how they chose which ewe lambs to join. Multiple answers were accepted e.g. by weight and condition score;

- 29% said they joined them all.
- 52% said they only joined those above a minimum weight. The median weight was 45 kg with 90% of responses between 38 and 60 kg.
- 17% said they have a target condition score most commonly "3 or 4 or 5" or "3 or 4"
- 7% only join some breeds.
- 3% said they only join early born ewes as they are more sexually mature.

Other approaches include using a classer, basing selection on breed standards, judged on weight and muscle, by size, by skin type and shedding ability, and "by accident".

Reproductive performance of ewe lambs

Of the producers who joined ewe lambs, 41% did not scan them for pregnancy status, 26% scanned for dry / pregnant, and 33% scanned for dry / single / twin.

The following table shows the proportion of ewe lambs that were pregnant in those flocks that were scanned for pregnant versus dry, and the overall scanning rate for ewes that were scanned for dry / single / twin (Table 4.4).

Table 4.4. Scanning results for ewe lambs joined in 2019. Percent pregnant for those flocks scanned only for dry versus pregnant. Overall scanning rate (foetuses per 100 ewe lambs) for flocks scanned for dry/single/twin. Results show mean, (5th and 95th percentile) and sample size.

Breed	Percent pregnant	Overall scanning rate
Merino	74 (40-100) (n=5)	85 (40-130) (n=6)
Maternal/X-bred/Meat	78 (50-95) (n=20)	103 (47-140) (n=28)
Shedding	82 (70-95) (n=6)	87 (60-110) (n=4)

Estimation of marking rates

Producers who reported that they had run the ewe lambs they joined separately were asked what marking rate they achieved and whether this marking rate was calculated as a percent of the ewe lambs that were run with rams, the ewe lambs that were scanned pregnant or the ewe lambs that were present at marking. This information and the recorded mortality rate was used to adjust all marking rates to a percent of the ewe lambs run with lambs. The adjusted marking rates are given in Table 4.5.

Table 4.5. Average marking rates by breed for ewe lambs joined in 2019. All rates adjusted to be as a percent of ewe lambs run with rams

Breed	Average (n)	5th and 95th percentile
Merino	58% (n=19)	7% - 100%
Maternal/Xbred/Meat	82% (n=56)	48% - 107%
Shedding	77% (n=11)	40% - 100%

Mortality rate of ewe lambs

The average ewe lamb mortality rate was 5.9% (n=117) with a 90% confidence interval of 0% to 30%. However, the distribution was skewed strongly to the left, as shown in Figure 4.4.

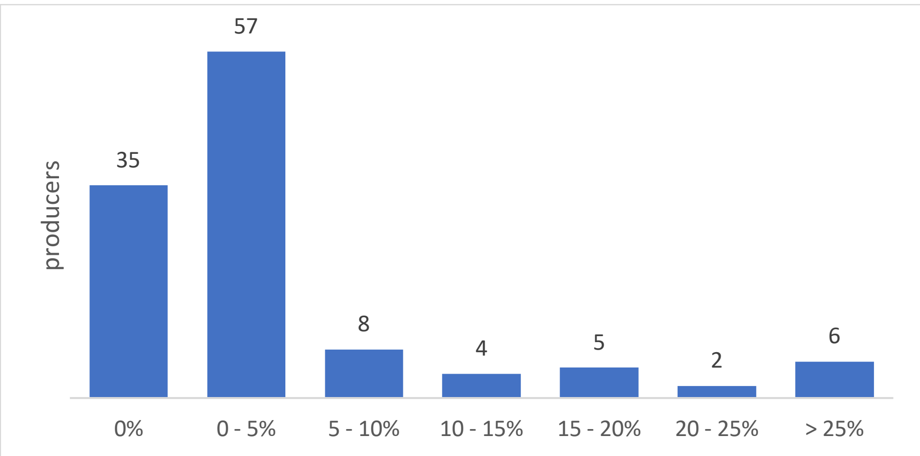


Figure 4.4. Distribution of producers (n=117) by reported mortality rate in ewes joined as lambs.

Only 34% of producers thought the mortality rate among ewe lambs was higher than for older ewes. The main reasons given for the higher mortality were lambing problems (birthing difficulties – lambs too big, mothers too small), too young/too small (not sufficiently developed), weather (cold, wet, wind, frost), drought, foxes and disease.

Attitudes and management practices associated with ewe lambs

Those producers who had joined ewe lambs, either in 2019 or previously, were asked to rate their level of agreement with six statements on joining ewe lambs. The results are shown in Table 4.6.

Table 4.6. Producers who have joined ewe lambs (n=224) were asked to rate on a scale of 1 to 9 a series of statements reflecting their view on joining ewe lambs. A rating of 1 meaning ‘strongly disagree’ with the statement and a rating of 9 for ‘strongly agree’. Average rating and distribution of ratings assigned are presented for each statement. The distribution of ratings in the mini-bar charts range from 1 (left end) to 9 (right end).

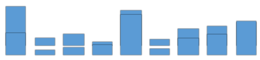
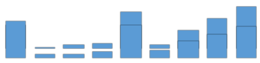
Statement	Average rating	Distribution of ratings
Joining ewe lambs is my usual practice	5.9	
I joined my ewe lambs because lamb prices make it worth the additional effort	5.9	
I join ewe lambs because I am trying to accelerate genetic gain	5.8	
I joined my ewe lambs because it improves the ewe's lifetime reproductive performance	5.5	
I join ewe lambs because I am trying to rebuild my flock	5.3	
I join ewe lambs in order to reduce the age of my flock	4.9	

Table 4.7 outlines the use of practices associated with mating ewe lambs. Only one-third of the producers that mate ewe lambs scanned for multiples, around one-quarter scan wet-dry only and 40% of producers that mate ewe lambs don’t scan them at all. Furthermore only 71% of producers run their ewe lambs separately from other age groups and together with the limited uptake of multiple scanning, it means very few producers actually know their lamb survival rates out of ewe lambs, either overall or for singles and twin born lambs, and many don’t even know their marking rate out of ewe lambs. Just over half of the producers mating ewe lambs employed a minimum joining weight when mating ewe lambs, which contrasted to the 29% of producers that had the policy of mating all ewe lambs. This is very useful background information on the practices associated with mating ewe lambs and will inform the adoption/education components of this project.

Table 4.7. The practices associated with mating ewe lambs

Question	Options	Responses	Percent
Did you join ewe lambs in 2019*	Yes.	117	23%
	No, but I have previously.	107	21%
	No, and I would never consider doing so.	207	41%
	No, but I might consider it in the future.	64	13%
	No, but I intend to do it from now on.	5	1%
Scanning practice	Did not scan.	47	40%
	Wet/Dry only.	31	26%
	Multiples.	39	33%
Did you run ewe lambs separately?	Yes.	83	71%
	No.	34	29%
How do you choose which ewe lambs to join?	I joined them all.	34	29%
	I only joined those above a minimum weight.	61	52%
	I have a target condition score.	20	17%
	I only join some breeds.	8	7%
	I only join early born ewe lambs as they are more sexually mature.	4	3%

* Or in the most recent "normal" year

Why producers don't join ewe lambs- barriers to adoption

For the producers who did not join ewe lambs, they were asked to rate statements indicating reasons for not joining ewe lambs. Their average rating for each statement and the distribution of those ratings are shown in Table 4.8.

Table 4.8. Producers who do not join ewe lambs (n=116) were asked to rate on a scale of 1 to 9 a series of statements indicating reasons for not joining ewe lambs. A rating of 1 meaning 'strongly disagree' with the statement and a rating of 9 for 'strongly agree'. Average rating and distribution of ratings assigned are presented for each statement. The distribution of ratings in the mini-bar charts range from 1 (left end) to 9 (right end).

Statement	Average rating	Distribution of ratings
They are not big enough to get into lamb	6.8	
It is not economically viable in my operation	6.7	
There are too many difficulties lambing ewe lambs	6.6	
They will grow less wool	6.3	
It is not suitable for my area/climate	6.2	
It would lead to an unacceptable increase in ewe lamb losses	5.7	
They are not good mothers and will wean poor lambs	5.5	
I've seen poor results elsewhere	4.9	
I buy in ewes more (older) than 1 year old.	3.3	

The main reasons given for not joining ewe lambs are summarised in Figure 4.5. The most prevalent view among these producers is a combination of the ewe lambs are too small, too immature, still growing and need more weight and or condition. Negative aspects associated with joining ewe lambs include the long-term impact on the ewe lamb (mother), and low lambing percent.

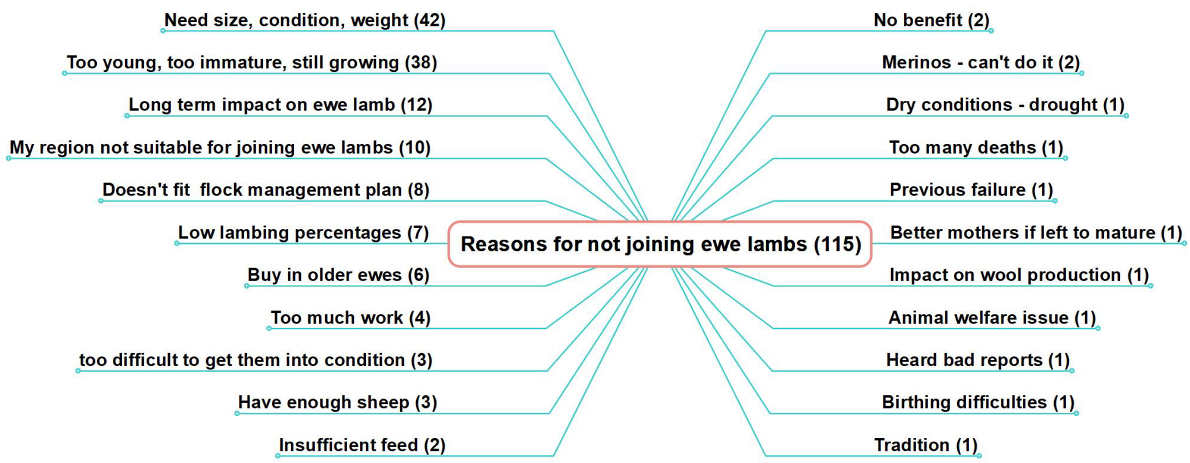


Figure 4.5. Summary of reasons for not joining ewe lambs. Numbers in parentheses indicate number of producers indicating that reason. Producers could nominate more than one reason.

4.3 Conclusions

From the survey of 500 producers it was found that 23% of producers had joined ewe lambs in 2019 (or in the most recent normal year), a further 21% had previously joined ewe lambs but didn't in 2019 and 55% of producers have never joining ewe lambs.

In addition to the 23% that joined ewe lambs in 2019, there are a further 10% of producers that join ewe lambs when conditions are suitable. Hence, in a year with suitable conditions, it could result in approximately one-third of producers mating ewe lambs (23% that joined ewe lambs in 2019, plus 10% that mate ewe lambs when conditions are suitable, totaling 33%, see Table 4.9 below). Also 1% of the producers who had never joined ewe lambs, intend to do it from now on. So, if you add the 1% of producers that intend to mate ewe lambs from now on, to those who already mate ewe lambs, and then include those producers who mate in a suitable year, the estimate of the maximum number of Australian sheep producers currently mating ewe lambs would be 34% (Table 4.9).

Table 4.9. The proportion of producers that mate ewe lambs- already, when conditions suit and intend to do so from now on.

Category	% of producers
Mated ewe lambs in 2019	23
Mate ewe lambs when conditions suit	10
Have never mated ewe lambs but intend to do so from now on	1
Total	**34**

Almost three quarters of the ewes joined by the producers interviewed were Merino, but two thirds of the ewe lambs joined were Maternal/Cross-bred/Meat breeds (Figure 4.3). Hence, joining ewe lambs is a lot more prevalent with Maternals, Crossbreds, meat breeds and shedding sheep, than in Merinos.

Summarised in Table 4.10 is the proportion of Merino, Maternal and Shedding Sheep producers that mate ewe lambs, the percent they get pregnant, their overall scanning and marking rate to ewe lambs mated. The national averages (all sheep types included) are also presented (Table 4.10).

Table 4.10. The proportion of producers that mated ewe lambs in 2019

Group	% producers mating ewe lambs	% pregnant	Overall scanning rate (%)	Marking rate (%)	Lamb survival rate (%)
Australia	**23**	**78**	**98**	**76**	**77**
Merino	8	74	85	58	68
Maternal / Xbred / Meat	35	78	103	82	80
Shedding	77	82	87	77	88*

The indicative estimate of overall lamb survival rates out of ewe lambs is 77% (76% marking/98% overall scanning rate). This comprised of a lamb survival estimate from Merino ewe lambs of 68% and 80% from Maternal ewe lambs. *For shedding breeds there is limited data available, so caution should be taken with the implied lamb survival rate from shedding ewe lambs of 88%. More data will be collected on reproductive performance of ewe lambs of different breeds in subsequent stages of this project.

The average ewe lamb mortality rate was 5.9%, which is similar to estimates of adult ewe mortality rates. For instance, a recently completed MLA project (B.AWW.0237) 'Assessing and addressing on-farm sheep welfare' found across all their study farms, both Merino and Maternal enterprises, that the average ewe mortality rate was 4.9%.

Only one-third of the producers that mate ewe lambs scanned for multiples, around one-quarter scan wet-dry only and 40% of producers that mate ewe lambs don't scan them at all. Furthermore only 71% of producers run their ewe lambs separately from other age groups. Just over half of the producers mating ewe lambs employed a minimum joining weight when mating ewe lambs, which contrasted by the 29% of producers that had the policy of mating all ewe lambs. This is very useful background information on the practices associated with mating ewe lambs and will inform the adoption/education components of this project.

The barriers to mating ewe lambs were also documented. These include; ewe lambs not being big enough or mature enough to join successfully, it is not economically viable and/or not suitable in their region, they will have too many lambing difficulties, be poor mothers and their will be high losses of ewe lambs themselves. Also, the potential negative aspects associated with joining ewe lambs including the long-term impact on their reproductive performance and longevity, outweigh the limited benefits by mating them as ewe lambs to only achieve low lambing percentages.

5. Gap analysis- breeding ewe lambs what's known and not known

Prof Paul Kenyon from Massey University was engaged to write a review of 'Breeding ewe lambs- what's known and not known'. This formed the basis, along with the industry consultation and national survey in the previous sections of this report, for gap analysis to be undertaken to prioritise the key gaps in understanding that require further investigation and/or validation with ewe lambs.

5.1 Methods

Identify the key gaps that impact on the reproductive performance of ewe lambs and prioritising those that warrant further validation in on-farm trials was undertaken using a combination of approaches. These include;

a) The findings from market research with consultants and producers to identify the range in industry recommendations and practices for mating ewe lambs and barriers to adoption,
b) The findings from the survey of a random sample of 500 producers to determine the national baseline for the prevalence, performance, practices and attitudes associated with mating ewe lambs,
c) Professor Paul Kenyon from Massey University review 'Breeding ewe lambs- what's known and not known'.

5.2 Review- 'Breeding ewe lambs- what's known and not known'

Why breed ewe lambs

Although reproductive performance of ewe lambs is lower than mature ewes (see brief summary Table 5.1) breeding a ewe lamb to successfully wean her lamb(s) at one year of age, has the potential to increase lifetime reproductive performance, productivity and profitability.

Table 5.1. Brief comparison of reproductive performance of ewe lambs and mature ewes.

Trait	Comparison with Mature ewe
Onset of breeding activity within breeding season	Later due the need to achieve puberty prior to cyclic activity.
Length of breeding season	Shorter due to delayed onset
Regularity of oestrous length	More likely to be irregular
Length of oestrus period	Shorter. More likely to have oestrus without ovulation or ovulation without oestrus.
Mating behaviour	Less likely to seek and stand appropriately for the ram. Ewe lambs shy breeders. Studies suggest ram prefer mature ewes.
Suggested ram to ewe ratio	Need approximately half the ratio
Ovulation rate	Lower
Ovum/Ova quality	Lower
Conception rate	Lower due to above factors
Early pregnancy loss	Higher due to lower embryo quality and impaired uterine environment
Pregnancy rate	Lower due to above factors
Scanning percentage	Lower due to above factors resulting in less pregnant and less multiple bearing
Mid- Late pregnancy loss rate	Higher due to being more susceptible to abortive organisms, also appear to have higher spontaneous loss rate
Number of lambs born	Lower due to above factors
Gestation length	Shorter
Lamb birth weight	Lower
Colostrum production	Lower
Milk production	Lower
Mothering ability	Some studies suggest poorer but not all
Lamb survival	Lower due to above factors
Lamb weaning weight	Lower due to above factors

Further advantages from successfully breeding ewe lambs include: i) improved utilisation of additional feed grown in the spring period, through more lactating ewes on farm ii) increased total number of lambs weaned on farm per year, iii) an early selection tool for ewe replacements displaying greater reproductive potential, iv) if replacements are selected from progeny born to ewe lambs the generation internal can be decreased and greater selection pressure achieved through increased total numbers of lambs on-farm to select from, and v) greater greenhouse gas efficacy per kg of product produced.

However, there are a number of potential disadvantages, inclusive of those in Table 5.1, which limit farmer uptake, including;

i) often disappointing and variable reproductive performance,
ii) increased total flock feed demand,
iii) the need for heavier live weights at 7 to 9 months of age,
iv) potential for future ewe liveweight and productivity to be negatively affected if poorly managed,
iv) lambs born to ewe lambs generally display poorer survival and lighter live weights,
vi) potential for increased total farm costs,
vii) reduced management flexibility because young ewes must meet specific liveweight targets,
viii) increase workload,
ix) reduced wool productivity, and
x) the potential for greater mortality rates in their first year of life.

Known means to maximise ewe lamb reproductive success

In cattle it is known that the number of follicles a heifer is born with is affected by both environmental and genetic factors. Further, it is known that poor dam nutrition and health issues such as mastitis can negatively affect the progenies final follicle number and reproductive function as an adult. In sheep, there appears to be sparse data examining the impacts of the dam's management on the resulting progenies reproductive performance as a ewe lamb. *This may warrant investigation although it would likely require intensive studies, some of which may need to be lab based*.

Genetics can influence ewe lamb reproductive performance. Genetic traits known to influence ewe lamb performance include: i) date of lambing, ii) number of oestrous cycles within season and iii) fertility as a two-year old. There is also variation between breeds in; i) timing and live weight at puberty, ii) proportions displaying oestrus (i.e. puberty achievement) within season, iii) length of season, iv) pregnancy and reproductive rate and, v) lambing percentage. Heritability data on ewe lamb reproductive traits is sparse but growing. Overall the data suggests heritability of traits such as; age and live weight at puberty, fertility, fecundity, number of lambs born and weaned by ewe lambs are low to moderate at best.

Although, over time even with these lower heritability levels, ewe lamb reproductive performance can be increased. Progress can also be made through indirect selection. For example, it has been shown by Thompson *et al*. (2019) in Merinos that those ewe lambs with higher breeding values for growth post-weaning, fat and eye muscle area, or whose sires had greater breeding values for these traits were; younger at puberty, more likely to achieve puberty by 8 to 10 months, were more fertile, associated with lower rates of pregnancy loss and achieved a higher overall reproductive performance. As more heritability data and genetic correlations are identified, it would be expected that farmers will use this information when selecting appropriate sires. *Therefore, where possible ewe lamb and later reproductive and non-reproductive performance data (as they age), should continue to be collected in recorded in both commercial and non-commercial breeding flocks.*

Highly fecund breeds and individuals with the Booroola gene, display greater ewe lamb reproductive performance. Farmers can therefore choose genotypes to maximise reproductive performance.

There is only a defined period in which ewe lambs can be successful bred during their first year of life due to the restriction of needing to achieve puberty first, within the defined sheep breeding season. The earlier a ewe lamb can be bred and therefore weaned, it allows more time for her to recover before re-breeding as a two-tooth. The breeding season tends to be shorter in ewe lambs, compared to mature ewes, as the onset of puberty generally occurs much later in the natural breeding season than the natural onset of mature ewe breeding activity. It has been found that this delayed onset can result in many ewe lambs only achieving one or two oestrus events before seasonal anoestrous begins, limiting their potential breeding period. Ewe lambs are also more likely than mature ewes to display oestrous without ovulation or vice versa. Although in ewe lambs, ovulation rate generally does not increase across the first to third oestrous cycles, fertility rates do. Therefore, ensuring ewe lambs reach puberty as early as possible will increase the numbers available to be successfully bred. Failure of ewe lambs to achieve puberty prior to or at least early during the breeding period is a driving factor for poor pregnancy rates in ewe lambs. Thus, knowledge of factors ensuring early onset of puberty are important these include age, time with breeding season, exogenous hormones, the male effect, and live weight all of which will be individually discussed in the following sections.

Age affects when a ewe achieves puberty. It has been suggested that farmers could/should select first born lambs within the lambing season as replacements, most suitable for ewe lamb breeding, especially if their breeding is delayed until late in the breeding season to maximise their age. However, most commercial farmers do not collect data on individual birthing dates.

Time within the breeding season also influences success with ewe lamb breeding. Reproductive performance in ewe lambs is not only influenced by day-length, it also requires the ewe lambs to be physiologically mature enough to achieve puberty. This is driven by hormonal factors and influenced by muscle and fat accumulation. In New Zealand, the traditional start of ewe lamb breeding is the first week of May, approximately a month after mature ewes. This is predominantly due to a low proportion of ewe lambs spontaneously attaining puberty in the period prior to this date and has been characterised in New Zealand (Figure 5.1). The optimal timing of breeding is also affected by both location and genotype. *It is unknown if this has been characterised in maternal and Merino genotypes across Australia but if it has not there would be benefit in doing so. This information would identify the optimal time for individual farmers to breed their ewe lambs if the aim is to achieve high pregnancy rates*.

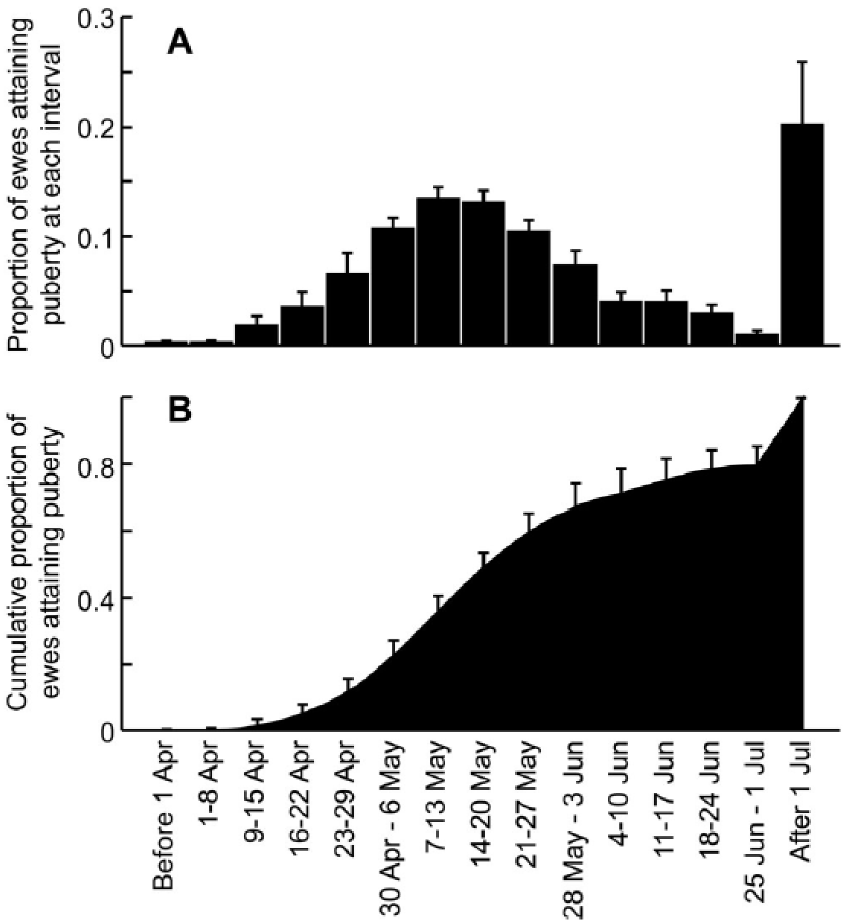


Figure 5.1. Adapted from: Edwards, S.J., Juengel, J.L.,2017. Limits on hogget lambing: the fertility of the young ewe. N.Z. J. Agric. Res. 60,1-22.

Puberty can be advanced though the use of either exogenous hormones or the ram effect, but both have limitations. Exogenous hormones can help ensure a ewe lamb reaches puberty and gets pregnant in her first autumn. However, the use of such regimens in light weight ewe lambs places the young ewe at risk of failure during later stages of pregnancy and/or in lactation or poorer performance as a mature ewe. Therefore, using exogenous hormones as a mechanism to advance puberty without an associated increase in live weight, through other management practices, is not recommended. The male (ram) effect, using vasectomised rams, can be used to advance breeding date, proportion of ewe lambs bred in the first 17-days of breeding and overall pregnancy rates. Data suggest that the optimal vasectomised ram to ewe lamb ratio is in the range of 1:70-100. Vasectomised rams should be used in the 17-day period directly prior to planned start of breeding. Short scrotum rams can also be used to induce puberty. *There appears to be sparse information on the use of hormone treated mature ewes or castrated males to induce puberty. This may warrant investigation under Australian conditions, if these groups are to be used on-farm to induce puberty*. However, care should be taken in utilising the male effect. While it may indeed increase pregnancy rates, it may set the ewe lamb up for failure in later stages of pregnancy, lactation or in future years if low live weights were the reason the young ewe had not naturally achieved puberty. It appears the focus of research on the male effect for inducing puberty has been just prior to the natural onset of puberty (i.e. mid/late Autumn). *There is a lack of information on trying to induce puberty and thus breeding outside this window. There is also a lack of information on the combined effects of the male effect and exogenous hormones.*

It is also important to note that in studies where ewe lambs were not bred, but achieved puberty in their first autumn, their later reproductive performance was greater than those that failed to achieve puberty. Therefore, using a vasectomised ram (or suitable alternative) to identify ewe lambs that achieve puberty in their first autumn can be used as a screening tool to select more fertile/fecund replacements in traditional systems where ewes are bred for the first time at an older age. *This may warrant investigation if it fits within the remit of the greater study.*

Live weight is likely the biggest driver of reproductive success of ewe lambs, within genotype. Greater ewe lamb live weights prior breeding is associated with a greater: i) proportion achieving puberty in their first autumn and ii) overall reproductive performance. Thus, factors affecting growth from birth to 8 – 10 months of age, will impact reproductive performance. It is known that both the growth and development of the ovarian follicle and its maturation to ovulation takes around six months. Therefore, ova quality is also affected by the environment the young ewe lamb is subjected too in its early life and potentially its in-utero experience. Current industry best practise guidelines in New Zealand for Romney type ewe lambs is that they need to be a minimum live weight of 42 kg at breeding. Farmers are advised to weigh a subset of their lambs monthly from their own weaning to ensure they are on the correct growth trajectory to achieve their target. Early identification of inappropriate live weights and changes in management to rectify any issues that arise, increases the chance for remedial action being effective. It has been found that faster growth pre- and post-weaning can result in the ewe lamb reaching puberty at a younger age, although at a slightly heavier live weight.

There is a general lack of an evidence to suggest ewe lambs respond to a 'flushing effect', in terms of greater proportion of multiple bearing ewe lambs. However, improved feeding levels just prior to, and during, breeding period increases live weight and the proportion of ewe lambs naturally achieving puberty prior to, or during the breeding period, increasing overall pregnancy rates. Reproductive data indicates pregnancy and fecundity rates in a large number of crossbred (Romney based) ewe lambs increased in a diminishing returns curvilinear manner up to a live weight plateau of approximately 48 kg. Similarly, in a subset of Merino ewe lamb's recent Australian data suggest a plateau of around 50 kg. *It is likely of benefit for more data in Australia, across a range of genotypes, to be collected to more accurately determine the relationship between live weight and reproductive performance.*

Further, it is well established in mammals that puberty occur in range of 40-65% of mature live weight. The same pre-mentioned large New Zealand data set indicated that ideally ewe lambs need to achieve 65% of their mature live weight by breeding, if high ewe lamb reproductive performance is to be achieved (Figure 5.2). Using this guideline, farmers can more accurately determine the appropriate minimum live weight for their own flock to achieve high ewe lamb reproductive performance. *These relationships appear not to have been examined in Australia and it would be of benefit to examine this.* Using percentage of mature live weight is a far better tool for farmers as ewe mature live weight can differ considerably between farms and therefore, a set industry live weight target can be somewhat meaningless.

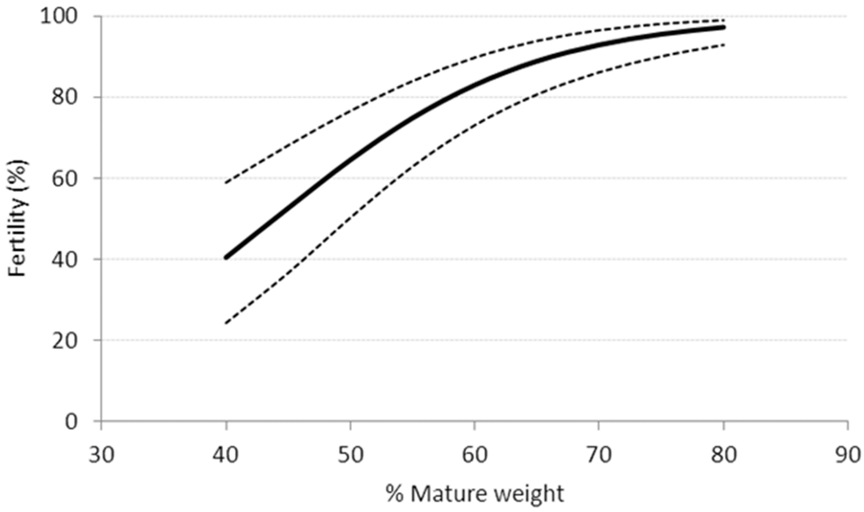


Figure 5.2. Adapted from: Kenyon PR, Corner-Thomas RA, Paganoni BL, Morris ST 2014. Percentage of Mature Liveweight Affects Reproductive Performance in Ewe Lambs. Proc. Aust. Soc. Anim. Prod. 30, 255

While body condition score (BCS) is known to have a general diminishing return relationship with most reproductive traits in mature ewes, less is known for ewe lambs. BCS in ewe lambs could be limited by the fact that a young animal is more likely to deposit lean (muscle) rather than adipose (fat) tissue. However, it has been suggested that a ewe lamb which displays greater levels of fat is more physiologically mature and more likely to achieved puberty and be breed successfully. Indeed, in the large New Zealand data set showed that pregnancy and fecundity rates rose in a diminishing returns curvilinear manner until a BCS of 3.0/3.5 was achieved (Figure 5.3), confirming data from smaller studies. *There is likely benefit from determining these relationships under Australian conditions with varying genotypes.*

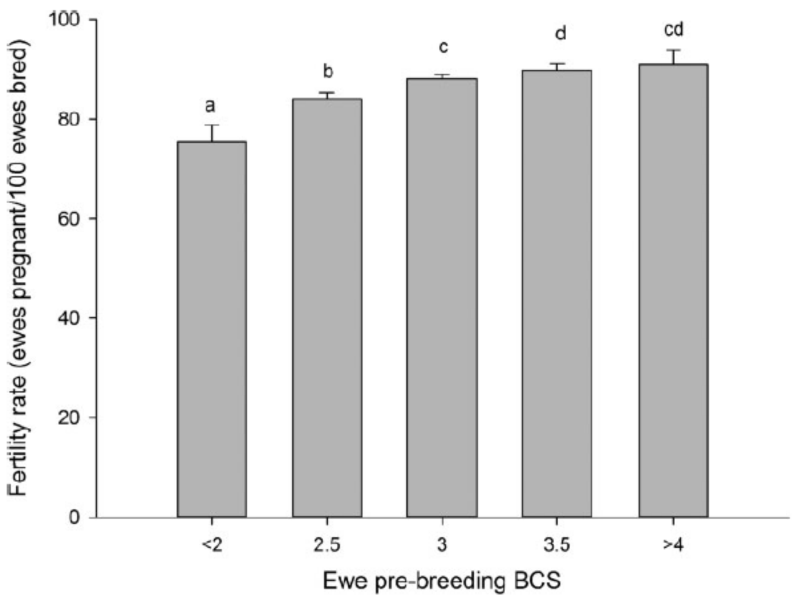


Figure 5.3. Adapted from: Corner-Thomas, R. A., Ridler, A. L., Morris, S. T., Kenyon, P. R., 2015. Ewe lamb live weight and body condition scores affect reproductive rates in commercial flocks. N.Z. Agric. Sci. 58, 26-34.

Pre-breeding shearing of ewe lambs has had inconsistent effects on ewe lamb breeding performance. However combined, the results suggest that shearing should be avoided within four weeks of breeding and during the breeding period. Shearing within this window can result in delayed onset of puberty, due to stress, and depressed ovulation and consequently pregnancy and multiple bearing rates. Although, under warm conditions in New Zealand, it has been suggested shearing can alleviate heat stress and thus stimulate appetite and live weight gain in young dry sheep. Therefore, it is a potential management tool to use before ewe lamb breeding, to help increase live weight and subsequent ewe lamb reproductive performance. *It appears this may not have been tested under Australian conditions and may warrant investigation, based on shearing policy and how timing of shearing may align with ewe lamb breeding.*

Ewe lambs are in oestrus (on heat) for only a relatively short period, are less likely to seek the ram and are less likely to stand for him, all of which individually, let alone combined, reduce pregnancy rates. Therefore more 'ram' power is required and traditionally ram to ewe lamb ratios of less than 1:50 have been advocated. However, more recent studies in New Zealand suggest ram to ewe lamb ratios of up to 1:75 are adequate, which is approximately half that used for mature ewes. Ram lambs as a breeding option should be avoided unless very low ratios are used. However, if progeny from ewe lambs are selected as replacements, then using both ewe and ram lambs minimises the generation interval. During the breeding period, ewe lambs and mature ewes should not be bred together as the more aggressive breeding behaviour of mature ewes will dominate the ram's attention. *It may be of benefit to examine ram ratios especially although, a ram to ewe lamb ratio of 1:50 is likely adequate.*

As indicated earlier, heavier live weights at breeding are associated with positive impacts on breeding performance. Therefore, improved levels of nutrition prior to, and during the breeding period, resulting in greater live weights will have positive effects on conception and pregnancy rates. However, high levels of nutrition over the breeding period, which result in live weights gains greater than approximately 170 g/d, the have been associated with higher returns to service rates in the first cycle of breeding, although overall pregnancy rates tend not to differ. This suggest that while farmers should ensure ewe lambs are gaining live weight prior to and during the breeding period, they should avoid very high live weight gains. The vast majority of these nutrition studies have been undertaken under pastoral conditions in New Zealand or using predominately concentrate feed types in the United Kingdom (UK). *Interestingly, in what appears to be the sole Australian study, in Merino ewe lambs live weight gains of up to 250 g/d did not show this affect, further studies are required to confirm this*.

The vast majority of pregnancy nutrition studies have also either occurred under New Zealand's pastoral conditions or in the UK under indoor conditions with concentrate feeds. The later studies have often been as a model for human studies examining aspects of teenage pregnancies. The UK studies, generally utilised concentrates as the main feed source, or even only feed source and have reported high live weight gains, frequently well above 200 g/d. These gains have been found to negatively affect pregnancy maintenance (i.e. cause fetal loss), fetal growth and subsequent birth weight, ewe and fetal metabolism, colostrum yield and lamb survival. However, caution is required when transferring these results to pastoral conditions due to the type of feed used, the live weight gains achieved, the fact that in many of these studies the ewe lambs were only 6 to 7 months of age at breeding and embryo transfer was often utilised. In UK studies where feeding conditions resulted in ewe lambs losing conceptus free live weight in pregnancy, they reported reduced fetal growth and lamb birth weight and reduced colostrum production.

Under New Zealand's pastoral conditions, pregnancy feeding resulting in live weight gains of approximately 180 g/d or greater for long periods of pregnancy, have also tended to result in higher rates of pregnancy loss rates and/or reduced lamb survival. Although, very few pastoral studies under New Zealand conditions have achieved live weights near or above 200 g/d and none have consistently reported gains throughout pregnancy in excess of 250 g/d. Current New Zealand pastoral based recommendations, indicate farmers should aim for total ewe lamb live weight gains throughout pregnancy in the range of 120 to 150 g/d. These recommendations are based on meeting the expected conceptus mass weight at term, plus allowing for the young dam to grow herself, especially in the first two-thirds of pregnancy. By continuing to grow herself in pregnancy the young dam will also be better prepared for parturition and lactation and allows for an easier transition towards rebreeding. Analysis has also indicated in ewe lambs with total live weight gains of approximately 200 g/d are less efficient in terms of kg feed consumed per kg of lamb live weight, a significant proportion of this effect is likely explained by the poor performance exhibit by those feed at higher levels. *It could be presumed that similar live weight guidelines would be appropriate in Australia. However, in farming systems that utilise a significant proportion of grain/concentrates as a feed source may wish to re-examine the effects of live weight change in pregnancy to identify the optimal live weight change profile.*

Ewe lamb live weight at all stages of pregnancy can have a small positive impact on the weight of her lamb(s) to weaning. However, modelling has shown that live weight of the ewe lamb at breeding compared to the various stages of pregnancy, has the biggest impact on both her live weight and that of her offspring at weaning. Somewhat it contrast to the potential negative effects of live weight gain in pregnancy on pregnancy outcome, higher live weight gains, at least up to 180 g/d, have been associated with greater lamb weaning weights. Further, the greater the live weight gain between mid-pregnancy and late pregnancy and the heavier the ewe lamb in late pregnancy, the greater the chance that a ewe lamb will successfully rear her lamb to weaning (Figure 5.4). Combined these indicate the importance of achieving both adequate live weight at breeding and in late pregnancy. The sparse data available suggests BCS of the ewe lamb in pregnancy has no impact n the weight of her offspring at weaning however high BCS may have negative effects on lamb birth weight. *Although, increased BCS data is likely warranted to allow for more firm guidelines to be developed*.

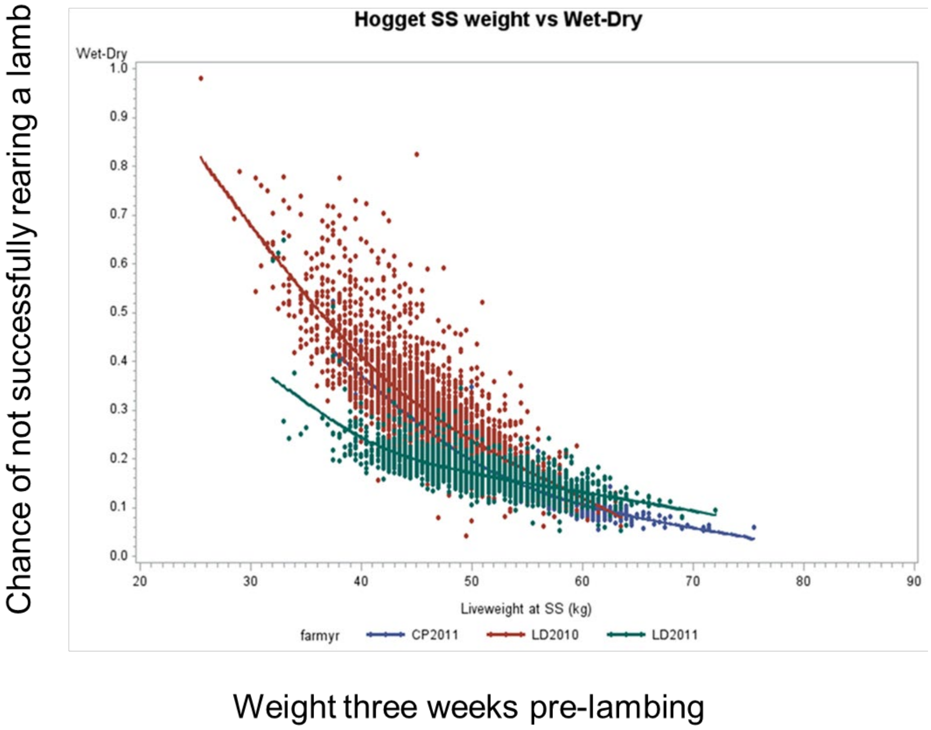


Figure 5.4. Adapted from Griffiths, K. J., Ridler, A. L., Heuer, C., Corner-Thomas, R. A., Kenyon, P. R., 2016. The effect of liveweight and body condition score on the ability of ewe lambs to successfully rear their offspring. Small. Rumin. Res. 145, 130-135.

Losses of pregnancy are greater in ewe lambs than in mature ewes, although the causes of many of these losses are poorly understood. As indicated earlier very high live weight gains in pregnancy can be an issue, although the total live weight gains required are likely well above conditions occurring on the vast majority of New Zealand farms. Under New Zealand conditions, low live weights pre-breeding and low live weight gains in early pregnancy are also risk factors for fetal loss. Further, there is data which indicates that ewe lambs who loose conceptus free live weight in pregnancy are more likely to have subsequent fetal loss. However, it is not known if this is a cause and effect relationship or if the loss in conceptus free live weight occurs as a result of pregnancy loss. Therefore, as indicated above, adequate live weights at breeding are important and farmers should aim for their ewe lambs to gain between 120 to 150 g/d in total live weight throughout pregnancy to minimise the risk of fetal loss. In addition, ewe lambs are naive in regards to abortive organisms and therefore in New Zealand vaccination programmes are used to protect against abortive organisms such as toxoplasmosis and campylobacteriosis. A number of studies have examined other disease causes of abortion and while they have on occasion been found, they are rare. *Further research is still required to identify 'other' consistent risk factors, and causes, for unexplained pregnancy losses in ewe lambs in New Zealand, and this is likely the case for Australia too. It is recommended that any study undertaken involving pregnant ewe lambs has a protocol in place to collect aborted material and it is worthwhile to scan both in mid and late-pregnancy (i.e. twice) to detect fetal loss*.

Mid-pregnancy (between approximately days 50 and 110 of pregnancy) shearing mature ewes is a well established as a management technique to positively effect on lamb birth weight and survival, especially in multiples. Less research has been undertaken with ewe lambs. The few studies that have been conducted suggest mid-pregnancy shearing can increase singleton lamb birthweight, but not twins, but it does not influence survival. It is possible that the later lambing dates (i.e. in the warmer later spring period) limits the potential advantage in terms of survival from heavier lambs at birth. Conversely, any management technique that increases birth weight, especially in young dams that are not well grown risks increasing losses due to dystocia. *There appears to be a lack of studies examining the potential impacts of late pregnancy shearing (after day 110 of pregnancy) in ewe lambs*.

Although industry often state perinatal (around the time of birth) lamb losses are far greater in ewe lambs than mature ewes, few studies have directly compared losses when the two age classes have been lambed together. Scientific literature which does not directly compared the two ewe age classes suggests higher lamb loss rates (12 to 60%) with ewe lambs. While the sparse data available from studies directly comparing the two ewe age classes, indicates only slightly higher loss rates although this has not always the case. It has also been found that due to less multiples with ewe lambs, 'mob average' lamb loss rates can be similar to that of mature ewes. Dystocia (or birthing difficulty) is reported as a major cause of progeny mortality, followed by starvation-exposure with ewe lamb breeding. Dystocia is predominantly driven due to the pelvic opening not being proportionally large enough to expel the fetus, this is especially an issue if the ewe lamb is not well grown. Farmers can mistakenly think they can reduce feed intake in later stages of pregnancy to mitigate against this. However, this will not significantly influence birth size/weight which is predominately driven by the genetic make of the fetus and the genetic ability of the ewe lamb to partition nutrients to the placental-fetal unit. To limit dystocia, farmers need to ensure ewe lambs are well grown via appropriate feeding levels prior to, and throughout pregnancy, so that the young dam continues to grow and is structurally large by lambing. *Appropriate sire selection for breeding is important and likely warrants further investigation in terms of both breed types and lines of sires within breeds who produce smaller but vigorous lambs at birth*.

Appropriate feeding levels will also reduce the risk of starvation-exposure by helping ensure lambs are of adequate size at birth and the young dam is producing suitable levels of colostrum and milk. Multiple born to ewe lambs are at greater risk of death due to starvation exposure than singletons. Therefore appropriate paddock selection, feeding levels and human intervention plans are required. Few studies to date have examined the optimal birth weight for lamb survival however the few data that exists suggests it's in the 4.0 to 5.0 kg range. *This also requires more research to quantify for various genotypes.* It appears the impacts of paddock size, slope, level of shelter, stocking rate, mixed mobs (both pregnancy rank and age) and mob size have not been examined with ewe lambs. *Advice given in regards to these factors has been primarily extrapolated from data collected for older ewes and further research is required.*

To date the vast majority of nutritional studies with ewe lambs have focused on the pre-breeding and pregnancy period. Very few studies have examined feeding levels in lactation. Therefore, the pastoral feeding guidelines in lactation indicate that intakes should not be limited, if the young dam is to continue to grow to meet later live weight targets and maximise milk production and so that her lamb(s) have unrestricted access to feed. *However, more studies are needed to quantify the optimal feeding level in lactation, for both the young dam and her progeny, to determine the cost effectiveness of varying feeding regimens*. In New Zealand, alternative herbages such at Herb clover mixes and pure Lucerne swards have been shown to increase the weight of the both the young dam and her lambs to weaning compared to unrestricted ryegrass white clover grazing conditions. *There are likely similar herbage options than could be assessed in Australia*.

There is a lack of studies who have examined the potential interactions between feeding levels in pregnancy and lactation. It might be expected that the importance of appropriate feeding levels in pregnancy are more important, in terms of both short- and long-term impacts for the ewe lambs and her offspring, that lactational feeding. This is especially the case when lambing is timed to match spring herbage growth. *This may warrant investigation however it is likely unwise to examine the impact of poor feeding levels in pregnancy to determine if these impacts can be mitigated against by improved feeding in lactation.*

There is also a lack of studies in ewe lambs examining the potential interactions between BCS and feeding levels, in either pregnancy or lactation. This may be due to the difficulty of achieving high BCS in young growing animals which tend to be more likely to deposit lean rather than fat tissue. It is important that regardless of BCS that the ewe lamb continues to grow structurally during pregnancy to reduce the risk of birthing difficulties. Therefore, while it might be expected that a ewe lamb of higher BCS can better buffer against poor feeding levels, as is the case with mature ewes, it is not an ideal situation if it impacts her growth. Further restricting ewe lambs of high BCS in lactation may limit their ability to achieve suitable live weight/BCS targets at rebreeding. *However, there may be benefit in examining these potential interactions to determine if this is indeed the case in either pregnancy or lactation.* Interestingly it has been suggested that growth rate of the young ewe pre-puberty can influence subsequent milk but not colostrum production at her first lactation. *Further work is required to validate this and to quantify the size of the effect.*

Under New Zealand conditions lambs born to mature ewes are weaned at approximately 100 days of age. Due to ewe lambs being bred approximately 30 to 45 days after mature ewes in New Zealand, farmers have two options in regard to weaning age/time. They can either wean lambs at approximately 100 days of age, however this reduces the time for the young ewe to gain live weight and body condition before rebreeding at 18 months of age, with the remainder of the mature flock. Alternatively, lambs born to ewe lambs can be weaned earlier. Early weaning of lambs born to ewe lambs has successfully occurred at 60 days of age onto high quality alternative herbages. This allows for a similar date of weaning on-farm regardless of ewe age class.

There is a lack of data examining the impacts of differing management and feeding regimens post weaning to ewe lamb rebreeding as a two-tooth. Given the established relationships between both live weight and body condition with reproductive performance in older ewes, it would be expected any intervention which ensures the young ewe continues to gain live weight and BCS post the weaning of her lambs, to meet appropriate targets would have positive impacts on her future performance.

Long term studies examining the impact of ewe lamb breeding

The literature can be somewhat inconsistent in terms of the longer-term impacts of breeding ewe lambs. Most of these studies have been undertaken under New Zealand and UK conditions. Although many studies have reported lighter live weights at 18 months from ewe lamb breeding, in most studies the impact has been relatively small in terms of live weight reduction. The potential for these lighter live weights to have negative consequences on two-tooth breeding performance only occurs if a significant negative impact on rebreeding live weight is observed (it has been suggested that it should not be greater than 3 kg).

Although, any impact on two-tooth live weight has been found not to persist past the weaning of her second set of lambs. While breeding as a ewe lamb can negatively affect fleece weight to approximately 18 months of age, no longer term impacts have been reported. When appropriate two-tooth live weight and body condition score targets have been meet the lifetime reproductive performance of ewes bred as a ewe lamb has been found to be greater than those that were not breed. Combined the results indicate the importance of appropriate feeding guidelines for ewe lambs in pre-breeding and in pregnancy/lactation periods to ensure two-tooth breeding weight is not negatively affected. Therefore, it can be suggested that the entire potential success of ewe lamb breeding, in terms of lifetime performance, is dependent on her management in the first 18 months. Many farmers have concern in regard to ewe lamb breeding negatively affecting longevity, but this has not been reported in the literature when live weight targets have been met. *There appears to be a lack of Australian data examining the potential long-term impacts of breeding ewe lambs.*

Selecting progeny born to ewe lambs as replacement ewes

There is currently sparse information on the long-term consequences of selecting progeny born to ewe lambs as replacement ewes. In late pregnancy, fetuses from ewe lambs tend to be lighter than those from mature ewes, as are lamb birth weights and live weights to at least one year of age. Further, it has been found that reproductive performance of ewe lambs born to ewe lambs are lower than those born to mature ewes, predominately driven by lower live weight. This suggests lambs born to ewe lambs may themselves be less suitable for breeding as a lamb. To date there is a general lack of data examining if this apparent negative effect would still apparent if heavier live weights at breeding could be achieved in progeny born to ewe lambs. When progeny born to ewe lambs were not bred until 18 months of age, no difference in reproductive and lactational performance has been observed. In addition, the lifetime reproductive data of these ewes to five years of age did not differ. Although interestingly, twins born to ewe lambs remained lighter than progeny born to either mature ewes or singletons born to ewe lambs, throughout their lifetime. *However, it needs to be acknowledged that the few studies to date, which have examined the effects of selecting progeny born to ewe lambs have included relatively low numbers of animals. Therefore, further studies are required to verify these apparent results*. One such studies is underway currently in New Zealand.

5.3 Results and Discussion

This Results and Discussion section summarises the key findings from each component of the project that inform the gap analysis for ewe lambs. This includes;

- Market research with consultants and producers to identify the range in recommendations and practices for mating ewe lambs to lamb at 12 to 15 months (section 5.3.1),
- National baseline of practices and attitudes associated with mating ewe lambs (5.3.2), and
- ‘Breeding ewe lambs- what’s known and not known’ (summary of research priorities for ewe lambs- 5.3.3).

5.3.1 Market research with consultants and producers to identify the range in recommendations and practices for mating ewe lambs to lamb at 12 to 15 months

Consultative analysis was undertaken with leading sheep industry consultants, extension specialists and producers running maternal, shedding or merino ewe lambs in both Australia and New Zealand to determine the range in current industry recommendations and suggested best practice for managing ewe lambs to lamb at 12-15 months. The approach taken highlighted the wide variation in recommendations and practices for ewe lambs around key management decisions such as joining weight/condition score, growth path to and during joining, growth path during pregnancy, vaccination, weight/condition score targets at lambing, feed-on-offer targets at lambing, paddock allocation and mob size for lambing, weaning age and weight/condition score targets for second joining, and genetic selection strategies.

Consultants feedback as to what the optimal package for improving the performance of ewe lambs that lamb at 12-15 months varied markedly (Table 5.2). Basically, this process verified the need for best practice guidelines for mating ewe lambs and to managing their pregnancy, lambing, weaning and recovery. Consultants had a lot of thoughts for the stages- ewe lamb selection, pre-mating and mating practices/targets but their recommendations varied a lot. Whereas for pregnancy, lambing/lactation and weaning/recovery the consultants had few recommendations that were specific to ewe lambs, just guiding clients to manage pregnant ewe lambs similar to their adult ewes.

Table 5.2. Suggested best practice for mating ewe lambs to lamb at 12-15 months

Stage	Practice	Consultant recommendations
Selection strategies for mating	Proportion of ewe lambs that should be mated	30-100% of drop
	Based on weight	85% Yes 15% No
	Based on born as multiple	20% Yes 80% No
	Base on born early in the drop (increase age at mating)	30% Yes 70% No
	Minimum mating weight for ewe lambs	38-50 kg
Pre-mating	Vaccinate for campylobacter prior to mating	60% Yes 40% No
	Use of teasers prior to mating	70% Yes 30% No
	Flushing on lupins or beans or green feed prior to mating	30% Yes 70% No
Mating	Recommended growth rate during mating	100-250 g/day
	Recommended age for mating ewe lambs	7-11 months
	Recommended ram density for mating ewe lambs (ram %)	2-4%
	Recommended joining length (weeks)	4-7 weeks
	Use low birth weight rams for mating ewe lambs	65% Yes 35% No
Pregnancy	Pregnancy scan for multiples (0, 1, multiple) in ewe lambs	100% Yes
	Recommend to keep or sell empty ewe lambs	Keep all to sell all
	Growth rate target for ewe lambs from mating to scanning	Nothing specific
	Growth rate target for singles from scanning to day 130	Nothing specific
	Growth rate target for twin from scanning to day 130	Nothing specific
Lambing and lactation	Condition score target for singles at lambing	Nothing specific
	Condition score target for twins at lambing	Nothing specific
	Feed-on-offer target for lambing singles	Nothing specific
	Feed-on-offer target for lambing twins	Nothing specific
	Mob size target for lambing singles	Nothing specific
	Mob size target for lambing twins	Nothing specific
	Lamb survival targets for singles and twins from ewe lambs	Nothing specific
	Lamb growth targets for singles and twins from ewe lambs	Nothing specific
Weaning /recovery	Weaning age of lambs	Nothing specific
	Weight gain target post weaning for ewe	Nothing specific
	Value of splitting heavy and lite ewes at weaning	Nothing specific
	Condition score target for next mating	Nothing specific

The biggest challenges that consultants consistently nominated with ewe lambs were;

- highly variable results in scanning and marking rates,
- impact if not managed well on 2-year old performance,
- getting the ewe lamb back in condition for the next mating.

The research priorities that consultants consistently nominated with ewe lambs were;

- understanding the causes of the gap between scanning rates and marking rates,
- improving lamb survival out of ewe lambs by developing pregnancy profile management guidelines and lambing guidelines for factors such as mob size and feed-on-offer,
- ways to lift lamb birth weight without increasing dystocia problems,
- impact of growth rates and/or green fed during joining on reproductive rate,
- understanding the impact of growth path, rather than just weight at mating, on reproductive performance, and
- management guidelines to enhance subsequent reproductive rate of ewe lambs.

The priority for research of the different aspects of mating ewe lambs to lamb at 12-15 months that the producers consulted as part of objective 1, would like investigated are outlined below (Table 5.3).

Table 5.3. Producer priorities for research for mating ewe lambs

Aspects of mating ewe lambs that require further research	Producer priority
Pregnancy weight/condition score profile management and its impacts of ewe and lamb survival	1
Impact of growth rate during joining on scanning rates	2
Impact of mob size at lambing on lamb survival from ewe lambs	3
Impact of feed-of-offer during lambing on lamb survival and lamb growth rate from ewe lambs	4
Impact of sire birth weight and lambing ease ASBVs on the survival rates of ewe lambs and their lambs	5

In summary the key research priorities identified from consultation with advisors and producers as part of Objective 1, include;

- impact of growth rate and flushing with green fed or lupins during joining on ewe lamb reproductive rate,
- pregnancy weight/condition score profile management and its impacts of ewe and lamb survival and lamb growth rates,
- impact of mob size at lambing on lamb survival from ewe lambs, and
- management guidelines for ewe lambs on their first lactation and recovery period to enhance subsequent reproduction rates.

5.3.2 National baseline of practices and attitudes associated with mating ewe lambs

The information gathered from surveying 500 producers nationally has been detailed fully in the previous section of this report. However, the management practices, attitudes, barriers to adoption and range in targets for ewe lambs documented can help identify key research gaps/information that needs to be gathered in the remaining stages of this project. The priorities that warrant further investigation/proofing include;

- **most productive and profitable approach for selection of ewe lambs for joining;** where currently 52% of producers who joined ewe lambs employ a minimum joining weight but that target ranges from 38 to 60 kg (90% of responses within that range) and yet 29% of producers just joining them all- so what is the right approach? Do you just feed them all and let the ram class them, or if the protocol for mating ewe lambs does promote a minimum joining weight what is the basis to that, such as ewe lamb reproductive rate, ewe and lamb survival rates, subsequent reproductive rate and longevity.
- **Concerns that ewe lambs are not big enough to get in lamb;** this is the primary barrier to producers mating ewe lambs. This project needs to identify for different breed types- Merino, Maternal and Shedding sheep what are the key characteristics of ewe lambs themselves and their flocks of origin that predispose them to being able to be joined as ewe lambs, as well as the management package/nutrition profile that needs to be implemented to ensure success. Producers that are contemplating mating ewe lambs can then use these key considerations to inform their decision to mate or not to mate as either a strategic decision (will I mate or not, as an ongoing strategy in my flock) or a tactical decision (will I mate or not in this current season).
- **Concerns that there will be too many difficulties lambing down ewe lambs;** this is also a key barrier to producers mating ewe lambs. This project needs to identify for different breed types- Merino, Maternal and Shedding sheep the management package, nutrition profile and targets at key stages that needs to be implemented to ensure reproductive success. This same barrier was identified in PDS research conducted almost 10 years ago into mating ewe lambs, yet for every producer involved in those trials, this concern was allayed by the actual outcomes achieved- in other words the ewe lambs lambed down much better than they were anticipating. Once the full protocols for mating and managing ewe lambs to lamb successfully are in place, the opportunity that exists will need targeted promotion to flocks that could capitalise on mating ewe lambs.
- **The economic viability of mating ewes;** this project needs to conduct economic modelling on the factors that influence the profitability of mating ewe lambs but also examine the potential profitability of mating ewe lambs compared to other opportunities in their flock, such as twin lamb survival from adult ewes. This modelling will form a central component of the supported learning training package for producers mating ewe lambs and will build on the decision support tool already commenced by John Young, Farming Systems Analysis.
- **Concerns the age and maturity of ewe lambs;** this is another barrier to producers mating ewe lambs. This project needs to examine the impact of age at first mating on ewe lamb reproductive rate, ewe and lamb survival rates, subsequent reproductive rate and longevity. This will provide guidance for producers on the appropriate age for mating ewe lambs and some of the trade-offs that existing, enabling producers to make a more informed decision and potentially overcome this barrier to mating ewe lambs.

5.3.3 'Breeding ewe lambs- what's known and not known' (summary of research priorities for ewe lambs)

In the table below the areas of potential research in ewe lambs are summarised (Table 5.4). Also, the level of priority for each piece of research (high, medium or low) to address gaps in understanding that impact on-farm performance and the stage of the reproduction cycle of the ewe lamb the research relates to, is outlined (Table 5.4).

Table 5.4. Potential areas requiring further research in ewe lambs

Potential research gaps	Priority level	Period
Gain knowledge of timing of natural onset of puberty for differing environments and for both maternal and Merino genotypes	Low	Pre-breeding
Examine potential use of hormone treated mature ewes or castrated males to induce puberty	Low	Pre-breeding
Examine use of male effect and exogenous hormones to ensure puberty either outside of very early in the natural breeding season (relevant to flocks that lamb down adult ewes in autumn and mate ewe lambs early)	Medium	Pre-breeding
Examine the impact of growth rate of the young ewe pre-puberty on subsequent milk production	Low	Pre-breeding
Examine use vasectomised rams (or suitable alternative) to identify ewe lambs that achieve puberty in their first autumn but not presented for breeding until following year	Low	Pre-breeding
Effect of the dam's management on the resulting ewe progenies reproductive performance when they are bred as a ewe lamb	Low	Pre-breeding
Effects of stressors on puberty onset	Low	Pre-breeding
Examine the impact of live weight gain just prior to and during breeding on ewe lamb reproductive performance	High	Pre-breeding/Breeding
Identifying relationships between BCS at breeding and reproductive performance across Merino and maternal genotypes	High	Breeding
Identifying the relationship between live weight at breeding and reproductive performance across both maternal and Merino genotypes	High	Breeding
Identifying relationship between percentage of mature weight and reproductive performance for both maternal and Merino genotypes	High	Breeding

Potential research gaps	Priority level	Period
Development of ABVs to improve reproductive performance of ewe lambs to ensure high pregnancy rates	High- but outside scope of this project	Breeding
Development of ABVs to reduce ewe lamb and her offspring losses through dystocia	High- but outside scope of this project	Breeding
Identifying appropriate sires, breeds and ABV's which produce smaller but vigorous lambs at birth	High- but outside scope of this project	Breeding
Examine ram to ewe lamb ratios	Medium	Breeding
Examine the impact of live weight gain in early- and mid-pregnancy on pregnancy maintenance and performance in lactation	Medium	Pregnancy
Examine the impact of BCS in pregnancy on lactation performance and its interaction with feeding level	Medium	Pregnancy
Examine the impact of live weight gain in late pregnancy on pregnancy maintenance, lamb survival and performance in lactation	High	Pregnancy
Identify level of pregnancy loss and causes and risk factors associated with these losses	Medium	Pregnancy
Identify optimal birth weight	Medium	Pregnancy/lactation
Examine potential interactions between feeding levels in pregnancy and in lactation	Medium	Pregnancy/lactation
Examine the potential interactions between BCS and feeding levels, in either pregnancy or lactation	Medium	Pregnancy/lactation
Examine impacts of paddock size, slope, level of shelter, stocking rate, mixed mobs (both pregnancy rank and age) and mob size	High	Lambing/Lactation
Identify and quantify the optimal pastoral feeding level in lactation	Medium	Lactation
Identify if alternative herbages can lift performance in lactation	Medium	Lactation
Examine the potential long-term impacts of breeding ewe lambs on future reproductive performance and longevity, including impact of weaning age of first lactation	High	Post weaning
Examine the effects of selecting progeny born to ewe lambs as replacement	Low	Post weaning

5.4 Conclusions

The on-farm trials in this project will each run for at least 18 months, which presents the opportunity to undertake trials/interventions at four distinct stage of their reproduction cycle; joining, pregnancy, lambing and lactation/recovery. All potential research gaps rated as 'High priority' in the review undertaken by Paul Kenyon have been shaded in green in the Table 11 above and will be addressed in the on-farm trials in this project (Table 5.5), with the exception of 'identifying relationship between percentage of mature weight and reproductive performance' as waiting for the ewes to mature is beyond the scope/time-frame of this current project. Also, incorporating outcomes from consultation with producers and advisors, the research priorities pin-pointed from the full process undertaken to be addressed in the on-farm trials are summarised in Table 5.5 below.

Research priorities 1 and 2 will be addressed by interventions/treatments imposed during the relevant stages of the ewe lamb reproduction cycle. Whereas Research priority 3 will be addressed by connective analysis of data across numerous data sets that have recorded ewe lamb live-weight and condition score at joining and subsequent conception and reproductive rate.

Table 5.5. Research priorities identified by the overall gap analysis process

	Stage of ewe lamb reproduction cycle			
	Joining	**Pregnancy**	**Lambing**	**Lactation/recovery**
Research priority 1	Impact of growth rate during joining on reproductive rate	Impact of live-weight change in late pregnancy on lamb survival and lamb growth rate	Impact of mob size during lambing on the survival of lambs from ewe lambs	Impact of weaning age during first lactation on subsequent reproductive rate
Research priority 2	Impact of short-term flushing on lupins and/or Lucerne on reproductive rate	Impact of live-weight change in late pregnancy on ewe survival and subsequent reproductive rate	Examine the impact of ewe lamb joining weight on ewe and lamb survival rates	Examine the impact of ewe lamb joining weight on subsequent reproductive rate and longevity
Research priority 3	Identifying the relationship between live weight and BCS at joining and reproductive rate			
Research priority 4	Identifying relationship between percentage of mature weight at joining and reproductive rate			

6. On-farm research

A total of 50 research sites have been established for this project between 2020 and 2023 (Table 6.1). This includes 16 sites joining Merino ewe lambs, 25 sites joining maternal ewe lambs, and 9 sites joining ewe lambs of a shedding breed. The criteria of a minimum of 400 ewes joined per site was exceeded at all sites, with between 406 and 3348 ewes joined at each site (Table 6.1). Over 57,000 ewe lambs have been joined as part of the project on a combination of commercial and seed-stock enterprises.

Table 6.1. Site leader, location, breed, number of ewe lambs joined, at research sites established across Australia between 2020-2022 as part of this project.

Site	Site leader	State	Postcode	Breed	Ewes joined
1	J.T. Agri-Source	VIC	3293	Maternal	686
2	J.T. Agri-Source	VIC	3301	Maternal	1127
3	J.T. Agri-Source	VIC	3379	Maternal	2130
4	J.T. Agri-Source	NSW	2656	Maternal	906
5	J.T. Agri-Source	VIC	3675	Maternal	800
6	J.T. Agri-Source	NSW	2877	Merino	482
7	J.T. Agri-Source	NSW	2820	Merino	1023
8	J.T. Agri-Source	VIC	3377	Maternal	2959
9	J.T. Agri-Source	VIC	3271	Maternal	2453
10	J.T. Agri-Source	VIC	3294	Maternal	3271
11	J.T. Agri-Source	NSW	2642	Maternal	492
12	J.T. Agri-Source	VIC	3301	Shedder	496
13	J.T. Agri-Source	NSW	2652	Maternal	452
14	J.T. Agri-Source	SA	5520	Merino	769
15	J.T. Agri-Source	VIC	3276	Shedder	1855
16	J.T. Agri-Source	VIC	3305	Maternal	1311
17	J.T. Agri-Source	VIC	3305	Shedder	406
18	J.T. Agri-Source	NSW	2868	Merino	1300
19	J.T. Agri-Source	VIC	3314	Merino	703
20	J.T. Agri-Source	SA	5291	Maternal	711
21	J.T. Agri-Source	VIC	3350	Merino	1800

Site	Site leader	State	Postcode	Breed	Ewes joined
22	Murdoch University	WA	6336	Merino	773
23	Murdoch University	WA	6395	Merino	1673
24	Murdoch University	WA	6395	Shedder	527
25	Murdoch University	WA	6304	Merino	680
26	Murdoch University	WA	6395	Merino	695
27	Murdoch University	WA	6317	Merino	967
28	Murdoch University	WA	6396	Maternal	1030
29	Murdoch University	WA	6317	Shedder	894
30	J.T. Agri-Source	NSW	2663	Maternal	2051
31	J.T. Agri-Source	NSW	2663	Maternal	1708
32	J.T. Agri-Source	NSW	2716	Merino	650
33	J.T. Agri-Source	NSW	2820	Merino	1006
34	J.T. Agri-Source	NSW	2630	Merino	601
35	J.T. Agri-Source	NSW	2843	Merino	827
36	J.T. Agri-Source	QLD	4357	Shedder	431
37	J.T. Agri-Source	QLD	4497	Shedder	414
38	J.T. Agri-Source	NSW	2399	Shedder	442
39	Murdoch University	WA	6394	Merino	622
40	J.T. Agri-Source	NSW	2720	Maternal	838
41	J.T. Agri-Source	SA	5291	Maternal	977
42	J.T. Agri-Source	VIC	3305	Maternal	2308
43	J.T. Agri-Source	VIC	3305	Shedder	913
44	J.T. Agri-Source	VIC	3675	Maternal	829
45	J.T. Agri-Source	VIC	3377	Maternal	3348
46	J.T. Agri-Source	VIC	3301	Maternal	1343
47	J.T. Agri-Source	VIC	3283	Maternal	890
48	J.T. Agri-Source	VIC	3300	Maternal	1880
49	J.T. Agri-Source	VIC	3241	Maternal	835
50	J.T. Agri-Source	VIC	3241	Maternal	721

6.1 Methods

Ewes were followed from their joining as a ewe lamb (7-10 months) through to pregnancy scanning at hogget age. At least 400 ewe lambs of Merino, maternal or shedding breeds will be joined at each research site. Experimental treatments will be undertaken at four distinct stages of the ewe lamb's reproductive cycle; (i) during joining, (ii) pregnancy, (iii) lambing and/or (iv) lactation/recovery. These treatments will investigate; (i) the impacts of short-term flushing with lupins or growth rate during joining on reproductive rate, (ii) the impact of change in liveweight or Regulin implantation during late pregnancy on ewe and progeny survival, (iii) the impact of mob size during lambing on the survival of lambs born to ewe lambs and examine the impact of ewe lamb joining weight on ewe and lamb survival rates, and (iv) the impact of age at weaning during the first lactation and the impact of ewe lamb joining weight on subsequent reproductive rate. Treatments are described in Table 6.2.

Data were analysed by the following methods using GENSTAT (Edition 22).

High and low growth joining treatments- to drive live-weight gain between rams in and rams out to generate differences in live-weight gain between the 'high growth treatment' and 'low growth treatment', while the ewe lambs were being mated. Liveweight change (paddock mean value) was assessed using the method of restricted maximum likelihood (GenStat Edition 22).

Joining growth treatment (high and low) and ewe liveweight at the start of the treatment period (paddock mean value) were fitted as fixed effects. The random terms fitted were farm and paddock (nested within farm). Upon a significant effect of treatment on liveweight change and hence impact on ewe, reproductive rate was examined at the individual ewe level using a General Linear Model with a multinomial distribution and logit link function with fitted effects of treatment, farm and ewe liveweight at the start of the treatment period. (VSN International 'GENSTAT for Windows.' 22nd edn. VSN International: Hemel Hempstead, UK).

Estimates of maiden ewe survival and maiden ewe wet-dry status at weaning were separately assessed by fitting Generalized Linear Mixed Models. For each measure single and twin bearing ewes were examined separately. The approach used a logit transformation and binomial distribution. Using additive models, logits were predicted as a function of liveweight at start of joining and liveweight change during pregnancy (not adjusted for conceptus) fitted as a fixed effect while experiment, farm (nested within experiment) and paddock (nested within farm) were fitted as random effects. The ewe liveweight variates were tested for quadratic effects.

The Method of Restricted Maximum Likelihood was used to fit mean lamb survival per mob with breed, pregnancy type (single or twin bearing ewe) and mob size and interactions thereof as fixed effects while year, farm (nested within year) and paddock (nested within farm) were fitted as random effects. Mob size was tested for quadratic effects.

Table 6.2. Treatments implemented between joining and weaning at research sites to investigate impacts on the reproductive performance of ewe lambs

Stage of ewe lamb reproductive cycle	Joining	Late pregnancy	Lambing	Lactation/recovery
Treatment	(a) Growth rate (b) Flushing	(a) Growth rate (b) Regulin inplant	Mob size	Time of weaning
Design	(a) Ewes will be divided into two treatments at the start of joining; 'High' or 'Low' growth rate. Target growth rates are ≥ 200g/hd/day for ewes in the 'High' group and 100 g/hd/day for ewes in the 'Low' group (b) Ewes will be divided into two treatments 7 days before the start of joining; Flushing or Control (no additional supplementation). Ewes may be flushed by feeding 500g/hd/day lupins from 7 days before until 7 days after joining with rams.	(a) Ewes will be divided into two treatments after pregnancy scanning; 'High' or 'Low' growth rate, achieved by; (i) altering the rate of supplementary feeding given, (ii) selecting paddocks with varying pasture composition, (iii) selecting paddocks with significant differences in FOO. The aim is for ewes in the 'Low' nutrition group to be fed to gain about 5kg in total weight (maternal ewe weight and foetus) between scanning and lambing, whereas the 'High' nutrition group will be fed to gain about 15kg in total weight between scanning and lambing. 11 - 12 sites/reps implementing the feeding treatment in late pregnancy with a minimum of 150 single and 100 twin bearing ewes per treatment.	Ewes will be divided into two treatments for lambing; 'High' or 'Low' mob size. Mob size for the 'Low' treatment must not be below 80 single-bearing ewes and 50 twin-bearing ewes. 'High' mob sizes must exceed the 'Low' mob size by at least 75 ewes. The characteristics of the lambing paddocks (e.g. shelter, FOO, pasture type) should be similar for the single- and twin-bearing ewes in the 'High' and Low' mob size treatments.	Half of the lambs will be weaned 'early' by removing 50% of ewes from the mob at 10-12 weeks from the start of lambing. The remainder will be weaned at ≥14 weeks of age.

		(b) Ewes will be divided into two treatments after pregnancy scanning; 'Regulin' or 'Control'. The Regulin treatment group will have a Regulin pellet implanted under the skin behind the ewe lamb's ear with, 1 x 18mg implant at Day 90-100 of pregnancy (from rams in). The control group doesn't receive any treatment. Both groups are weighed the day the treatments commence. The Regulin and Control groups can then be run together throughout late pregnancy, up until allocation for lambing at Day 130-140 of pregnancy (from rams in). This will help minimise any nutrition/animal health differences between the treatment groups so the impact of Regulin can be quantified. 7 - 8 sites/reps implementing Regulin in late pregnancy with a minimum of 150 single bearing ewes and 100 twin bearing ewes per treatment.		

6.2 Results and Discussion

6.2.1 Joining treatment- impact of growth during joining on reproductive rate

High and low growth joining treatments were implemented for Maternal ewe lambs. This was a major gap in understanding at the joining stage of Maternal ewe lambs. The response had already been documented in previous research conducted on Merino ewe lambs by Thompson *et al*. (2019). The objective of this treatment was to drive live-weight gain between rams in and rams out to generate differences in live-weight gain between the high and low growth treatments, while the Maternal ewe lambs were being mated. The summary of raw data from growth treatments is outlined in Table 6.3.

Table 6.3. Average (range) for weight (WT; kg) at the start of joining (rams in), change in WT (kg) between the start and end of joining, conception rate (%) and reproductive rate (%) for research sites investigating the impact of growth rate during joining on the reproductive performance of Maternal ewe lambs. Values presented are the raw data.

Breed	Joining treatment	Total ewes	WT at rams in	WT change during joining	Conception rate	Reproductive rate
Maternal	High growth rate	5610	44.0 (39.7 – 47.5)	5.3 (1.5 – 9.6)	80.4 (65.6 – 89.2)	119.7 (88.1 – 133.5)
	Low growth rate	5872	45.2 (40.4 – 52.5)	2.1 (-1.0 – 4.4)	74.6 (60.6 – 89.5)	108.3 (81.4 – 129.7)

Statistical analysis, found the high growth joining treatment gained 4.67 kg during joining and the low growth treatment gained 2.00 kg during joining, representing a significant difference of 2.67 kg ($p<0.001$). Given the significant live-weight change generated the effect of the treatments (high and low growth) on reproductive rate were examined. The effect of starting live-weight ($p<0.001$) and joining growth treatment ($p<0.001$) in maternal ewe lambs on the percentage of dry, single, twin, triplet ewe lambs and overall reproductive rate are outlined in Table 6.4 (Values presented are predicted values).

Table 6.4. The impact of live-weight at the start of joining, and joining growth treatment (high and low), on the percentage (%) of dry, single, twin, triplet ewes lambs and overall reproductive rate.

Starting liveweight	Joining Treatment	Dry	Single	Twin	Triplet	Reproductive rate (lambs per 100 ewes)
30	50	58.2	33.3	8.4	0.1	50.3
35	50	43.0	42.4	14.4	0.2	71.8
40	50	30.4	46.8	22.5	0.3	92.7
45	50	21.3	46.4	31.9	0.5	111.6
50	50	15.1	42.9	41.2	0.8	127.6
55	50	11.2	38.2	49.2	1.1	140.6
60	50	8.7	33.7	56.3	1.4	150.4
30	150	53.2	36.6	10.1	0.1	57.1
35	150	38.1	44.5	17.1	0.2	79.4
40	150	26.3	47.1	26.2	0.4	100.7
45	150	18.1	45.0	36.3	0.6	119.5
50	150	12.7	40.3	46.1	0.9	135.2
55	150	9.3	35.0	54.4	1.3	147.7
60	150	7.2	30.3	60.8	1.7	157.1

30	250	48.2	39.6	12.1	0.1	64.2
35	250	33.5	46.1	20.1	0.3	87.2
40	250	22.5	46.7	30.3	0.5	108.6
45	250	15.3	43.0	41.0	0.8	127.3
50	250	10.6	37.3	50.9	1.1	142.6
55	250	7.7	31.6	59.0	1.6	154.5
60	250	5.9	26.9	65.0	2.1	163.3

As outlined, after live-weight gain was adjusted with starting live-weight the differences in live-weight gain generated between the high and low treatments was 2.67 kg ($p<0.001$), which equates to 76 g/day difference in growth over a 35-day joining, between the high and low growth treatments. As shown in Table 6.4 for Maternal ewe lambs the response to weight gain during joining, where increasing weight gain by 100 g/day, equates to around an 8% lift in reproductive rate.

6.2.2 Joining treatment- impact of flushing during joining on reproductive rate

Flushing joining treatments were implemented for ewe lambs. This was a major gap in understanding in the response to flushing in ewe lambs. The flushing treatment was implemented using 500 g/day of Lupins fed to ewe lambs from 7 days before joining until 7 days into joining (a total of 14 days). The objective of this treatment was to quantify the impact of flushing ewe lambs on both conception and reproductive rate. The summary of raw data from the Lupin flushing treatments is outlined in Table 6.5.

Table 6.5. Average for weight (WT; kg) at the start of joining (rams in) and end of joining (rams out), change in Average daily gain (g/hd/day) between the start and end of joining, conception rate (%) and reproductive rate (%) for research sites investigating the impact of Lupin flushing at the beginning of joining on the reproductive performance of ewe lambs. Values presented are the raw data.

	Flushed	Not Flushed
Total number of ewes	4931	5268
Joining weight (kg)	42.0	42.0
End of joining weight (kg)	46.3	46.2
Average daily gain (g/hd/day)	66.6	73.4
Conception (%)	73.1	70.9
Reproduction rate (per 100 ewes)	95.6	93.2

Statistical analysis found that flushing ewe lambs with Lupins had no significant impact on their conception or reproductive rate ($p>0.05$) and the breed of the ewe lamb had no significant bearing on the response to flushing ($p>0.05$).

A key point to note and observation on the sites that implemented this treatment was that the ewe lambs often struggled to consume the extra supplement (500 g/day of Lupins) offered in the flushing period, over and above their paddock feed and base supplementation. Hence their true intact in most cases was much likely much less than 500 g/day, however this was not quantified in the on-farm trials, where the animals were trail fed on the ground.

6.2.3 Late pregnancy treatment- impact of growth rate on ewe and lamb survival

Twelve sites/reps were analysed for the effect of late-pregnancy nutrition. Ewes were divided into high and low nutrition treatments post-scanning to create growth rate differences between the treatments. The overall mean mob characteristics are outlined in Table 6.6 below.

Table 6.6. Mean mob characteristics for the late pregnancy nutrition experiment.

	Single birth type	Twin birth type
Joining weight (kg)	43.2	45.7
Mid pregnancy weight (kg)	48.1	54.3
Pre lambing weight (kg)	58.3	65.7
Stocking rate (ewes /ha)	10.3	8.0
Number of ewes at lambing	163	109

The effect of late pregnancy growth treatment and lamb birth type mob, on ewe growth rate (g/day), lamb survival (%) and ewe mortality (%) is shown in Table 6.7. The effect of the late-pregnancy growth treatment on ewe growth (g/day) was significant ($P<0.001$), with the low growth treatment gaining 128.3 g/day in late pregnancy and the high growth treatment gaining 284 g/day, on average (Table 6.7).

The effect of the late-pregnancy growth treatment on lamb survival was around 8% ($P<0.001$) with the low and high growth treatments having a lamb survival of 66.5% and 74.6%, respectively (Table 6.7). Both singles and twins had similar effect, interaction of treatment and birth type mob was not significant ($P=0.956$), to the growth treatment (Table 6.7).

Table 6.7. The effect of late pregnancy growth treatment and lamb birth type mob on ewe growth rate (g/day), lamb survival (%) and ewe mortality (%).

Birth type mob	Late pregnancy growth treatment	Ewe growth rate (g/day)	Lamb survival (%)	Ewe mortality (%)
Single		174.9	79.0	2.73
Twin		237.3	62.2	2.32
l.s.d. (P=0.05)		40.37	3.69	0.633
F prob		0.004	<0.001	0.182
	Low	128.3	66.5	3.58
	High	284.0	74.6	1.46
	l.s.d. (P=0.05)	35.74	3.31	0.587
	F prob	<0.001	<0.001	<0.001
Single	Low	95.7	75.0	3.73
	High	254.2	83.0	1.73
	Low	160.9	58.1	3.44
Twin	High	313.8	66.3	1.20
	l.s.d. (P=0.05)[A]	58.37	5.41	0.959
	F prob	0.866	0.956	0.670

[A] Based on the maximum treatment comparison

The effect of the late-pregnancy growth treatment on ewe mortality was around 2% (P<0.001) with the low and high growth treatments having ewe mortality rates of 3.58% and 1.46%, respectively (Table 6.7). Both singles and twins had similar effect, interaction of treatment and birth type mob was not significant (P=0.670), to the growth treatment.

The data collected in these trials has enabled us to examine the impact of joining weight and pregnancy weight gain on the mortality of the ewe lamb herself. For ewe mortality, their joining weight had a significant quadratic effect on the mortality of single and twin bearing ewes, while liveweight change during pregnancy had a linear effect on the mortality of single and twin bearing ewes (P<0.05, highest P given for any term fitted). Table 6.8 shows how the combination of joining weight and pregnancy weight gain impacts on single ewe mortality. The shading highlights combinations of join weight and pregnancy weight gain resulting in;

- Less than 1% ewe mortality- green shading (industry best practice),
- 1-3% ewe mortality- amber shading (acceptable mortality levels), and
- Greater than 3% ewe mortality- red shading (unacceptable mortality levels).

Table 6.8. Impact of joining weight and pregnancy weight gain on single ewe mortality.

LWCPreg	0	5	10	15	20	25	30
Join wt							
33			44.7	19.3	6.6	2.1	
35		48.7	21.9	7.7	2.4	0.7	
40	22.7	8.0	2.5	0.8	0.2	0.1	0.0
45	3.8	1.1	0.3	0.1	0.0	0.0	0.0
50	0.7	0.2	0.1	0.0	0.0	0.0	100.0
55		0.1	0.0	0.0	0.0		
60			0.0	0.0	0.0		

Table 6.9 shows how the combination of joining weight and pregnancy weight gain impacts on ewe mortality for twin bearing ewe lambs. The shading highlights combinations of join weight and pregnancy weight gain resulting in;

- Less than 1% ewe mortality- green shading (industry best practice),
- 1-3% ewe mortality- amber shading (acceptable mortality levels), and
- Greater than 3% ewe mortality- red shading (unacceptable mortality levels).

Table 6.9. Impact of joining weight and pregnancy weight gain on ewe mortality for twin bearing ewe lambs.

LWCPreg	5	10	15	20	25	30
Joinwt						
35			32.6	15.6	6.6	2.6
40	26.2	11.9	4.9	1.9	0.7	0.3
45	5.6	2.2	0.9	0.3	0.1	0.0
50	1.5	0.6	0.2	0.1	0.0	0.0
55		0.2	0.1	0.0	0.0	0.0
60		0.2	0.1	0.0	0.0	
65		0.2	0.1	0.0		

Current practice and extension messaging advocates joining the majority of your ewe lambs and let the rams do the drafting, especially if the cost of rams for mating ewe lambs is low (ie. using existing ram team by offsetting the ewe lamb mating time to after the main flock). At best, producers will have a joining weight they are targeting for the average of the mob, around which there is often a large range. In other words, disciplined minimum joining weight are not adhered to like the cattle industry has promoted for over 20 years. Furthermore, the late pregnancy management/nutrition of ewe lambs is very often compromised because they are lambing after the main flock, and in tight seasonal conditions producers must allocate most of their feed (pasture and supplement) to the adult lambing ewes. This regularly means that an immature (not fully grown) ewe lamb, is trying to complete her own growth and also feed a foetus or foetuses, under restricted nutrition, which ultimately compromises her and her lambs survival. In these circumstances, which are not uncommon across the industry, profound wastage is occurring that is compromising productivity, profitability and welfare outcomes.

The impact of joining weight and pregnancy weight change on the survivability on the lambs is shown in Tables 6.10 and 6.11, where the data highlights the percentage of ewe lambs that rear at least one lamb at various joining weight and pregnancy weight gain combinations. For ewe lambs rearing status at weaning, both the single and twin bearing ewes had a significant quadratic effect of their joining weight and linear effect of liveweight change during pregnancy ($P<0.001$ $P<0.05$, highest P given for any term fitted).

The shading in Tables 6.10 and 6.11 highlights combinations of joining weight and pregnancy weight gain that result in;

- 90% or more of the ewe lambs rearing- green shading (industry best practice),
- 80-89% of the ewe lambs rearing- amber shading (acceptable lamb loss), and
- Less than 80% of the ewe lambs rearing- red shading (unacceptable lamb loss).

Table 6.10. Impact of joining weight and pregnancy weight gain on single bearing ewe lambs rearing their lamb (wet=100%, dry=0%)

LWCPreg	0	5	10	15	20	25	30
Joinwt							
33			36	45	54	63	
35			48	57	66	73	80
40	56	65	72	79	84	89	92
45	74	81	86	90	93	95	96
50	84	88	92	94	96	97	
55		92	94	96	97		
60			95	96	97		

Table 6.11. Impact of joining weight and pregnancy weight gain on twin bearing ewe lambs rearing at least one lamb (wet=100%, dry=0%)

LWCPreg	5	10	15	20	25	30
Joinwt						
35			28	41	54	67
40	37	51	64	76	84	90
45	66	77	85	91	95	97
50	82	89	93	96	98	99
55	88	93	96	97	99	99
60		94	96	98	99	
65		93	96	97		

The best practice guidelines for ewe lambs will use the information in Tables 6.8 to 6.11 to inform minimum joining and pregnancy weight gain targets. This will be an integral component for developing guidelines that are suitable from a productivity, profitability and welfare perspective. This is particularly important given the sheep industry has already had criticism and risks more in future for the 'practice of young ewes in the pursuit of extra profits'.

6.2.4 Late pregnancy treatment- impact of Regulin on ewe and lamb survival

Research led by Adelaide University Flinn *et al*. (2020) found that one treatment of Melatonin (Regulin) administered to adult twin bearing ewes post-scanning resulted in gains in twin lamb survival of 5-13%. Melatonin provides a neuroprotection to the brain via antioxidant and anti-inflammatory actions, which improves teat-seeking behaviour in hypoxic lambs. Given the promising outcomes in adult twin bearing ewes, Dr Joe Gebbles from MLA and the lead of this project, Dr Jason Trompf, considered evaluating the impact of melatonin on lamb survival from ewe lambs would be a worthwhile pursuit. Regulin (melatonin) was administered to pregnant ewe lambs (singles and twins) post scanning in accordance with the approach that has been used in research on twin bearing adult ewes.

Eight sites/reps were analysed for the effect of Melatonin (Regulin). A Regulin pellet was implanted under the skin behind the ewe lamb's ear with, 1 x 18mg implant at Day 90-100 of pregnancy (from rams in) for the Regulin treatment group and no Regulin treatment was given to the Control group. The overall mean mob characteristics are outlined in Table 6.12 below.

Data were analyzed by the following methods using GENSTAT (Edition 22). For the Regulin experiment lamb survival and ewe mortality were analyzed using analysis of covariance (ANCOVA). The treatment structure was modelled as a factorial between Regulin treatment and birth type mob, where Treatment represented the two treatments (Regulin and control); and birth type mob represented the single bearing and twin bearing mobs. The block structure was modelled as paddock nested with birth type group nested within farm. The covariates included in the model were the mid pregnancy weight and stocking rate.

Table 6.12. Mean mob characteristics for the Regulin experiment.

	Single birth type	Twin birth type
Joining weight (kg)	43.6	45.5
Mid pregnancy weight (kg)	49.8	52.0
Pre lambing weight (kg)	55.9	63.2
Stocking rate (ewes /ha)	8.0	7.6
Number of ewes at lambing	158	136

The effect of Regulin on lamb survival both overall and for single and twin born lambs separately is outlined in Table 6.13.

Table 6.13. The effect of Regulin and lamb birth type on lamb survival (%) adjusted for mid pregnancy weight and stocking rate.

Birth type mob	Regulin Treatment	Lamb Survival (%)
Single		77.0
Twin		66.
l.s.d. (P=0.05)		7.12
F prob		0.005
	Regulin	70.7
	Control	70.6
	l.s.d. (P=0.05)	3.77
	F prob	0.974
Single	Regulin	76.4
	Control	77.6
Twin	Regulin	66.5
	Control	64.6
	l.s.d. (P=0.05) A	7.29
	F prob	0.751

[A] Based on the min-max treatment comparison (within Regulin Treatment)

From the analysis, Regulin had no discernible influence on lamb survival (P=0.974), with the control and Regulin treatments having similar lamb survival 70.6% and 70.7%, respectively (Table 6.13). There were also no significant differences within either singles or twins for Regulin and control treatments (Table 6.13).

The effect of Regulin on ewe mortality, both overall and for single and twin born lambs separately, is outlined in Table 6.14.

Table 6.14. The effect of Regulin and lamb birth type on ewe mortality (%) adjusted for mid pregnancy weight and stocking rate.

Birth type mob	Regulin Treatment	Lamb Survival (%)
Single		2.96
Twin		3.82
l.s.d. (P=0.05)		3.18
F prob		0.411
	Regulin	3.24
	Control	3.68
	l.s.d. (P=0.05)	1.611
	F prob	0.530
Single	Regulin	2.59
	Control	3.32
Twin	Regulin	3.97
	Control	3.71
	l.s.d. (P=0.05) A	3.320
	F prob	0.780

[A] Based on the min-max treatment comparison (within Regulin Treatment)

From the analysis, Regulin had no discernible influence on ewe mortality (P=0.530), with the control and Regulin treatments having similar ewe mortality of 3.68% and 3.24%, respectively (Table 6.14). There were also no significant differences for ewe mortality within either single or twin bearing ewe lambs for Regulin and control treatments (Table 6.14).

Based on these results it appears that the treatment of pregnant ewe lambs with Regulin with the intent to improve the survival of their lambs, will not be part of the repertoire of practices advocated to producers that are joining ewe lambs. Given that other MLA funded research, such as that conducted by Adelaide University, has found positive effects from Regulin on twin lamb survival from adult ewes, then perhaps there needs to be an MLA led discussion among researchers so that a consistent messaging about the use of Regulin implants to improve lamb survival are extended to producers.

6.2.5 Lambing treatment- impact of mob size on lamb survival

The impacts of mob size at lambing on lamb survival were investigated at 18 sites (n = 10 maternal, n = 5 Merino, n = 3 shedder). The average mob sizes are shown in Table 6.15.

Table 6.15. Average mob size at lambing for the high and low mob size at 18 research sites across Australia

Ewe breed	Pregnancy status	High mob size	Low mob size
Maternal	Single	260	97
	Twin	169	78
Merino	Single	192	91
	Twin	146	58
Shedder	Single	315	153

Ewe lambs mob size at lambing had a significant effect on lamb survival per mob and the interaction of mob size by pregnancy type (single or twin bearing ewes) was deemed important (p=0.072), but there was no effect of breed. Figure 6.1 shows the deterioration of mean lamb survival per mob for single bearing ewes at around 3.9% per 100 ewes increase in mob size, while for twin bearing ewes the decrease is around 6.3% per 100 ewes increase in mob size.

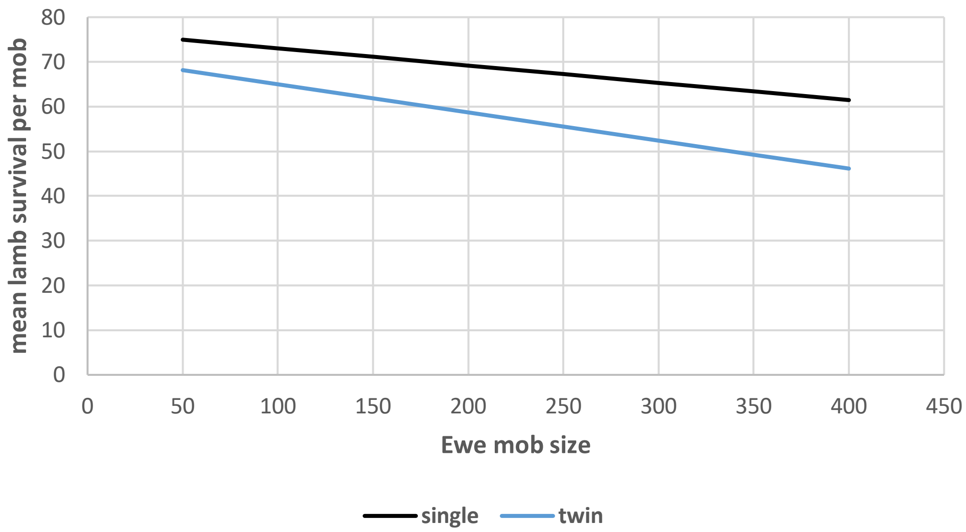


Figure 6.1. Impact of lambing mob size on single and twin lamb survival from ewe lambs.

The best practice guidelines for ewe lambs will use this information to inform extension messages on mob size for lambing ewe lambs. This will be integral for developing guidelines that are suitable from a productivity, profitability and welfare perspective. This is particularly important given sheep producers have received messages about the impact of mob size in adult ewes previously and heard that to reduce mob size in twins, it's reasonable to increase mob size in singles. These messages were based on lamb survival per mob for single bearing ewes at around 0.85% per 100 ewes increase in mob size, while for twin bearing ewes the decrease is around 2.25% per 100 ewes increase in mob size (Lockwood *et al*. 2020a). The research conducted in this project show that the impact of mob size at lambing on lamb survival with ewe lambs is at least 3-times more responsive than it is with adult ewes, hence ewe lambs need to be managed/prioritised accordingly.

6.2.6 Carryover reproductive performance of ewe lambs at hogget age

The carryover reproductive performance of ewe lambs when joined for the second time, at hogget age, was measured. Statistical analysis of the impact of joining weight at hogget age and hogget reproductive rate found that for both Maternal and Merino hoggets, weight at hogget joining had a significant impact ($p<0.001$) on hogget reproductive rate. Tables 6.16 and 6.17 outline the impact of live-weight at hogget joining in Maternal and Merino ewe hoggets, on the percentage of dry, single, twin, triplet ewe hoggets and overall reproductive rate. The joining weight for Maternals was generally heavier than for Merinos. As shown in Figure 6.2 the relationship between hogget joining weight and hogget reproductive rate appears to differ, in that for Maternals it's a quadratic relationship, whereas for Merinos its linear. For every 1 kilogram of Merino hogget joining weight, reproductive rate increases by 1.84% ($p<0.001$).

Table 6.16. The impact of live-weight at hogget joining in Maternal ewe hoggets, on the percentage of dry, single, twin, triplet ewe hoggets and overall reproductive rate. Values presented are predicted values.

Hogget joining weight	Dry	Single	Twin	Triplet	Reproductive rate (lambs per 100 ewes)
40	17.7%	43.9%	36.3%	2.1%	122.8
45	13.1%	39.9%	44.1%	2.9%	136.9
50	9.8%	35.0%	51.1%	4.0%	149.3
55	7.5%	30.3%	56.9%	5.3%	160.0
60	5.9%	26.0%	61.4%	6.8%	169.1
65	4.7%	22.3%	64.5%	8.4%	176.6
70	3.9%	19.4%	66.6%	10.1%	182.9
75	3.3%	17.1%	67.9%	11.7%	188.0
80	2.9%	15.4%	68.5%	13.2%	192.1
85	2.6%	14.1%	68.8%	14.5%	195.2
90	2.4%	13.3%	68.9%	15.5%	197.4

Table 6.17. The impact of live-weight at hogget joining in Merino ewe hoggets, on the percentage of dry, single, twin, triplet ewe hoggets and overall reproductive rate.
Values presented are predicted values.

Hogget joining weight	Dry	Single	Twin	Reproductive rate (lambs per 100 ewes)
35	30.8%	61.3%	7.9%	77.1
40	24.3%	65.1%	10.6%	86.4
45	18.8%	67.1%	14.2%	95.4
50	14.3%	67.1%	18.6%	104.3
55	10.7%	65.2%	24.1%	113.4
60	8.0%	61.5%	30.6%	122.6
65	5.9%	56.2%	37.9%	132.0
70	4.3%	49.9%	45.8%	141.5

Most of Merino ewes that were scanned as single-bearing as a ewe lamb were again scanned as singles at hogget age (66.2%). However, 58.4% of maternal ewes that were scanned as single-bearing as a ewe lamb were scanned as twin-bearing at hogget age.

Most of the maternal ewes (63.4%) that were scanned as twin-bearing as a ewe lamb were scanned again as twin-bearing at hogget age whilst 56.0% of the Merino ewes scanned as twin-bearing as a ewe lamb were scanned as single-bearing at hogget age.

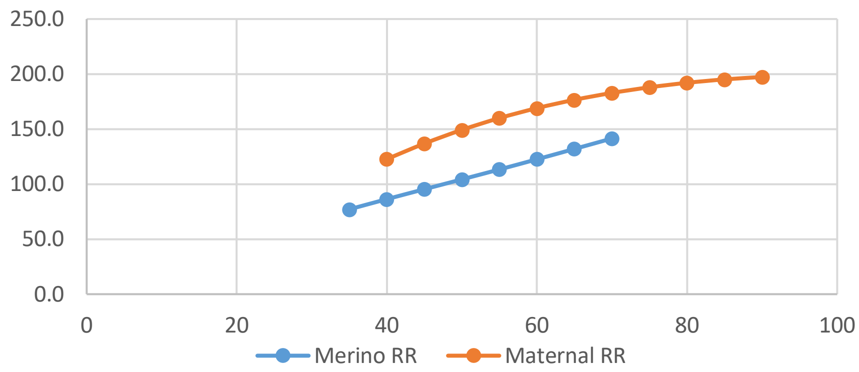


Figure 6.2. Relationship between hogget joining weight for Maternal (red) and Merino (blue) ewe hoggets and overall reproductive rate as hoggets. Predicted values presented.

Further examination of the impact of parity as a ewe lamb on reproductive rate on the subsequent hogget joining (Table 6.18), shows that for Maternals, conceiving twins as a ewe lamb results in about a 14-17% increase in reproductive rate as a hogget over and above single bearing or dry ewe lambs, at similar weights. Maternal ewe lambs conceiving triplets had a further 14% increase in reproductive rate as a hogget over twin bearing ewe lambs, although they were almost 3 kilograms heavier at the time of hogget joining (Table 6.18). For Merinos, conceiving twins as a ewe lamb, results in about a 9% increase in reproductive rate as a hogget over and above single bearing and dry ewe lambs, although they were 3.7 kilograms heavier at the time of hogget joining (Table 6.18).

Table 6.18. Summary of the effects of pregnancy status as a ewe lamb on hogget joining weight and reproductive rate for Maternal and Merino ewes.

	Maternals		Merinos	
Pregnancy status as a ewe lamb	**Hogget joining weight (kg)**	**Hogget reproductive rate**	**Hogget joining weight (kg)**	**Hogget reproductive rate**
0	62.84	162.1%	53.45	119.9%
1	61.85	164.8%	55.26	119.7%
2	61.98	179.4%	58.97	128.2%
3	64.77	193.8%	-	-

6.2.7 Cashmore Oakley data set- lambing ease impacts

The Cashmore Oakley data set comprising of twelve years of ewe lamb information (2010 – 2021) was examined to assess the impact of different variables, in particular, lambing ease, period between ewe lamb joining and hogget joining, on ewe and lamb survival, and hogget age performance.

Data were analyzed by the following methods using GENSTAT (Edition 22). Hogget reproductive rate was analyzed using a Generalized Linear Mixed Model with a multinomial distribution and logit link function as a function of different variables, including maiden ewe liveweight at the start of breeding, liveweight change from this to hogget joining, the birth type rear type of the maiden lambing and days from maiden lambing to hogget joining as fixed effects and year as a random effect. For maiden ewe liveweight at the start of breeding, liveweight change from this to hogget joining and days from maiden lambing to hogget joining, quadratic effects were also examined.

Estimates of maiden ewe lambing difficulties (had difficulties, no difficulties) were assessed by fitting Generalized Linear Mixed Models. The approach used a logit transformation and binomial distribution. Using additive models, logits were predicted as a function of liveweight at start of breeding fitted as a fixed effect while year was fitted as a random effect. Ewe liveweight was tested for quadratic effects.

Twelve years of ewe lamb information (2010 – 2021) was examined for the effect of various periods from ewe lamb joining and hogget joining on hogget reproduction without lamb ease information due to it only having 4 years of valid data. The period from ewe lamb lambing date to the next hogget joining date (days from lambing to hogget joining) was the only period worth examining but did not noticeable (P=0.168) add to the hogget reproduction once ewe lamb join weight, liveweight change from ewe lamb join weight to hogget join weight and ewe lamb birth type and rear type was accounted for. The effect of days from maiden lambing on hogget reproduction 2010-2021 is shown in Figure 6.3.

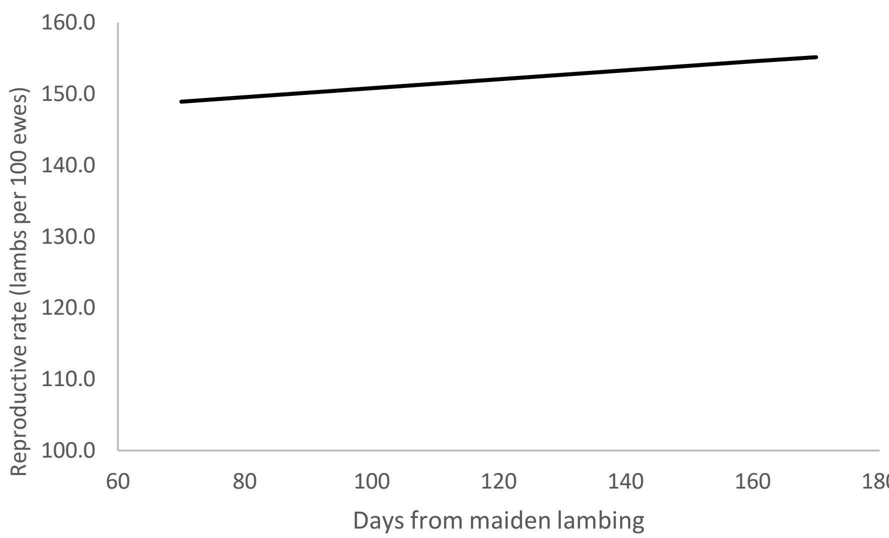


Figure 6.3. The effect of days from maiden lambing on hogget reproduction 2010 – 2021 based on a maiden ewe join weight of 45 kg and liveweight change from this weight to hogget join weight of 15 kg. Data is presented in the back-transformed state.

For lambing ease, the examination done to date involves the effect of joining weight (P=0.014) of maidens (ewe lambs) on lamb ease and subsequent effect of the lambing ease groups on lamb survival as examined through the birth type and rear type categories. On reviewing the data, the above modification of the proposed analysis for lamb ease were considered more informative. The effect of liveweight at the start of breeding (joining weight) on lambing difficulties for ewe lambs 2018 – 2021 in the Cashmore data set is shown in Figure 6.4.

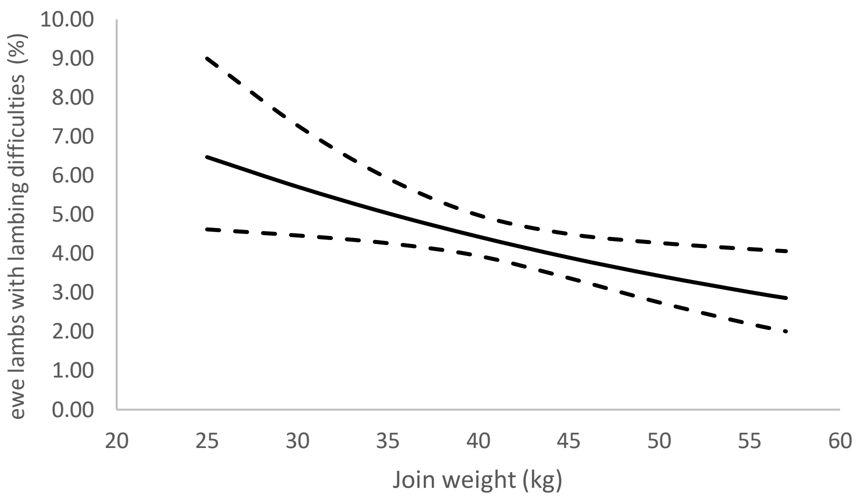


Figure 6.4. The effect (± 95% confidence interval) of liveweight at the start of breeding on lambing difficulties for ewe lambs 2018 - 2021. Data is presented in the back-transformed state.

It can been seen in Figure 6.4 that significantly more ewe lambs have lambing difficulties at lighter joining weights than ewe lambs with heavier joining weights (P=0.014), with around 5% of ewe lambs having lambing difficulties at a 35 kg joining weight, whereas only 3% of ewe lambs have lambing difficulties at a 55 kg joining weight. Furthermore, as shown in Table 6.19, these lambing difficulties are having direct consequences on lamb survival. A much greater proportion of the ewes that have lambed and lost (ie. birth type-rear type of 1,0 and/or 2,0) have experienced lambing difficulties than ewes that have reared a lamb(s) (birth types 1,1, 2,1 and/or 2,2). For instance, with single bearing ewes, 20% of ewes with a birth type-rear type of 1,0 have experienced lambing difficulties whereas those that reared their lamb (1,1), only about 2% experience lambing difficulties, which is a ten-fold difference. With twin bearing ewes, 10% of ewes with a birth type-rear type of 2,0 have experienced lambing difficulties whereas those that reared their lamb (2,1 or 2,2), only about 1% experienced lambing difficulties, which is again a ten-fold difference.

Table 6.19. The number of ewes within each birth type rear type and lambing difficulties categories as used for testing rearing ability.

Birth type rear type	Lambing difficulties	No lambing difficulties
1,0	147	602
1,1	57	2459
2,0	49	420
2,1	37	1411
2,2	11	1796

6.2.8 Identifying the relationship between live weight and body condition at joining and reproductive rate

Research priority 3 identified in the gap analysis was addressed by connective analysis of data across numerous ewe lamb data sets. Data were analysed from over 17,000 records from Merino and non-Merino ewe lambs from 22 different flocks from across Australia. There were significant curvilinear relationships between liveweight ($p < 0.001$) or condition score ($p < 0.001$) prior to breeding and reproductive rate for both Merino and non-Merino ewe lambs. For both breeds there was a significant ($p < 0.001$) quadratic effect of condition score prior to breeding on reproductive rate independent of the correlated changes in liveweight, and even at the same liveweight an extra 0.5 of a condition score up to 3.3 improved reproductive rate by about 20%.

Nevertheless, the results indicated that if only a proportion of ewe lambs were selecting for breeding, then selection based on both liveweight, and condition score may only improve overall reproductive rate by 1 to 2% compared to selection on liveweight alone. It was concluded that liveweight is a more effective method than condition score for selecting ewe lambs for breeding. A journal paper was published in Animals on 12th of March 2024, citation below and full manuscript attached as Appendix 3. This work was lead by Dr Andrew Thompson from Murdoch University.

Thompson, A.N., Ferguson, M.B., Kearney, G.A., Kennedy, A.J., Kubeil, L.J., Macleay, C.A., Rosales-Nieto, C.A.; Paganoni, B.L., Trompf, J.P. Additive Impacts of Liveweight and Body Condition Score at Breeding on the Reproductive Performance of Merino and Non-Merino Ewe Lambs. *Animals 2024*, **14**, 867. https://doi.org/ 10.3390/ani14060867

6.3 Conclusion

Results from the experimental work showed that;

- For Maternal ewe lambs the response to weight gain during joining, where increasing weight gain by 100 g/day, equates to around an 8% lift in reproductive rate (p<0.001),
- Flushing ewe lambs with Lupins, fed at a rate of 500g/day for 14 days, had no significant impact on their conception or reproductive rate (p>0.05) and the breed of the ewe lamb had no significant bearing on the response to flushing,
- The effect of the late-pregnancy growth treatment (+156 g/day between low and high growth) on lamb survival was around 8% (P<0.001) with low and high growth treatments having a lamb survival of 66.5% and 74.6%, respectively. The effect on ewe mortality was around 2% (P<0.001) with low and high growth treatments having ewe mortality rates of 3.58% and 1.46%, respectively. Both singles and twins had similar effect.
- For ewe lambs, their joining weight had a significant quadratic effect on the mortality of single and twin bearing ewes and their lambs, while liveweight change during pregnancy had a linear effect on the mortality of single and twin bearing ewes and their lambs (P<0.001, P<0.05, highest P given for any term fitted).
- Treatment of pregnant ewe lambs with Regulin (melatonin) post-pregnancy scanning, had no discernible influence on lamb survival (P=0.974) or ewe mortality (P=0.530) of either single or twin bearing ewe lambs,
- Mob size at lambing has a significant effect on lamb survival from both single and twin bearing ewe lambs but there was no effect of breed (Merinos, Maternals or Shedders), which is consistent with research done on adult ewes. For single bearing ewe lambs, every 100 less ewes in the mob at lambing, lamb survival increases by around 3.9%, while for twin bearing ewe lambs, lamb survival improved by around 6.3% per 100 less ewes at lambing,
- Significantly more ewe lambs have lambing difficulties at lighter joining weights than ewe lambs with heavier joining weights (P=0.014),
- Lambing difficulties have direct consequences on lamb survival, with a much greater proportion (10-fold increase) of the ewe lambs that have lambed and lost experiencing lambing difficulties than ewes that have reared a lamb(s),
- There were significant curvilinear relationships between liveweight (p < 0.001) or condition score (p < 0.001) prior to breeding and reproductive rate for both Merino and non-Merino ewe lambs. It was concluded that liveweight is a more effective method than condition score for selecting ewe lambs for breeding,
- The relationship between hogget joining weight and hogget reproductive rate appears to differ, in that for Maternals it's a quadratic relationship, whereas for Merinos its linear, where for every 1 kilogram of Merino hogget joining weight, reproductive rate increases by 1.84% (p<0.001). For Maternals between 45 and 65 kg at hogget joining every 1 kilogram of Maternal hogget joining weight, increases reproductive rate increases by almost 2%, whereas between 65 and 85 kg at hogget joining every 1 kilogram of Maternal hogget joining weight, increases reproductive rate increases by less than 1%.
- Examination of the impact of parity as a ewe lamb on reproductive rate on the subsequent hogget joining, shows that for Maternals, conceiving twins as a ewe lamb results in about a 14-17% increase in reproductive rate as a hogget over and above single bearing or dry ewe lambs, whereas for Merinos, conceiving twins as a ewe lamb, results in about a 9% increase in reproductive rate as a hogget over and above single bearing and dry ewe lambs.

7. Benefit-cost analysis of management strategies when mating ewe lambs

The benefits and costs of managing reproduction in ewe lambs is centered on the benefit of increasing the number of lambs weaned from the ewe lambs compared with the cost of improving nutrition. The analyses have evaluated 3 aspects of ewe lamb management:

1. Nutrition during joining,
2. Managing the liveweight profile during pregnancy, and
3. Management at lambing

7.1 General assumptions

The value of the extra lambs weaned is from a detailed wholefarm analysis carried out as part of the MLA funded project L.APD.2109 “Joining Ewe Lambs Tool” and results from Young *et al.* (2014). These detailed whole farm analyses include the feeding cost of having more ewes pregnant, more ewes lactating and extra weaners that require feed from weaning until they exit the flock. It also includes extra husbandry costs and production penalties associated with increasing reproduction. As such the net value of increasing weaning rate is much lower than the sale price of the lambs or hoggets being sold (Table 7.1).

Table 7.1: Value of increasing weaning rate of ewe lambs (Source Young *et al*. 2014 and subsequent revisions).

	Meat price ($/kg dressed weight)					
	$4	$5	$6	$7	$8	$9
Merino	30	43	55	68	80	92
Maternals	37	52	67	81	96	110

The feed budget calculations for the cost of providing the extra feed to achieve the liveweight targets are based on the Australian Feeding Standards (as updated by Freer *et al.* 2007). The increase in energy intake to gain weight is based on the energy content of the tissue gained, the efficiency with which energy is used for weight gain and the increase in heat production associated with increasing ME intake. An allowance has been made for an increase in maintenance requirement for heavier animals, the magnitude of the increase being dependent on the duration of the higher weight. For the short term analysis of LW change during joining the allowance is for 35 days, for increased weight at joining is 150 days of gestation and increased LW gain during joining is 75 days. See Tables 7.2, 7.3 and 7.4.

Table 7.2: General assumptions regarding the cost of feeding supplementary barley grain

Feeding out & storage costs ($/t)	$35
Wastage in paddock (%)	20%
ME content of barley (MJ/kg)	12.6

Table 7.3: Cost of supplementary barley (c/MJ of ME consumed)

Barley price $/t		
$200	$300	$400
2.33	3.32	4.32

Table 7.4: Feed budget assumptions for extra feeding required to achieve 1kg increase in liveweight.

Energy content of the gain (MJ/kg)	25
Efficiency of gain	43%
Extra ME required (MJ/kg)	58.1
Increase in HP (due to increased ME)	9%
Increase in MEI to provide ME (MJ/kg)	63.9

7.2 Nutrition during joining

7.2.1 Background

Increasing liveweight (LW) gain during the joining period has been shown to increase the number of lambs conceived by ewe lambs, which is a finding consistent with other research projects, although the gain measured in this project is lower than previous studies. In the ewe lambs monitored in this project the benefit of increasing LW gain varied with LW at the start of joining, with heavier ewes responding less. For ewes joined at 40kg the response to an increase of 100g/hd/d during joining was approximately 9% for Merinos and 8% for Maternals.

7.2.2 The economic problem

The benefits of improving nutrition during joining to increase liveweight gain and reproductive rate has an economic trade-off with the cost of providing more or better quality feed during the joining period. The source of this improved feed will alter the cost and could be either:

- extra supplementary feeding of concentrates which has a direct cash cost or
- reallocating the forage resource from
    - other classes of animals or
    - other times of the year.

7.2.3 Analysis

Supplementary feeding to provide energy to increase LW gain during joining

Evaluating the benefit and costs of feeding extra supplement is a straightforward analysis because the feed budget to calculate the extra supplementary feeding is well defined and the assumptions outlined above (an extra 63.9 MJ of ME consumed to gain an extra 1 kg of LW) can link differences in liveweight change with changes in feeding rate. The results from this analysis can be extrapolated to the other sources of providing the extra feed during joining.

The benefits accruing from increasing LW gain during the joining period are the value of an extra lamb (outlined above) multiplied by the response in weaning rate from the higher rate of LW gain.

Table 7.5:Production assumptions for calculations for the benefits of increasing LW gain during joining using supplementary feeding.

LW at start of joining	40
Average Lamb survival	70%
Merino: RR increase from LWC +100g/d	9%
WR increase	6.3%
Maternal: RR increase from LWC +100g/d	8%
WR increase	5.6%

Table 7.6: Value of extra lambs weaned from ewe lambs for different value of lamb if the rate of LW gain during joining is increased by 100g/hd/day.

	$4	$5	$6	$7	$8	$9
Merino	$1.91	$2.71	$3.49	$4.26	$5.02	$5.78
Maternal	$2.05	$2.89	$3.73	$4.56	$5.37	$6.18

Table 7.7: Assumptions for extra feeding required to achieve and retain an increase in liveweight gain of 100g/hd/d during joining.

Number of days of feeding	35
Weight increase from gaining extra 100g/hd/d	3.5
Energy required to gain weight (MJ)	224
Energy required to maintain heavier animal (MJ)	8
Total extra MJ fed	232

Table 7.8: Total cost of the extra supplement required to increase LW gain during joining by 100g/hd/d for a range of grain prices.

Barley price ($/t)		
$200	$300	$400
$5.41	$7.71	$10.01

Table 7.9: Benefit-cost of feeding extra supplement to Merino ewe lambs during joining to increase LW gain during the joining period by 100g/hd/d to increase reproductive rate.

	Meat Price ($/kg DW for lamb)					
Grain price	$4	$5	$6	$7	$8	$9
$200	-$3.50	-$2.70	-$1.92	-$1.15	-$0.39	$0.37
$350	-$5.80	-$5.00	-$4.22	-$3.45	-$2.69	-$1.93
$450	-$8.10	-$7.31	-$6.52	-$5.75	-$4.99	-$4.23

Table 7.10: Benefit-cost of feeding extra supplement to maternal ewe lambs during joining to increase LW gain during the joining period by 100g/hd/d to increase reproductive rate.

	Meat Price ($/kg DW for lamb)					
Grain price	$4	$5	$6	$7	$8	$9
$200	-$3.34	-$2.49	-$1.65	-$0.83	-$0.01	$0.80
$350	-$5.63	-$4.78	-$3.95	-$3.12	-$2.30	-$1.49
$450	-$7.92	-$7.08	-$6.24	-$5.41	-$4.60	-$3.79

7.2.4 Discussion

Supplementary feeding

It only pays to feed extra grain to ewe lambs during joining to increase reproductive rate and weaning rate if the price of lamb was at least $9/kg and the cost of supplement was no greater than $200/t (Table 7.9 & Table 7.10). This conclusion was the same for both Merino and maternal lambs and is a change from previous analyses based on other datasets that had shown larger gains in RR from ewe lambs gaining weight during joining. This finding for ewe lambs is consistent with the recommendation for adult ewes that it is not cost effective to feed extra supplementary grain to mature ewes to gain weight prior to or during joining.

Allocation between animal classes

Evaluating the cost and optimal level of reallocation of feed from different classes of sheep (mature ewes or dry sheep) would be a more complex analysis and would require knowledge of both the production of the ewe lamb but also of the alternative stock class. This has not been tested in this project but the expectation (Andrew Thompson *pers comm.*) is that the benefits of

LW gain during joining for adults would only relate to the benefits due to higher absolute LW on the day of joining. This indicates that the ewe lambs being mated would be the priority mob and be allocated the best quality forage on the farm during joining. However, the value of this is tempered by the higher value of lambs born to mature ewes compared with ewe lambs.

Temporal reallocation of feed

Deferring the consumption of good quality feed destined for the ewe lamb class from prior to joining into the joining period is a trade-off between the benefit of higher weight at the start of joining (if feed is not deferred) versus lower weight at start of the joining but the benefit of increased weight gain during joining. The statistical analysis carried out on the data collected in this project showed that the increase in reproductive rate for a flock gaining an extra 100 g/hd/d for the duration of joining (35 days) was between 6 and 10% per 100g with the higher values achieved by the Merino ewe lambs. In comparison the benefit for a flock with an absolute increase LW at joining was between 1.5% and 4% per kg with Maternals achieving the higher response. A flock of ewe lambs that gain 100 g/hd/d for a 35 day period prior to the start of joining will be 3.5kg heavier at the start of joining, the predicted increase in reproduction rate averages 14%. This is 6% greater than the increase in reproduction rate predicted for a flock that starts the joining period lighter but utilises the feed saved to gain 100 g/hd/d during joining. As such temporal reallocation of feed to boost the rate of liveweight gain during joining is not expected to improve flock profitability.

There is a further factor at play when considering deferring high-quality feed from pre-joining to the joining period related to the impact of LW at joining (LWj) on ewe and lamb survival at birth. This production effect of LWj was examined in this project and is discussed in the next section.

7.3 Live-weight profile at joining and during pregnancy

7.3.1 Background

Biological relationships developed in a number of different research projects provide the basis for economic analyses carried out examining a range of production decision and on-farm feed allocation questions. Improving these relationships can lead to improvements in the economic analyses and the advice provided to farmers.

Improving the relationships used to calculate the profitability and optimum management associated with mating ewe lambs has been a priority area because mating ewe lambs is a technique that increases the number of lambs produced on farm, which is an industry priority. This project developed new knowledge regarding the relationships between the nutrition profile of the ewe lambs and the mortality of the ewe lamb herself at lambing and the survival of her progeny.

This report utilises the new relationships to inform feed allocation decisions prior to joining and during pregnancy.

7.3.2 The economic problem

The economic benefit of a higher production profile - ewe lambs that are heavier at joining and gaining more weight during pregnancy – trades off with the cost of providing the extra feed. A similar analysis as that described above was carried out comparing the benefit of increased weaning rate with the cost of providing the extra feed, assuming the feed was provided through altering the rate of supplement offered.

7.3.3 Method

Production relationships

The relationships developed in this project link the nutrition profile of the ewe lamb dam (via her LW profile) with her peri-natal mortality and the peri-natal survival of her progeny. These relationships are based on improved data compared to the previous relationships and include greater detail on the nutrition profile that is used to predict productivity.

Peri-natal ewe mortality

The relationships developed in this project (Table 7.11 & Figure 7.1) include a measure of both absolute liveweight and LW change during the pregnancy period. The relationship is more sensitive to low condition score, with the prediction of twin bearing ewes in CS 2 at scanning having a mortality of greater than 35%. The mortality of ewes scanned in CS 3 is close to zero.

Table 7.11: Coefficients to predict peri-natal mortality of single- and twin-bearing ewe lamb dams from joining LW and LW change. Note: The prediction equation must be back transformed using a logit function to calculate actual mortality.

	Singles	Twins
Intercept	-28.27	-30.41
Joining wt (kg)	1.034	1.121
Joining wt^2	-0.00416	-0.008975
LW change during pregnancy	0.2436	0.1930

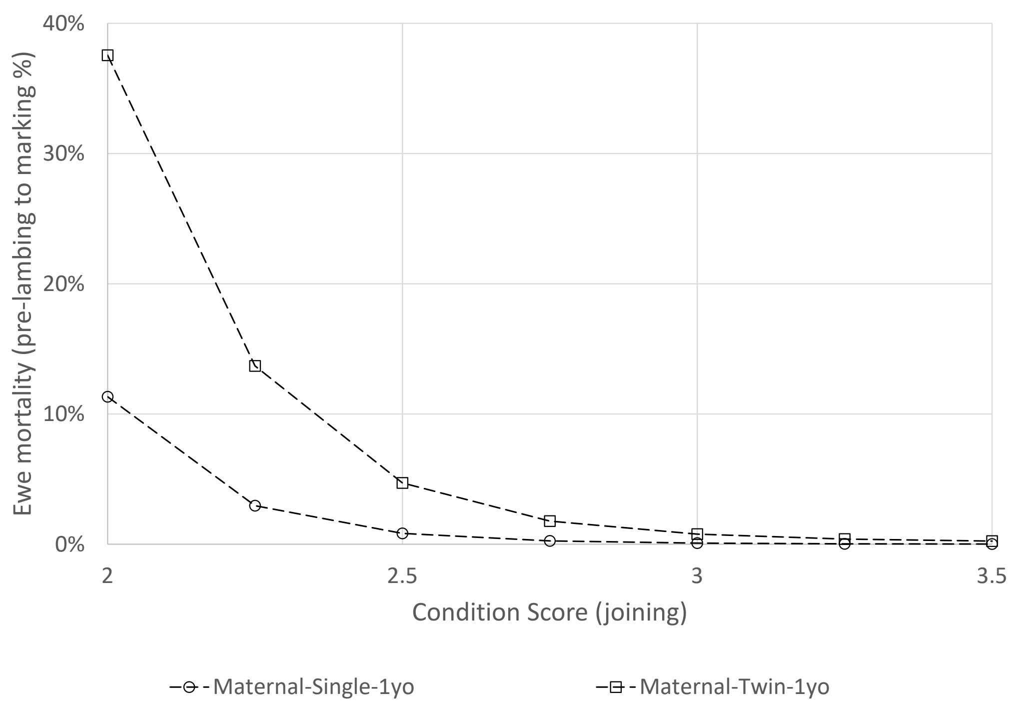


Figure 7.6: Peri-natal mortality of individual maternal single (■) and twin-bearing (☐) ewe lamb dams predicted from CS at joining and gaining ½ CS during pregnancy.

Low LW/CS at joining can be offset by increasing LW gain during pregnancy (Figure 7.2). For ewes weighing 40kg at joining, every kg lighter at joining is fully offset by between 2 and 3 kg extra LW gain during pregnancy. Due to the diminishing effect of LW at joining, the offset for heavier ewes is less and is between 1 and 2kg of LW gain during pregnancy to offset a kg of joining weight for a 50 kg ewe.

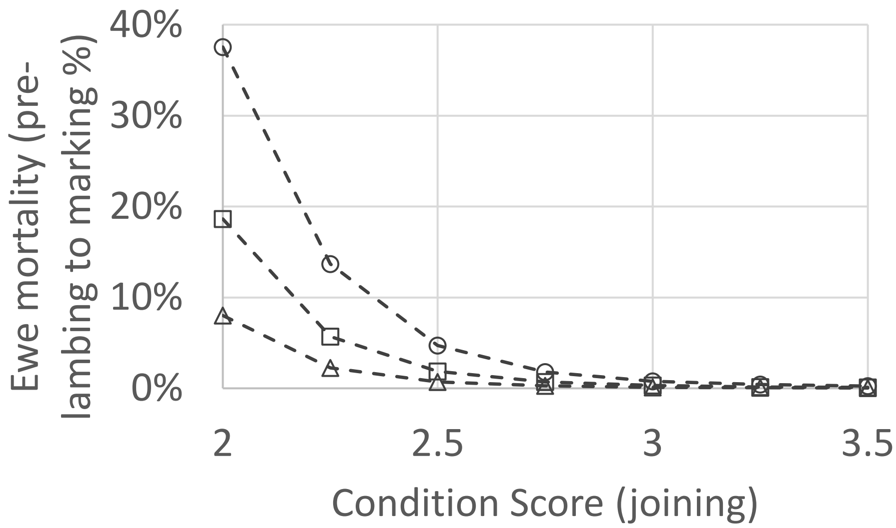


Figure 7.7: Peri-natal ewe mortality for twin-bearing maternal ewe lambs with different rates of LW gain during pregnancy (■ +10 kg, ☐ +15kg, △ +20kg)

Lamb mortality

The updated relationships predict the proportion of ewes that retain at least one lamb to marking. For single bearing ewes this is equivalent to lamb survival, however, for twins a further adjustment must be made to estimate survival of twin born lambs. Firstly, an assumption has to be made that the survival of each lamb in the litter is independent i.e. that the survival or mortality of the second lamb in the litter is independent of the survival or mortality of the first lamb in the litter. After making that assumption the survival of twin born lambs can be estimated from the proportion of 'wet' ewes as in Equation 1

Equation 1: $twinlambsurvival = 1 - \sqrt{1 - proportionwet}$

Table 7.12: Coefficients to predict proportion of single- and twin-bearing maternal ewe lambs that retain at least one lamb (ewes are 'wet') from joining LW and LW change. Note: The prediction equation must be back transformed.

	Singles	Twins
Intercept	-14.33	-22.51
Joining wt (kg)	0.5421	0.8038
Joining wt^2	-0.004444	-0.006694
LW change during pregnancy	0.07235	0.1098

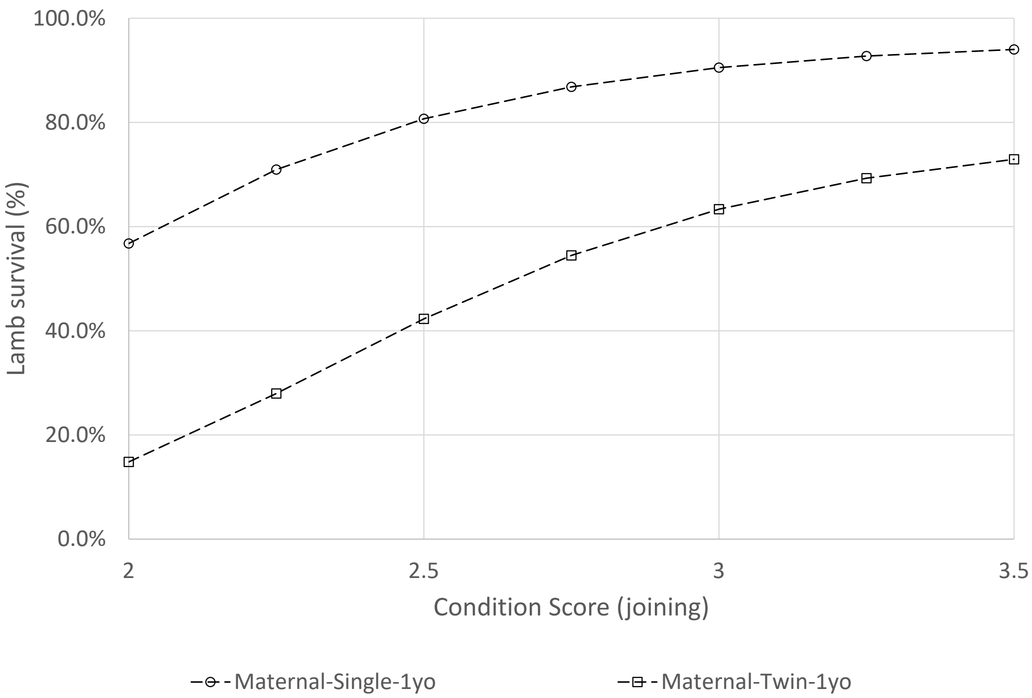


Figure 7.8. Survival of single (■) and twin-born (☐) lambs from maternal ewe lamb dams predicted from CS at joining and gaining ½ CS during pregnancy.

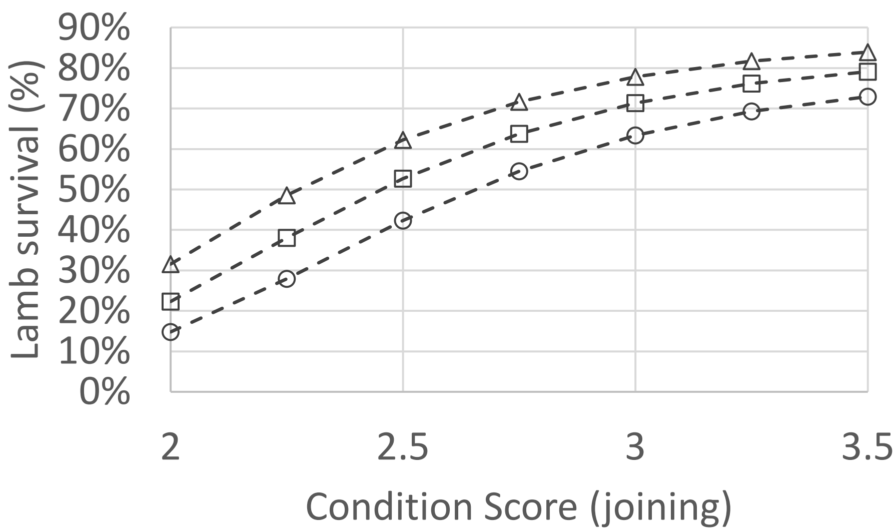


Figure 7.9. Predicted survival of twin-born maternal lambs from ewe lambs with different rates of LW gain (maternal weight + conceptus weight) during pregnancy (+10 kg - ■, +15kg ☐, +20kg △)

Predicted production levels

The improvement in survival of the ewe lamb dam and the ewe lamb progeny from improving the profile of the ewe lambs during pregnancy was predicted using the updated equations. A sensitivity analysis was carried out for a range of ewe lamb joining weight and LW gain during pregnancy.

Two interventions were examined

1. Increasing LW gain during pregnancy (Table 7.13, Table 7.14, Table 7.15 and Table 7.16)
2. Increasing LW at joining (Table 7.17, Table 7.18, Table 7.19 and Table 7.20)

Both interventions improve both ewe mortality and lamb survival. The increment from increasing LWG during pregnancy and increasing LW at joining have been separately valued to evaluate the potential to improve profitability by adjusting the ewe lamb nutrition targets.

The interventions outlined above were only calculated if the scenario was within the data range used to fit the relationships. Therefore, there are some blank cells in the tables where that scenario has no data from the experiments.

Table 7.13: Predicted reduction in mortality of single-bearing ewe lamb dams per kg extra increase in LW gain during pregnancy for a range of LW at joining and base case LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35		5.4%	2.8%	1.1%	0.3%	0.1%
40		1.1%	0.4%	0.1%	0.0%	0.0%
45		0.2%	0.0%	0.0%	0.0%	0.0%
50		0.0%	0.0%	0.0%	0.0%	
55		0.0%	0.0%	0.0%		
60			0.0%	0.0%		

Table 7.14: Predicted reduction in mortality of twin-bearing ewe lamb dams per kg extra increase in LW gain during pregnancy for a range of LW at joining and base case LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35				3.4%	1.8%	0.8%
40			1.4%	0.6%	0.2%	0.1%
45			0.3%	0.1%	0.0%	0.0%
50			0.1%	0.0%	0.0%	0.0%
55			0.0%	0.0%	0.0%	0.0%
60			0.0%	0.0%	0.0%	

Table 7.15: Predicted improvement in survival of single-born lambs from ewe lambs per kg extra increase in LW gain during pregnancy for a range of LW at joining and base case LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35			1.8%	1.7%	1.5%	1.3%
40		1.6%	1.3%	1.1%	0.8%	0.6%
45		1.0%	0.8%	0.6%	0.4%	0.3%
50		0.6%	0.5%	0.3%	0.3%	
55		0.5%	0.3%	0.2%		
60			0.3%	0.2%		

Table 7.16: Predicted improvement in survival of twin-born lambs from ewe lambs per kg extra increase in LW gain during pregnancy for a range of LW at joining and base case LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35				1.5%	1.9%	2.1%
40			2.0%	2.1%	2.0%	1.7%
45			1.9%	1.7%	1.4%	1.1%
50			1.5%	1.2%	0.9%	0.7%
55			1.2%	1.0%	0.8%	0.6%
60			1.1%	0.9%	0.7%	

Table 7.17: Predicted reduction in mortality of single-bearing ewe lamb dams per kg increase in LW at joining for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35		8%	4%	1%	0%	0%	0%
40		1%	0%	0%	0%	0%	0%
45		0%	0%	0%	0%	0%	
50		0%	0%	0%	0%		
55			0%	0%	0%		

Table 7.18: Predicted reduction in mortality of twin-bearing ewe lamb dams per kg increase in LW at joining for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35				6%	3%	1%	0%
40			2%	1%	0%	0%	0%
45			0%	0%	0%	0%	0%
50			0%	0%	0%	0%	0%
55			0%	0%	0%	0%	

Table 7.19: Predicted improvement in survival of single-born lambs from ewe lambs per kg increase in LW at joining for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35			5%	4%	4%	3%	2%
40		3%	3%	2%	2%	1%	1%
45		2%	1%	1%	1%	0%	
50		1%	0%	0%	0%		
55			0%	0%	0%		

Table 7.20: Predicted improvement in survival of twin-born lambs from ewe lambs per kg increase in LW at joining for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35				5%	6%	6%	5%
40			4%	4%	4%	3%	3%
45			3%	2%	2%	2%	1%
50			1%	1%	1%	1%	1%
55			0%	0%	0%	0%	

7.3.4 Benefit cost analysis

The above ewe mortality and lamb survival were converted to an increase in farm income per 1kg change in either LW gain during pregnancy or the LW at joining target using the value of an extra ewe lamb surviving and extra progeny from ewe lambs surviving (Table 7.1). The feed budget assumptions were based on Table 7.2, Table 7.3 and Table 7.4 assuming that the extra LW had to be maintained for a 150 day period for extra LW at joining and for 75 days for LW change during pregnancy.

7.3.5 Results and Discussion

Peri-natal ewe mortality

The updated ewe mortality relationships predict high mortality for ewes that are mated at light weights and gain little weight during pregnancy. The increased mortality reduces the profitability of mating the lighter ewe lambs and the optimal management will be to implement a higher LW for joining and leave a greater proportion unmated. This is likely to be combined with increasing the nutrition of the ewe lambs during either pre-joining or pregnancy. To some extent the increased mortality predicted from joining light ewe lambs can be mitigated if the ewes gain weight during pregnancy (Figure 7.2). However, to compensate for being 5 kg lighter at joining requires gaining an extra 10 to 15kg during pregnancy, so this is only likely to be feasible for flocks that are lambing in spring rather in autumn or winter, so that there is sufficient green feed available for liveweight gain.

This finding is an important extension message for farmers that are considering mating ewe lambs.

Lamb mortality

The updated lamb survival relationships are – similar as for the ewe lamb dam mortality – much more sensitive to ewe LW at joining than the previous research. The increased sensitivity compared to the relationships measured in adults is up to 8 times the impact on survival for a given change in ewe liveweight at joining and 2 to 3 times the impact of LW change during pregnancy.

The increased sensitivity will increase the financial importance of achieving the target liveweight change during pregnancy and is also likely to increase the target LW gain during pregnancy.

The changes are also likely to increase the financial importance of implementing a minimum target LW at joining. Previous analyses have shown the target LW at joining to be a low priority target, however, that is likely to change with new relationships.

Reproductive success

Reproductive success is defined as a single-bearing ewe surviving to weaning with their lamb alive or a twin-bearing ewe with at least one live lamb. Reproductive success is greater if the ewe lambs are heavier at joining or gain more weight during pregnancy (Table 7.21 and Table 7.22).

Table 7.21: Proportion of pregnant single-bearing ewes lambs achieving 'reproductive success', that they survive to marking with their lamb alive.

Joining weight	LWC during pregnancy (kg)						
	0	5	10	15	20	25	30
35			38%	53%	64%	73%	80%
40	43%	60%	71%	78%	84%	89%	92%
45	72%	80%	85%	89%	92%	95%	96%
50	83%	88%	92%	94%	96%	97%	
55		92%	94%	96%	97%		
60			95%	96%	97%		

Table 7.22: Proportion of pregnant twin-bearing ewes lambs achieving 'reproductive success', that they survive to marking with at least one live lamb.

Joining weight	LWC during pregnancy (kg)						
	0	5	10	15	20	25	30
35				19%	34%	51%	65%
40		28%	45%	61%	74%	84%	90%
45		62%	75%	85%	91%	94%	97%
50		80%	88%	93%	96%	98%	99%
55			93%	96%	97%	99%	99%
60			94%	96%	98%	99%	

Improving nutrition of the ewe lambs prior to joining increases reproductive success of singles and twin lambs if examined independently. However, the improved nutrition will also be associated with converting single-bearing dams into twin-bearing dams and this comes with a reduction in reproductive success. Furthermore, Young *et al.* (2014) showed that the value of improving weaning rate through improved conception is only 30% as valuable as improving lamb survival. This indicates that the most economic pathway to increasing reproductive success in ewe lambs will be through focusing on improving lamb survival, indicating that emphasis should be placed on improved pregnancy nutrition prior to emphasising the benefits of better pre-joining nutrition.

Benefit-cost of interventions

Increasing target LW at joining

If achieved by feeding extra supplementary feed the increased cost of increasing LW at joining by 1kg is between $2.00 and $3.60/ewe. This cost is partly offset by the increased reproductive rate achieved by joining at a heavier weight. The net value of the supplement cost versus the extra lambs weaned due to the higher reproductive rate for the Merino ewe lambs is a cost of between $0 and $3/ewe lamb and for Maternals is between a cost of $2.50 and a benefit of $1/ewe lamb, with the range dependent on the price of grain and the lamb value. These net values can be used to adjust the values in the following tables.

Increasing LW at joining is most valuable for ewes that are joined at lighter weights and have a lower growth expectation during pregnancy (Table 7.23 and Table 7.24). The benefits of higher joining targets are greater for the portion of the flock that conceive twins because the twin bearing ewes are more sensitive for both ewe mortality and lamb survival than the singles, furthermore the benefit of the improved survival is achieved for 2 lambs, although each lamb is slightly less valuable.

For a flock in which 80% of the pregnant ewe lambs have conceived singles (approx. reproductive rate 110%) it will be profitable to feed grain to increase LW at joining if the expected LW of the ewes is less than 42kg, and to feed to reduce weight loss if less than 47kg. This indicates that the target for minimum LW at joining is between 42-47kg and that the ewes joined in the range 42 to 47kg should be fed extra grain during pregnancy to increase pregnancy weight gain. This aligns with acceptable levels of reproductive success if the single bearing ewes are gaining at least 10kg during pregnancy and the twins are gaining at least 15kg.

Table 7.23: Increase in value of production ($/hd/kg increase in LW at joining) from single-bearing ewes and their lambs from increasing the target LW at joining by 1kg for a range of LW at joining and LWG during pregnancy.

Joining target	LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35			$11.82	$6.37	$3.93	$2.75	$2.03
40		$5.37	$3.02	$1.97	$1.39	$1.00	$0.72
45		$1.62	$1.07	$0.75	$0.53	$0.38	
50		$0.61	$0.42	$0.30	$0.21		
55			$0.14	$0.10	$0.07		

Table 7.24: Increase in value of production ($/hd/kg increase in LW at joining) from twin-bearing ewes and their lambs from increasing the target LW at joining by 1kg for a range of LW at joining and LWG during pregnancy.

Joining target	LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35				$20.37	$14.78	$11.30	$9.09
40			$11.29	$8.49	$6.68	$5.31	$4.19
45			$5.11	$4.00	$3.13	$2.43	$1.88
50			$2.29	$1.78	$1.38	$1.06	$0.81
55			$0.67	$0.52	$0.40	$0.30	

Increasing LW gain during pregnancy

If achieved by feeding extra supplementary feed the increased cost of gaining extra weight during pregnancy by 1kg is between $1.75 and $3.20/ewe depending on the cost of supplementary feed. These values can be used to adjust the values in the following tables.

Increasing LW gain during pregnancy is most valuable for ewes that are joined at lighter weights (Table 7.25 and Table 7.26) and for twin-bearing ewes rather than single-bearing ewes. If ewes are joined at 40kg or less, then it will be profitable to feed grain to increase LW gain during pregnancy. If joining at 50kg or more then it is unlikely to be profitable to feed grain to increase LW gain. In the range 40 to 50kg then it will be profitable to feed the multiple bearing ewe lambs but not the single-bearing ewe lambs. However, a whole farm analysis is required to determine the priority of ewe lambs for allocation of the feed resource on the farm.

Table 7.25: Increase in value of production ($/hd/kg of extra LWG) from single-bearing ewes and their lambs from increasing LW gain during pregnancy by 1kg for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35			$7.24	$3.52	$1.92	$1.25
40		$3.49	$1.78	$1.08	$0.74	$0.53
45		$1.14	$0.73	$0.50	$0.36	$0.26
50		$0.59	$0.41	$0.29	$0.20	
55		$0.40	$0.28	$0.20		
60			$0.24	$0.17		

Table 7.26: Increase in value of production ($/hd/kg of extra LWG) from twin-bearing ewes and their lambs from increasing LW gain during pregnancy by 1kg for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35				$10.18	$7.04	$5.03
40			$6.38	$4.60	$3.55	$2.82
45			$3.58	$2.79	$2.18	$1.70
50			$2.47	$1.92	$1.49	$1.14
55			$1.96	$1.52	$1.17	$0.90
60			$1.81	$1.40	$1.08	

7.3.6 Conclusions

The new information gained in this project regarding the impact of ewe lamb joining weight and LW gain during pregnancy on the survival of the ewe lamb and her progeny, indicates that the optimal management of ewe lambs that are mated should have more emphasis on nutrition prior to and during the pregnancy period. The most economic potential to increase reproductive success in ewe lambs appears to be to concentrate on nutrition during pregnancy to increase lamb survival. This should be the focus prior to increasing the number of foetuses conceived by improving LW at joining.

The results indicate that directing efforts towards enhancing LW gain in single-bearing ewe lambs joined at less than 40kg and twin-bearing ewe lambs joined at less than 50kg will result in profitable gains in lamb survival.

7.4 Lambing management – Optimum mob size at lambing

7.4.1 Background

Previous research trials and surveys have shown that survival of single-, twin- and triplet-born lambs can be improved by reducing the number of ewes in the lambing paddock (Lockwood *et al*. 2019). Economic analysis has shown that this relationship alters the optimum mob size depending on the scanned litter size and profit can be increased through either sub-dividing paddocks or differentially allocating the single-, twin- and triplet-bearing ewes to existing paddocks (Lockwood *et al.* 2020).

This research project has quantified the impact on lamb survival of altering the number of ewe lambs in the lambing paddocks and shown that the response to mob size is greater than in adult ewes. Therefore, it is likely that the optimum mob size for ewe lambs will be smaller than for adult ewes.

7.4.2 The economic problem

The higher responsiveness to mob size at lambing for the ewe lambs indicates that the optimum mob size at lambing for ewe lambs will be lower than for adult ewes. The economic problem is to optimise the trade-off of reducing the mob size for ewe lambs by allocating extra paddocks to the ewe lambs while increasing the mob size for adult ewes by allocating fewer paddocks.

This analysis determined the optimum mob size for ewe lambs if producers subdivide the lambing paddocks and compared this to the optimum mob size for adult ewes.

7.4.3 Method

Impact of mob size on lamb survival

The impacts of mob size on single and twin lamb survival were reviewed in Lockwood *et al*. (2020) and the average values are reproduced in Table 2 along with the value for triplet born lambs from the paddock trials in the Triplet project (Thompson & Lockwood 2022).

Table 7.27: Coefficients that predict the change in single, twin and triplet lamb survival for each additional 100 ewes in the lambing paddock. The ewe lamb values were determined in this project. All values are relevant for both Merino & maternal/shedding breeds

	Singles	Twins	Triplets
Adults	-0.85%	-2.25%	-15.1%
Ewe lambs	-3.86%	-6.29%	

Calculation of Profitability

The calculations described here followed a similar process as outlined in Lockwood *et al*. 2020, except that the effect of paddock size on pasture utilisation were not included. The analysis was carried out in 2 steps:

1. the increase in income achieved from increasing lamb survival
2. the cost of sub-dividing paddocks to reduce mob size.

Increase in income

The value of extra single and twin born lambs from ewe lambs were calculated using the Australian Farm Optimisation model (Table 28). The value of an extra lamb is net of the costs associated with feeding the extra lactating ewes and feeding the lamb through to the time of sale. It accounts for the reduced productivity of the progeny of ewe lambs relative to progeny from 2-tooths and adults. It also accounts for the lower weaning weight of lambs from ewe lambs and the feed required to achieve joining targets at the next mating.

Table 7.28: Value of an extra single and twin lamb out of a ewe lamb surviving, for a self-replacing flock based on a maternal/shedding genotypes lambing in spring in SW Victoria and a Merino genotype averaged across 2 environments and 2 times of lambing (Source: Triplets project).

	Merino		Maternal/Shedding	
Age of dam	Singles	Twins	Singles	Twins
Ewe Lamb	58	56	81	77
Adult	64	64	88	87

The total value of the extra lambs surviving as a result of reducing ewe mob size at lambing was calculated using the formula:

$$Valueofextralambsewelambs = lambsperewe * change \in lambsurvival * Valueofextralambs$$

where

$$change \in lambsurvival = change \in numberofewes \in thelambingpaddock * Survivalcoefficient$$

Cost of sub-division

The cost of sub-dividing paddocks could vary greatly depending on the individual farm layout including the shape of paddocks and position of water points. The cost also depends on whether permanent or temporary fencing is used and whether watering points are required in the new paddocks. This analysis has only considered permanent fencing, previous analysis has shown that the optimum mob size is much smaller if using temporary fencing.

In this analysis it was assumed that existing paddocks were square, as square paddocks are the most expensive to subdivide because for any given area they require the longest dividing fences. A long narrow paddock is cheaper to sub-divide, depending on the location & requirement for water. By using square paddocks with the existing water point in the corner, the values calculated for profitability of sub-dividing will be a conservative estimate of the value that farmers would achieve.

The analysis included the following details for dividing paddocks:

- cost of materials and cost of labour
- both fencing and provision of water.
- The cost of providing water included pipe to move the water and a trough for the animals.
- Life of the fence and water points was assumed to be 15 years.

Costs are itemised in Table 7.29.

Table 7.29: Cost of materials and labour to sub-divide paddocks ($/unit).

Item	Unit	Upfront capital cost		Annual maintenance
		Materials	Labour	Labour
Permanent Fencing	km	$1990	$1000	
Pipe	km	$1000	$200	
Trough	unit	$2200	$50	$20

The size of the paddock was calculated from the size of the mob, the stocking rate of the ewes at lambing and the DSE rating of the ewes (Twins 1.8 and Triplets 2.1 DSE/hd). A lower stocking rate means a larger paddock and therefore a higher cost of subdivision. It was assumed that the water point was in the corner of the paddock and that pipe was required to get halfway across the paddock to the newly installed fence that was down the middle of the paddock.

The Analysis

The analysis examined the scenarios where farmers are considering sub-dividing paddocks and want to know the optimum mob size or return on investment for Merino and maternal/shedding ewe lambs and how it compares with adults.

An investment analysis calculated the benefits and costs of halving paddock size. Examining halving paddock size is a sensible option because that is the decision faced by farmers – do they split an existing paddock in half. In the investment analysis framework, the annual income (associated with increased lamb survival) is compared to the annual maintenance costs plus the annuity of the up-front costs (associated with paddock subdivision). The optimum is the level of subdivision that generates the maximum equivalent annual value in $ per year per flock.

The analysis evaluated a given flock size with varying stocking rates (Table 7.30) and varying initial paddock size. This structure allows optimum mob size and return on investment (ROI) to be derived. The optimum mob size is a range and if the current paddock size is within the range (or below) then it is not profitable to subdivide the paddock, if the paddock size is larger than the upper end of the range then subdividing the paddock would increase profit and achieve the target ROI or greater.

Table 7.30: Parameters tested in the sensitivity analysis of the optimum flock size.

	Levels evaluated
Stocking rate	2.1 DSE/ha, 4.2 DSE/ha, 8.4 DSE/ha, 14.7 DSE/ha, 21.0 DSE/ha

7.4.4 Results and Discussion

The scenarios calculated are for single- and twin-bearing ewes, with permanent fencing, $7/kg for lamb and 5% minimum ROI. There are a number of factors that affect optimum mob size/paddock size. The optimum varies with the target ROI for the investment and stocking rate of the ewes. The following table compares the optimum for single- and twin-bearing ewes for a number of scenarios.

The optimum flock size for single-bearing ewe lambs varies between 77 and 125 and twins between 42 & 59 for the scenarios tested (Table 7.31 and 7.32). This is between 45% and 60% of the optimum mob size for adult ewes which reflects the greater response in lamb survival for ewe lambs compared with adults. The optimum paddock size for twin bearing ewe lambs varies from 6 ha up to 51 ha depending predominantly on stocking rate. This is more variation than for mob size because paddock size is a combination of the optimum mob size and the stocking rate.

Table 7.31: Optimum mob size and optimum paddock size for Merino single- & twin-bearing ewe lambs and adult ewes.

	(a) Singles			(b) Twins		
DSE/ha	Ewe Lambs	Adults	Prop'n	Ewe Lambs	Adults	Prop'n
Optimum Mob Size						
2.1	125	265	47%	59	101	58%
4.2	108	241	45%	53	89	60%
8.4	98	219	45%	49	80	61%
14.7	92	205	45%	46	74	62%
Optimum Paddock Size						
2.1	90	190	47%	51	87	59%
4.2	39	86	45%	23	38	61%
8.4	18	39	46%	11	17	65%
14.7	9	21	43%	6	9	67%

Table 7.32: Optimum mob size and optimum paddock size for maternal & shedding single- & twin-bearing ewe lambs and adult ewes.

	(a) Singles			(b) Twins		
DSE/ha	Ewe Lambs	Adults	Prop'n	Ewe Lambs	Adults	Prop'n
Optimum Mob Size						
2.1	107	210	51%	53	89	60%
4.2	93	193	48%	48	80	60%
8.4	82	178	46%	44	72	61%
14.7	77	168	46%	42	67	63%
Optimum Paddock Size						
2.1	90	170	53%	51	87	59%
4.2	39	78	50%	23	39	59%
8.4	17	36	47%	11	18	61%
14.7	9	19	47%	6	9	67%

7.4.5 Conclusions

This analysis shows that the magnitude of the impacts of mob size on survival of the progeny of ewe lambs justify reducing mob size of ewe lambs compared with adults. The optimum mob size for ewe lambs is approximately 50% of the optimum mob size for adults.

7.4.6 Key messages

The key messages are:

- Ewe lambs give a bigger return on subdivision and have smaller optimum mob size than adults. Therefore, allocate the reproducing ewe lambs to the smaller paddocks.
- The optimum mob size for ewe lambs when using permanent fencing is between 42 and 59 head for twins and 77 to 125 head for singles which relates to an optimum paddock size of between 6 & 90 hectares (depending predominantly on stocking rate).
- The optimum mob size for Merinos is 10 to 20% larger than the corresponding mob size for maternal/shedding breeds.

8. Key reflections- opportunities for extension and research

8.1 Background

This More Lambs from Ewe Lambs (MLEL) project has engaged with over 600 stakeholders (producers, sheep advisors, researchers and consultants). The post-code identification of the 500 producers surveyed in the national baseline study is contained in the relevant excel file submitted to MLA. In addition, the following table lists a further 106 producers engaged in this project by their postcode, whether or not they typically mate ewe lambs and how many they typically mate (Table 8.1)

Table 8.1. List of producers involved in the MLEL project- identified by postcode and typical ewe lamb matings.

Postcode	Breed	Typically mate ewe lambs	Typical number mated	Postcode	Breed	Typically mate ewe lambs	Typical number mated
3293	Shedders	N	0	3289	Maternal	N	0
3377	Maternal	Y	3200	3303	Maternal	N	0
3301	Maternal	Y	500	3300	Maternal	Y	1400
3302	Maternal	Y	1400	3294	Maternal	N	0
3244	Maternal	Y	1700	3293	Maternal	Y	700
3238	Shedders	Y	1700	3301	Maternal	Y	1100
3378	Maternal	Y	1400	3379	Maternal	Y	2100

3286	Maternal	Y	2000	2656	Maternal	Y	900
3294	Maternal	Y	3000	3675	Maternal	Y	800
3272	Maternal	Y	920	2877	Merino	Y	500
3301	Shedders	Y	600	2820	Merino	Y	1000
3377	Maternal	Y	130	3377	Maternal	Y	3000
3289	Maternal	Y	3000	3271	Maternal	Y	2500
3373	Merino	N	0	3294	Maternal	Y	3300
3468	Maternal	Y	1500	2642	Maternal	Y	500
3312	Maternal	Y	1350	3301	Shedder	Y	500
3226	Maternal	Y	60	2652	Maternal	Y	450
3293	Shedders	Y	500	5520	Merino	Y	770
3301	Maternal	Y	950	3276	Shedder	Y	1900
3293	Maternal	N	0	3305	Maternal	Y	1300
3361	Maternal	Y	300	3305	Shedder	Y	400
5291	Maternal	Y	780	2868	Merino	Y	1300
5290	Maternal	Y	5500	3314	Merino	Y	700
5290	Maternal	Y	5000	5291	Maternal	Y	700
3315	Maternal	Y	2000	3350	Merino	Y	1800
3305	Maternal	Y	2700	6336	Merino	Y	800
3289	Maternal	Y	2500	6395	Merino	Y	1700
3287	Shedders	Y	1000	6395	Shedder	Y	550
3287	Maternal	Y	2000	6304	Merino	Y	700
3312	Maternal	Y	350	6395	Merino	Y	700
3458	Maternal	Y	300	6317	Merino	Y	1000
3300	Maternal	Y	800	6396	Maternal	Y	1050
3472	Maternal	Y	900	6317	Shedder	Y	900
3314	Maternal	Y	750	2663	Maternal	Y	2050
3287	Shedders	Y	1000	2663	Maternal	Y	1700
3352	Maternal	Y	500	2716	Merino	Y	650
3294	Maternal	Y	3000	2820	Merino	Y	1000
3379	Maternal	Y	2500	2630	Merino	Y	600
3377	Maternal	Y	3300	2843	Merino	Y	800
3301	Maternal	Y	1350	4357	Shedder	Y	440
3283	Maternal	Y	900	4497	Shedder	Y	400
3300	Maternal	Y	1900	2399	Shedder	Y	450
3241	Maternal	Y	800	6394	Merino	Y	600
3241	Maternal	Y	700	2720	Maternal	Y	850
6152	Maternal	Y	300	5291	Maternal	Y	1000
6315	Merinos	Y	2000	3305	Maternal	Y	2300
6528	Merinos	Y	800	3305	Shedder	Y	900
6326	Shedders	Y	1100	3675	Maternal	Y	850
6335	Merinos	N	0	6395	Merino	Y	2000
6391	Shedders	Y	600	6304	Merino	Y	600
6395	Merino	Y	1750	6317	Merino	Y	800
6396	Maternals	Y	1500	6395	Maternals	Y	1300
3675	Maternal	Y	800	6395	Merino	Y	500

8.2 Method

To inform the key reflections from this project, particularly for future extension endeavours, the producers involved in the project were surveyed using the questionnaire attached (Appendix 3) to garner their behaviours, attitudes and practices with respect to ewe lambs.

8.3 Results and Discussion

The sheep enterprises engaged in the MLEL project are of significant scale, averaging 2,276 ha and 6,593 breeding ewes (Table 8.2). Most of the enterprises are running Maternal Composite ewes (74%), while 21% were running Merino ewes and there is an increasing number of shedding sheep, now comprising 16% of the breeding ewes on enterprises involved in the project.

The majority of the producers in the project mate ewe lambs as part of normal practice, typically mating around 1,400 ewe lambs each year (Table 8.2). These matings represent 75% of the ewe lambs that could be mated, and they are being mated on average 27 days after the adult ewes- hence most ewe lambs are around 8 months old at the start of their mating (Table 8.2). Ewe lambs are typically joined for around 6 weeks, at a ram percentage of 3.1% (1 ram to 32 ewe lambs).

This information is useful for highlighting that some of the best practice information/guidelines for improving joining outcomes of ewe lambs are already being readily adopted, such as joining ewe lambs at 8 months (rather than 7 months) to enhance reproductive rate outcomes. These producers are already mating ewe lambs at increased ram percentages, which has been found to lift conception rates. Ewe lambs are in oestrus (on heat) for only a relatively short period, are less likely to seek the ram and are less likely to stand for him, all of which individually, let alone combined, reduce pregnancy rates.

Table 8.2. Enterprise scale and ewe lamb mating details for producers in MLEL project.

Land area (ha)	No. of breeding ewes (head)	Join ewe lambs as annual practice	Usual no. ewe lambs mated (head)	Portion of what could mate (%)	Days gap after adult mating	Join length (weeks)	Joining % of rams
2276	6593	88%	1408	75%	27 days	6.0	3.1%

Producers involved in the MLEL project were questioned about their criteria for determining if a ewe lamb was appropriate to join. The majority of producers believed they were using joining weight (76% of producers) and joining age of 8 months or more (69% of producers) as criteria to determine if ewe lambs were suitable to join (Table 8.3). Only 22% of producers were using the birth type of the ewe lambs, as a multiple, as a criterion to select ewe lambs for joining (Table 8.3). Ewe lamb weight as a proportion of adult weight, condition score and seasonal conditions had a bearing on the selection of ewe lambs for joining of very few farms (Table 8.3).

Table 8.3. Producers' involved in MLEL project criteria for determining if a ewe lamb was suitable to join.

Based on joining weight	Based on % of adult weight	8 months of age or more	Condition score at joining	Ewe lamb was born as a multiple	Seasonal conditions
76%	2%	59%	7%	22%	2%

The existing knowledge, skills and confidence of producers was examined in relation to managing ewe lambs to achieve good pregnancy scanning rates and for the management of ewe lambs to achieve high ewe and lamb survival. Producer knowledge, skills and confidence for managing ewe lambs for scanning results exceeded that for lamb survival (Table 8.4). This was also reinforced by the fact that in a separate 'open question' to producers about the area/aspect of ewe lamb performance that needed to improve most, the vast majority of producers nominated lamb survival as the key improvement area. This highlights the need among producers for the new understanding developed in the MLEL project for improving lamb survival, such as weight profile managing for joining and pregnancy, and the relationships between ewe lamb mob size at lambing and lamb survival.

Table 8.4. Producers' knowledge, skill and confidence (rated out of 10) in managing ewe lambs for either good pregnancy rates or high ewe and lamb survival outcomes.

Managing to achieve good scanning			Managing to achieve high lamb survival		
Knowledge	Skill	Confidence	Knowledge	Skill	Confidence
7.4	6.5	6.9	6.3	5.6	6.0

A stock-take of the current practices for managing ewe lambs was also examined (Table 8.5). It can be seen in Table 8.5 that it is common practice for producers to weigh ewe lambs leading up to and at the start of joining, to pregnancy scan the ewe lambs for multiples (0, 1 and 2) and manage singles and twins separately. However very few producers weigh ewe lambs during pregnancy, either at scanning or pre-lambing, which is a big opportunity for practice change in the future (Table 8.5), with only 8% of producers having a target pregnancy weight gain. Given that the MLEL project has identified pregnancy weight gain as key driving of ewe and lamb survival, this will be an integral part of future extension campaigns and messages.

Around two-thirds of producers have a minimum critical joining weight for ewe lambs (Table 8.5), which averaged 41.3 kg (data not presented). Given that the MLEL project has identified joining weight as key driving of ewe and lamb survival, and that a minimum joining weight of 45kg is beneficial, extension efforts will have to target producer mindset to firstly implement a minimum joining weight target and to lift that target towards 45kg. Interestingly the original message coming from the Maternal Central Progeny Test (MCPT) project conducted from 2002-04 was that ewe lambs need to be a minimum of 45kg by 7 months to be suitable for joining, which is summarized in MLA's Tip n Tools- 45 x 7 joining ewe lambs for more profit. However, for many farmers they talk about a target of 45kg, as an average of the mob, not implemented as a intended as a 'cut-off' weight. This is a key shift in mindset and behavior that the outcomes of this project can be used to target.

Table 8.5. Current percentage of producers involved in MLEL project undertaking key practices for managing ewe lambs.

Weigh 1-2 mth prior to joining	Weigh at start of joining	Weigh at end of joining	Preg. scan for multiple (0, 1, 2)	Manage single and twin separate	Weigh at/after preg. scan	Weigh at pre-lambing treating	Critical mate weight	Target preg. weight gain
64%	74%	33%	92%	82%	5%	8%	67%	8%

Other practices for managing ewe lambs were also examined (data not presented) and it was found that most producers used teasers prior to joining ewe lambs (69%) and vaccinated ewe lambs against Campylobacter (60%). Whereas a lower proportion of producers undertook energy and protein budgets for managing ewe lambs (44%).

The average current mob size for lambing single-bearing ewe lambs was 229 for producers in the MLEL project, and for twin-bearing ewe lambs the average was 116 (Table 8.6). As far as being aware of the optimum mob size for lambing single or twin ewe lambs, 58% of producers were unaware. Those producers that felt they knew the optimum mob size for lambing single and twin bearing ewe lambs, estimated an average of 137 and 72, as the respective optimum mob sizes for singles and twins. Referring to the best practice information identified in this project for lambing mob size of ewe lambs, this indicates that there is a significant adoption challenge for optimum mob size of ewe lambs to improve their lamb's survival.

Table 8.6. Lambing mob sizes for ewe lambs by producers involved in MLEL project.

Single bearing ewe lambs			Twin bearing ewe lambs		
Current mob size	**Estimate of optimum mob size**	**Unsure of optimum**	**Current mob size**	**Estimate of optimum mob size**	**Unsure of optimum**
229	137	55%	116	72	58%

The 2023 reproductive performance (scanning, marking and survival rates) of ewe lambs on farms involved in the MLEL project are outlined in Table 8.7. Interestingly the lamb survival rates achieved on-farm in 2023 are very similar to that documented in the research undertaken in this project over the last few years. In essence only about two-thirds of the lambs conceived by ewe lambs are surviving to the lamb marking cradle. Implementation of best practice discovered in this project for ewe lamb weight profile management for joining and pregnancy, and smaller mob sizes at lambing, can both contribute significantly to improving current survival rates.

Table 8.7. Ewe lamb performance (scanning, marking and survival) for producers in 2023.

Ewe lamb metric	**Observer producers**
Number of ewe lambs mated	1417
Pregnancy scanning rates	103.1%
Lamb marking rates	71.2 %
Lamb survival rates	68.7 %
Ewe mortality rates	3.6 %

8.4 Key reflections for extension

The key reflections survey has highlighted the need for future extension endeavours to target;

- Changing extension messages and producer mindset to adopt and focus on a minimum critical mating weight for ewe lambs, not a target weight, which has been misconstrued as a mob average by industry over recent years,
- Current knowledge, skills and confidence of producers to achieve satisfactory ewe and lamb survival outcomes out of ewe lambs is much lower than the knowledge, skills and confidence of producers to achieve satisfactory scanning rates,
- Changing the mindset of producers from focussing on pregnancy scanning rates as the measure of success when mating ewe lambs to focussing on improving ewe and lamb survival rates to lift weaning rates by adopting more proactive weight profile management from prior to joining through to lambing- where currently the weighing of ewe lambs throughout pregnancy to monitor growth rates and hit growth targets is almost non-existent,
- Changing producers' mindset and understanding that optimum mob size targets for single and twin bearing ewe lambs are 50% of that of adults due to ewe lambs being much more influenced by the need for privacy and the subsequent risks of miss-mothering when mob sizes are elevated, and
- Prioritise investment in extension campaigns that extend best practice to improve lamb survival from ewe lambs as a matter of urgency given that survival rates from pregnancy scanning to lamb marking in ewe lambs are consistently around 66%, hence one in every three lambs conceived is lost, which concerning from a production, profit and welfare perspective.

8.5 Key reflections for research

The MLEL project has filled a number of key gaps in understanding that existed for improving the reproductive success of ewe lambs. Further research that needs to be conducted on ewe lambs, includes;

- Identifying for Merino, Maternal and Shedding genotypes the relationship between percentage of mature weight and reproductive performance of ewe lambs. If the joining and lambing weight targets for ewe lambs could be as expressed as a percent of mature weight, as has been done with heifers in the beef industry for many years, this would improve the universal extension and interpretation of the information being extended. An opportunity exists in the short term (2024/2025) to re-engage with flocks that participated in the MLEL project to capture mature weight data on ewes that were part of the ewe lamb trials in recent years and evaluate the robustness of the weight targets as a percent of adult weight. This would be a very efficient approach and it would value add to the thousands of ewe lamb records already collected in this project.
- Evaluating the impact of feed-on-offer (FOO) in the lambing paddock on lamb survival from ewe lambs. This research has been undertaken in the Lifetime Wool and Lifetime Maternal projects for adult ewes and has revealed differing outcomes, where Merino ewe maternal behaviour and resultant lamb survival was found to be much more sensitive to FOO in the lambing paddock. This is a further gap in understanding with ewe lambs that may contribute to reducing lamb loss from ewe lambs.
- Evaluating the impact of grain feed in late-pregnancy on ewe and lamb survival from ewe lambs. This research has been undertaken recently with adult triplet bearing ewes and revealed significant improvements in survival outcomes. This is a gap in understanding with ewe lambs that may contribute to reducing ewe and lamb loss from ewe lambs.
- Research into the optimum genotypes to mate ewe lambs to, for evaluating the impact of direct sire effects on lamb survival from ewe lambs. Currently many producers select low birth weight sires to mate ewe lambs and this may be exacerbating the loss of ewe lamb's progeny due to too low birth weight. Birth weight, lambing ease and body composition have been found to directly affect lamb survivability but have never been evaluated in ewe lamb dams.

9. Ewe Lamb Best Practice Guide

SECTION 1- Background

Mating ewes to lamb at 12 to 15 months is an effective avenue to rapidly build maternal (including shedding breeds) and merino ewe numbers and increase lamb supply. Currently a maximum of one-third of Australian producers mate ewe lambs, based on 23% of producers mating ewe lambs annually and a further 10% who join ewe lambs when condition are suitable. The industry has encouraged the adoption of mating ewe lambs to lift lamb production especially whilst the national flock has struggled to sustain itself or the turn-off of sheep meat demanded globally or both.

However, a national survey of 500 producers showed that the average lamb marking from ewe lambs was 76% from ewe lambs mated and annual ewe mortality rates of 5.9%. While on-farm research conducted between 2020-2023 discovered that one-third of lambs conceived by ewe lambs are lost between scanning and lamb marking. Hence, the reproductive performance of ewe lambs is much lower than that achieved by mature ewes and highly variable. This variation in performance and lack of information on best practice and the financial ramifications of joining ewe lambs has contributed to relatively poor adoption and lack of improvement. This Ewe Lamb Best Practice Guide (BPG) documents the responses, practices and targets at key stages like joining, during pregnancy and lambing required to lift ewe lamb performance, via gains in ewe and lamb survival (Table below).

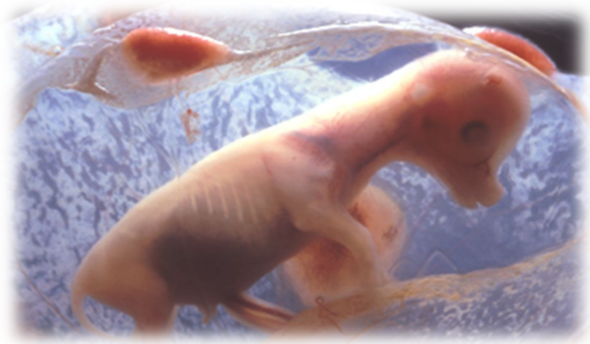
There is 5 sections to the Ewe Lamb BPG, including;

- Section 1- Background,
- Section 2- Identifying ewe lamb's pregnancy status- what's happening, when, why and how to address,
- Section 3- Improving ewe and lamb survival from ewe lambs by increasing joining weight and pregnancy weight gain- what's happening, when, why and how to mitigate the risks,
- Section 4- Lamb loss from ewe lambs - what's happening, when, why and how to mitigate the risks,
- Section 5- Summary of Ewe Lamb BPG actions and next steps.

Aspect	Section of the BPG affecting ewe lambs and their lambs		
What	Section 2. Scanning ewe lambs	Section 5. Ewe and lamb survival	Section 6. Lamb loss
When	Day 75-100 of pregnancy	Loss in late pregnancy & lambing	Point of lambing
Why	To improve ewe nutrition and lambing paddock allocation	Inadequate development of ewe and lamb- especially low birth wt	Lack of lambing privacy and miss-mothering
How	Pregnancy scanning to identify dry, single and twin ewe lambs	Increase joining weights and increase pregnancy weight gain	Optimum lambing mob size for single & twin ewe lambs

SECTION 2 – The identification of ewe lamb's pregnancy status- what's happening, when, why and how to address

What's happening on Australian sheep farms with ewe lambs?



Mating ewes to lamb at 12 to 15 months of age is more common practice nowadays, with up to one-third of Australian producers mating ewe lambs. This data is based on a survey of 500 sheep producers from across Australia. It was also found that only one-third of the producers that mate ewe lambs scanned for multiples, around one-quarter scan wet-dry only and 40% of producers that mate ewe lambs don't scan them at all. Furthermore only 71% of producers run their ewe lambs separately from other age groups. This section of the BPG outlines when, why, how, and the economic basis to pregnancy scanning ewe lambs that are mated.

When

The optimum time to pregnancy scan ewes for triplets is 80-90 days from the start of joining. The earliest and optimum time that ewes can be pregnancy scanned is shown in Table 1. Ewes cannot be scanned before 40 days from the end of joining or beyond 100 days from the start of joining.

Table 1. Earliest and optimum time that ewe lambs can be scanned for multiples for a 35-day or 42-day joining.

Length of joining	Earliest	Optimum
35-days/5-weeks	40 days after the rams have been removed	45 days after the rams have been removed
42-days/6-weeks		45 days after the rams have been removed

Tips for preparing for pregnancy scanning include;

- Joining for no more than 6 weeks,
- Withholding feed and water the night before scanning,
- Ensuring adequate staff are available to keep ewes up to the scanner,
- Good yard set-up with secure, separate pens for each pregnancy status (dry, single, twin, triplet),
- Avoid having wet or daggy ewes, which can be an issue with ewe lambs being scanned in winter, and
- Book your scanner early!

Why - producers should be scanning their joined ewe lambs

The More Lambs from Ewe Lambs Project has determined that the survival of pregnant ewes and/or their lambs can be improved by increasing the ewe lambs live-weight (growth rate) between pregnancy scanning and lambing, and lambing ewe lambs in smaller mobs. Both these significant opportunities to improve the performance of pregnant ewe lambs can only be capitilised on effectively is they are pregnancy scanned and managed accordingly.

How – scan ewe lambs to determine pregnancy status and differentially managed

First, scanning and identifying the dry ewe lambs is critical. From mid-pregnancy onwards the requirements of the pregnant ewe lambs start to escalate compared to the dry ewe lambs. By identifying the dry ewe lambs, they can be removed from the mob immediately at scanning and either sold or retain for future breeding.

Second, scanning ewe lambs for single versus twin is also beneficial. Very few ewe lambs on commercial farms will have high enough reproductive rate to warrant scanning for triplets but producers should liaise with their pregnancy scanning practitioners to help determine this. The biggest opportunity with identifying single and twin bearing ewe lambs is with paddock allocation at lambing, where twin bearing ewe lambs are at least twice as sensitive to mob size at lambing than single bearing ewe lambs. This opportunity is discussed in more detail in a subsequent section of this BPG.

Economics

Work by Young & Brien 2023 shows that pregnancy scanning is a high value practice, increasing profit by $5.75 per ewe scanned. Although they did not specifically address scanning ewe lambs they showed that the value of scanning was insensitive to the reproductive rate of the flock and therefore is unlikely to be less valuable for ewe lambs. Furthermore, work in this project has shown that the optimum mob size for ewe lambs is lower than for adults indicating there is a higher value from identifying the non-pregnant ewes and differentially managing paddock allocation at lambing. These findings indicate that there is untapped potential to improve profitability of 66% of flocks that are currently mating ewe lambs and not utilising pregnancy scanning to identify the multiple-bearing ewes.

What are the best-practice recommendations?

- Scan joined ewes to determine pregnancy status- empty, single, twin,
- Remove empty (non-pregnant) ewe lambs from the mob immediately at scanning to sell or retain, but most importantly the pregnant ewe lambs have escalating nutritional requirements compared to the empty ewe lambs,
- The improvements in survival of pregnant ewe lambs and their lambs is achieved through both better nutritional management and better paddock allocation for lambing,
- Pregnancy scanning is a high value practice, increasing profit by $5.75 per ewe scanned, and given the optimum mob size for ewe lambs is much lower than for adults, this indicates there is a higher value from identifying the non-pregnant ewes and differentially managing paddock allocation at lambing, and
- There are social license, animal welfare and potential market access benefits from improving management of ewes lambs and their lambs and these benefits need to be considered.

SECTION 3- Improving ewe and lamb survival from ewe lambs by increasing joining weight and pregnancy weight gain

What's happening on Australian sheep farms with ewe and lamb loss from ewe lambs?

A national survey of 500 producers showed that the average lamb marking from ewe lambs was 76% from ewe lambs mated and annual ewe mortality rates of ewe lambs was 5.9%. Producers in Australia that have been scanning for multiples in ewe lambs and managing ewe lambs separately from other age groups have reported average survival of single lambs born from ewe lambs to be 70% and the average survival of twin born lambs was 62%. This level of ewe and lamb mortality limits the productivity of this cohort and in turn overall flock performance. It also represents an animal welfare challenge that needs to be addressed, especially given nowadays that up to one-third of Australian sheep farms are mating ewe lambs.

When is the majority of ewe and lamb loss from ewe lambs happening on farms?

The considerable nutritional demand of ewe lambs during pregnancy, particularly late-pregnancy, is often not matched by increases in feed intake, as typically the ewe lambs are heavily pregnant throughout the winter months and most available feed has been allocated to adult ewes lambing. If ewe lamb nutrition during late pregnancy is limited this reduces the development of the ewe lamb herself and the birth weight of her lamb(s) and this subsequently compromises the survivability of both the ewe lamb herself and her progeny. On average, one in every three lambs conceived by ewe lambs are loss between pregnancy scanning and lamb marking.

Why ewe and lamb loss is occuring out of ewe lambs

The primary driver of the poor ewe and lamb survival of ewe lambs is the weight of the ewe lamb at joining. However, just over half of the producers mating ewe lambs employ a minimum joining weight when mating ewe lambs, with an average minimum joining of 41.3kg. From a lamb survival perspective ewe lamb joining weight has a significant impact on birth weight (Figure 1) and birth weight is a critical driver of lamb survival.

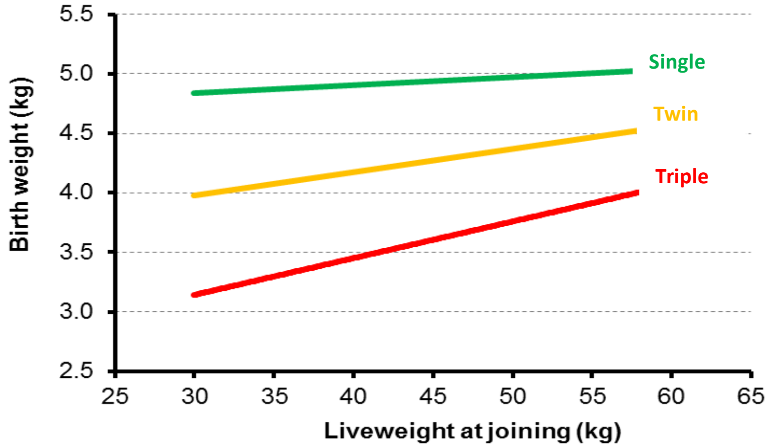


Figure 1. Impact of liveweight at joining on lamb birth weight based on 11,599 Maternal ewe lamb records from Cashmore Oakley data between 2010-2017 (Thompson et al. 2021).

Ewe lambs that were heavier at joining produced lambs that were heavier at birth. An extra 10 kg of liveweight at joining increased lamb birthweight by 0.2kg. Increasing liveweight at breeding increased the survival of the single-, twin- and triplet-born lambs significantly. An extra 10 kg of liveweight at joining increased lamb survival of the single-, twin- and triple-born lambs by 4% between 35 and 45 kg and there were no further gains in survival of offspring if the ewe lambs achieved 45 kg or more at the start of joining.

More recent analysis of the Cashmore Oaklea data set for the years 2018-2021 in the More Lambs from Ewe Lambs Project discovered the effect of liveweight at the start of breeding (joining weight) on lambing difficulties for ewe lambs (Figure 2).

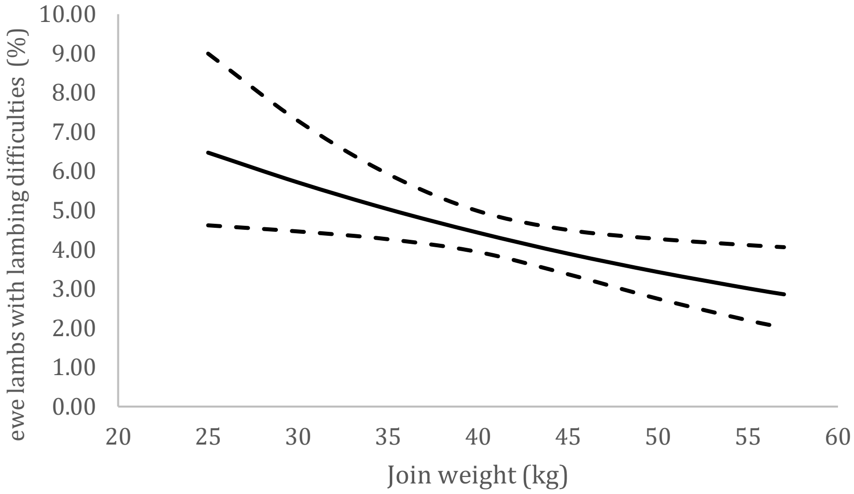


Figure 2. The effect (± 95% confidence interval) of liveweight at the start of breeding on lambing difficulties for Maternal ewe lambs in the Cashmore Oakley data set between 2018 - 2021.

It can be seen in Figure 2 that significantly more ewe lambs have lambing difficulties at lighter joining weights than ewe lambs with heavier joining weights, with around 5% of ewe lambs having lambing difficulties at a 35 kg joining weight, whereas only 3% of ewe lambs have lambing difficulties at a 55 kg joining weight. Furthermore, these lambing difficulties are having direct consequences on lamb survival. A much greater proportion of the ewes that have lambed and lost (ie. birth type-rear type of 1,0 and/or 2,0) have experienced lambing difficulties than ewes that have reared a lamb(s) (birth types 1,1, 2,1 and/or 2,2). For instance, with single bearing ewes, 20% of ewes with a birth type-rear type of 1,0 have experienced lambing difficulties whereas those that reared their lamb (1,1), only about 2% experience lambing difficulties, which is a ten-fold difference. With twin bearing ewes, 10% of ewes with a birth type-rear type of 2,0 have experienced lambing difficulties whereas those that reared their lamb (2,1 or 2,2), only about 1% experienced lambing difficulties, which is again a ten-fold difference.

How to minimise ewe and lamb loss from ewe lambs

Ewe mortality- Research conducted in the More Lambs from Ewe Lambs Project identified the impact of joining weight and pregnancy weight gain on the mortality of the ewe lamb herself. For ewe mortality, their joining weight had a significant curve-linear effect on the mortality of single and twin bearing ewes, while liveweight change during pregnancy had a linear effect on the mortality of single and twin bearing ewes. Table 2 and 3 shows how the combination of joining weight and pregnancy weight gain for ewe lambs impacts on single ewe mortality (Table 2) and twin ewe mortality (Table 3), respectively.

The shading in Tables 2 and 3 highlights combinations of join weight and pregnancy weight gain resulting in;

- Less than 1% ewe mortality- green shading (industry best practice),
- 1-3% ewe mortality- amber shading (acceptable mortality levels), and
- Greater than 3% ewe mortality- red shading (unacceptable mortality levels).

Table 2. Impact of joining weight and pregnancy weight gain on single ewe mortality.

LWCPreg	0	5	10	15	20	25	30
Join wt							
33			44.7	19.3	6.6	2.1	
35		48.7	21.9	7.7	2.4	0.7	
40	22.7	8.0	2.5	0.8	0.2	0.1	0.0
45	3.8	1.1	0.3	0.1	0.0	0.0	0.0
50	0.7	0.2	0.1	0.0	0.0	0.0	100.0
55		0.1	0.0	0.0	0.0		
60			0.0	0.0	0.0		

Table 3. Impact of joining weight and pregnancy weight gain on ewe mortality for twin bearing ewe lambs.

LWCPreg	5	10	15	20	25	30
Joinwt						
35			32.6	15.6	6.6	2.6
40	26.2	11.9	4.9	1.9	0.7	0.3
45	5.6	2.2	0.9	0.3	0.1	0.0
50	1.5	0.6	0.2	0.1	0.0	0.0
55		0.2	0.1	0.0	0.0	0.0
60		0.2	0.1	0.0	0.0	
65		0.2	0.1	0.0		

The key findings relating to ewe lamb mortality are;

- The ewe mortality relationships in Table 2 and 3 predict high mortality for ewes that are mated at light weights and gain little weight during pregnancy,
- The increased mortality reduces the profitability of mating the lighter ewe lambs and the optimal management will be to implement a higher LW for joining and leave a greater proportion unmated,
- This is likely to be combined with increasing the nutrition of the ewe lambs during either pre-joining or pregnancy,
- To some extent the increased mortality predicted from joining light ewe lambs can be mitigated if the ewes gain weight during pregnancy,
- To compensate for being 5 kg lighter at joining requires gaining an extra 10 to 15kg during pregnancy, so this is only likely to be feasible for flocks that are lambing in spring rather in autumn or winter, so that there is sufficient green feed available for liveweight gain.

Lamb survival- Research conducted in the More Lambs from Ewe Lambs Project identified the impact of joining weight and pregnancy weight gain on the survival of lambs born from ewe lambs. The impact of joining weight and pregnancy weight change on the survivability on the lambs is shown in Tables 4 and 5, where the data highlights the percentage of ewe lambs that rear at least one lamb at various joining weight and pregnancy weight gain combinations. For ewe lambs rearing status at weaning in both single and twin bearing ewes, their joining weight and weight change during pregnancy had significant effects.

The shading in Tables 4 and 5 highlights combinations of joining weight and pregnancy weight gain that result in;

- 90% or more of the ewe lambs rearing- green shading (industry best practice),
- 80-89% of the ewe lambs rearing- amber shading (acceptable lamb loss), and
- Less than 80% of the ewe lambs rearing- red shading (unacceptable lamb loss).

Table 4. Impact of joining weight and pregnancy weight gain on single bearing ewe lambs rearing a lamb (wet=100%, dry=0%)

LWCPreg	0	5	10	15	20	25	30
Joinwt							
33			36	45	54	63	
35			48	57	66	73	80
40	56	65	72	79	84	89	92
45	74	81	86	90	93	95	96
50	84	88	92	94	96	97	
55		92	94	96	97		
60			95	96	97		

Table 5. Impact of joining weight and pregnancy weight gain on twin ewe lambs rearing at least one lamb (wet=100%, dry=0%)

LWCPreg	5	10	15	20	25	30
Joinwt						
35			28	41	54	67
40	37	51	64	76	84	90
45	66	77	85	91	95	97
50	82	89	93	96	98	99
55	88	93	96	97	99	99
60		94	96	98	99	
65		93	96	97		

The lamb survival relationships are similar as for the ewe lamb dam mortality and much more sensitive to ewe liveweight at joining than the previously understood. The increased sensitivity compared to the relationships measured in adults is up to 8 times the impact on survival for a given change in ewe liveweight at joining and 2 to 3 times the impact of liveweight change during pregnancy. These changes increase the financial importance of implementing a minimum liveweight at joining and achieving the target liveweight change during pregnancy.

Economics

Economic analysis has been based on 'ewe lamb reproductive success' which is defined as a single-bearing ewe surviving to weaning with their lamb alive or a twin-bearing ewe surviving with at least one live lamb. Reproductive success is greater if the ewe lambs are heavier at joining or gain more weight during pregnancy (Tables 6 and 7).

Table 6. Proportion of pregnant single-bearing ewes lambs achieving 'reproductive success', that they survive to marking with their lamb alive.

Joining weight	LWC during pregnancy (kg)						
	0	5	10	15	20	25	30
35			38%	53%	64%	73%	80%
40	43%	60%	71%	78%	84%	89%	92%
45	72%	80%	85%	89%	92%	95%	96%
50	83%	88%	92%	94%	96%	97%	
55		92%	94%	96%	97%		
60			95%	96%	97%		

Table 7. Proportion of pregnant twin-bearing ewes lambs achieving 'reproductive success', that they survive to marking with at least one live lamb.

Joining weight	LWC during pregnancy (kg)						
	0	5	10	15	20	25	30
35				19%	34%	51%	65%
40		28%	45%	61%	74%	84%	90%
45		62%	75%	85%	91%	94%	97%
50		80%	88%	93%	96%	98%	99%
55			93%	96%	97%	99%	99%
60			94%	96%	98%	99%	

Increasing liveweight at joining

If achieved by feeding extra supplementary feed the increased cost of increasing LW at joining by 1kg is between $2.00 and $3.60/ewe. This cost is partly offset by the increased reproductive rate achieved by joining at a heavier weight. The net value of the supplement cost versus the extra lambs weaned due to the higher reproductive rate for the Merino ewe lambs is a cost of between $0 and $3/ewe lamb and for Maternals is between a cost of $2.50 and a benefit of $1/ewe lamb, with the range dependent on the price of grain and the value of lamb. These net values can be used to adjust the values in the following tables.

Increasing liveweight at joining is most valuable for ewes that are joined at lighter weights and have a lower growth expectation during pregnancy (Tables 8 and 9). The benefits of higher joining targets are greater for the portion of the flock that conceive twins because the twin bearing ewes are more sensitive for both ewe mortality and lamb survival than the singles, furthermore the benefit of the improved survival is achieved for 2 lambs, although each lamb is slightly less valuable.

For a flock in which 80% of the pregnant ewe lambs have conceived singles (approx. reproductive rate 110%) it will be profitable to feed grain to increase liveweight at joining if the expected liveweight of the ewes is less than 42kg, and to feed to reduce weight loss if less than 47kg. This indicates that the target for minimum liveweight at joining is between 42-47kg and that the ewes joined in the range 42 to 47kg should be fed extra grain during pregnancy to increase pregnancy weight gain. This aligns with acceptable levels of reproductive success if the single bearing ewes are gaining at least 10kg during pregnancy and the twins are gaining at least 15kg.

Table 8. Increase in value of production ($/hd/kg increase in LW at joining) from single-bearing ewes and their lambs from increasing the target LW at joining by 1kg for a range of LW at joining and LWG during pregnancy.

Joining target	LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35			$11.82	$6.37	$3.93	$2.75	$2.03
40		$5.37	$3.02	$1.97	$1.39	$1.00	$0.72
45		$1.62	$1.07	$0.75	$0.53	$0.38	
50		$0.61	$0.42	$0.30	$0.21		
55			$0.14	$0.10	$0.07		

Table 9. Increase in value of production ($/hd/kg increase in LW at joining) from twin-bearing ewes and their lambs from increasing the target LW at joining by 1kg for a range of LW at joining and LWG during pregnancy.

Joining target	LWC during pregnancy						
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg	Gain 30kg
35				$20.37	$14.78	$11.30	$9.09
40			$11.29	$8.49	$6.68	$5.31	$4.19
45			$5.11	$4.00	$3.13	$2.43	$1.88
50			$2.29	$1.78	$1.38	$1.06	$0.81
55			$0.67	$0.52	$0.40	$0.30	

Increasing LW gain during pregnancy- If achieved by feeding extra supplementary feed the increased cost of gaining extra weight during pregnancy by 1kg is between $1.75 and $3.20/ewe depending on the cost of supplementary feed. These values can be used to adjust the values in the following tables. Increasing liveweight gain during pregnancy is most valuable for ewes that are joined at lighter weights (Tables 10 and 11) and for twin-bearing ewes rather than single-bearing ewes. If ewes are joined at 40kg or less then it will be profitable to feed grain to increase liveweight gain during pregnancy. If joining at 50kg or more then it is unlikely to be profitable to feed grain to increase liveweight gain. In the range 40 to 50kg then it will be profitable to feed the multiple bearing ewe lambs but not the single-bearing ewe lambs.

Table 10. Increase in value of production ($/hd/kg of extra LWG) from single-bearing ewes and their lambs from increasing LW gain during pregnancy by 1kg for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35			$7.24	$3.52	$1.92	$1.25
40		$3.49	$1.78	$1.08	$0.74	$0.53
45		$1.14	$0.73	$0.50	$0.36	$0.26
50		$0.59	$0.41	$0.29	$0.20	
55		$0.40	$0.28	$0.20		
60			$0.24	$0.17		

Table 11. Increase in value of production ($/hd/kg of extra LWG) from twin-bearing ewes and their lambs from increasing LW gain during pregnancy by 1kg for a range of base case LW at joining and LW gain during pregnancy.

Joining weight	Initial LWC during pregnancy					
	Maintain	Gain 5kg	Gain 10kg	Gain 15kg	Gain 20kg	Gain 25kg
35				$10.18	$7.04	$5.03
40			$6.38	$4.60	$3.55	$2.82
45			$3.58	$2.79	$2.18	$1.70
50			$2.47	$1.92	$1.49	$1.14
55			$1.96	$1.52	$1.17	$0.90
60			$1.81	$1.40	$1.08	

Key findings include;

- The optimal management of ewe lambs that are mated should have more emphasis on nutrition prior to and during the pregnancy period,
- The most economic pathway to increasing reproductive success in ewe lambs is through focusing on improving lamb survival, indicating that emphasis should be placed on improved pregnancy nutrition prior to emphasising the benefits of better pre-joining nutrition to increasing the number of foetuses conceived by ewe lambs,
- The results indicate that directing efforts towards enhancing liveweight gain in single-bearing ewe lambs joined at less than 40kg and twin-bearing ewe lambs joined at less than 50kg will result in profitable gains in lamb survival,
- The target for minimum liveweight at joining is between 42-47kg and that the ewes joined in the range 42 to 47kg should be fed extra grain during pregnancy to increase pregnancy weight gain. This aligns with acceptable levels of reproductive success if the single bearing ewes are gaining at least 10kg during pregnancy and the twins are gaining at least 15kg.

What- the best-practice key messages for ewe lambs at joining and during pregnancy?

- Current practice of joining the majority of your ewe lambs and letting the rams do the drafting must change,

- Joining weight of ewe lambs is the primary driver of their lambs birth weight and subsequent survival rates,

- The late pregnancy nutrition of ewe lambs is very often compromised because they are lambing after the main flock, and in tight seasonal conditions producers allocate most of their feed (pasture and supplement) to the adult lambing ewes, which can severely affect pregnancy weight gain of ewe lambs with dire effects,

- Minimum liveweight targets at joining for ewe lambs should be 45kg,

- Minimum liveweight gains during pregnancy should be at least 10kg for singles and 15kg for twins,

- Hence minimum liveweights of ewe lambs at lambing (weighed at pre-lamb treatments) should be 55kg for singles and 60kg for twin bearing ewe lambs.

SECTION 5. Lamb loss from ewe lambs due to missmothering- what's happening, when, why, and how to mitigate the risks

What's happening on Australian sheep farms with lamb survival from ewe lambs?

Producers in Australia that have been scanning for multiples in ewe lambs and managing ewes lambs separately from other age groups have reported average survival of lambs from ewe lambs of 66%. By contrast, the average survival of lambs from adult ewes is much higher. Hence, one-third of lambs conceived from ewe lambs are lost between pregnancy scanning and lamb marking. This level of lamb mortality limits the productivity of this cohort and in turn overall flock performance. It also represents an animal welfare challenge that needs to be addressed, especially given that nowadays up to one-third of Australian sheep farms are mating ewe lambs.

When is the majority of lamb mortality happening on Australian farms?

Most (>80%) lamb mortality occurs in the first few days following birth. Lamb birthweight is the biggest contributor to lamb survival, which is heavily influenced by ewe nutrition in late pregnancy. Miss-mothering is also a significant contributor to lamb loss, which is known to be exacerbated by larger mob sizes at lambing, compromising the privacy that ewe needs during and after lambing to bond successfully to her progeny.

Why do the lambs born from ewe lambs die?

The main causes of mortality of single- and twin-born lambs are dystocia and the starvation-mismothering-exposure complex. In comparison lambs born from ewe lambs are typically of lower birthweight, receive less colostrum and milk which combined results in lower survival rates. Poorer ewe-lamb behaviour of ewe lambs and their lambs also increases the risk of mismothering.

How to minimise mortality of lambs born from ewe lambs due to miss-mothering

The impacts of mob size at lambing on lamb survival were investigated at 18 sites (n = 10 maternal, n = 5 Merino, n = 3 shedder) in the More Lambs from Ewe Lambs Project. The average mob sizes are shown below in Table 12.

Table 12. Average mob size at lambing for the high and low mob size at 18 research sites across Australia

Ewe breed	Pregnancy status	High mob size	Low mob size
Maternal	Single	260	97
	Twin	169	78
Merino	Single	192	91
	Twin	146	58
Shedder	Single	315	153

Ewe lambs mob size at lambing had a significant effect on lamb survival per mob and the interaction of mob size by pregnancy type (single or twin bearing ewes) was deemed important, but there was no effect of breed. Figure 3 shows the deterioration of mean lamb survival per mob for single bearing ewes at around 3.9% per 100 ewes increase in mob size, while for twin bearing ewes the decrease is around 6.3% per 100 ewes increase in mob size.

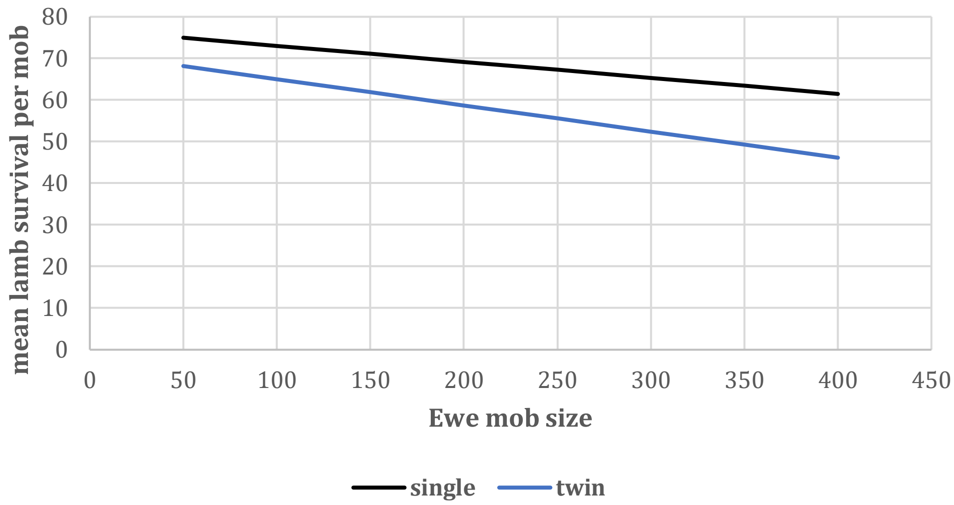


Figure 3. Impact of lambing mob size on single and twin lamb survival from ewe lambs.

This research shows that the impact of mob size at lambing on lamb survival with ewe lambs is at least 3-times more responsive than it is with adult ewes, where the reduction in lamb survival for single bearing ewes was found to be 0.85% per 100 ewes increase in mob size, while for twin bearing ewes the decrease is around 2.25% per 100 ewes increase in mob size.

Economics

The scenarios calculated are for single- and twin-bearing ewes, with permanent fencing, $7/kg for lamb and 5% minimum ROI. There are a number of factors that affect optimum mob size/paddock size. The optimum varies with the target ROI for the investment and stocking rate of the ewes. The following table compares the optimum for single- and twin-bearing ewes for a number of scenarios.

The optimum flock size for single-bearing ewe lambs varies between 77 - 125 and twins between 42 - 59 for the scenarios tested (Tables 13 and 14). This is between 45% and 60% of the optimum mob size for adult ewes which reflects the greater response in lamb survival for ewe lambs compared with adults. The optimum paddock size for twin bearing ewe lambs varies from 6 ha up to 51 ha depending predominantly on stocking rate. This is more variation than for mob size because paddock size is a combination of the optimum mob size and the stocking rate.

Table 13. Optimum mob size and paddock size for Merino single- & twin-bearing ewe lambs and adult ewes.

	(a) Singles			(b) Twins		
DSE/ha	Ewe Lambs	Adults	Prop'n	Ewe Lambs	Adults	Prop'n
Optimum Mob Size						
2.1	125	265	47%	59	101	58%
4.2	108	241	45%	53	89	60%
8.4	98	219	45%	49	80	61%
14.7	92	205	45%	46	74	62%
Optimum Paddock Size						
2.1	90	190	47%	51	87	59%
4.2	39	86	45%	23	38	61%
8.4	18	39	46%	11	17	65%
14.7	9	21	43%	6	9	67%

Table 14. Optimum mob size and optimum paddock size for maternal & shedding single- & twin-bearing ewe lambs and adult ewes.

	(a) Singles			(b) Twins		
DSE/ha	Ewe Lambs	Adults	Prop'n	Ewe Lambs	Adults	Prop'n
Optimum Mob Size						
2.1	107	210	51%	53	89	60%
4.2	93	193	48%	48	80	60%
8.4	82	178	46%	44	72	61%
14.7	77	168	46%	42	67	63%
Optimum Paddock Size						
2.1	90	170	53%	51	87	59%
4.2	39	78	50%	23	39	59%
8.4	17	36	47%	11	18	61%
14.7	9	19	47%	6	9	67%

The key findings are:

- This analysis shows that the magnitude of the impacts of mob size on survival of the progeny of ewe lambs justify reducing mob size of ewe lambs compared with adults. The optimum mob size for ewe lambs is approximately 50% of the optimum mob size for adults.
- Ewe lambs give a bigger return on subdivision and have smaller optimum mob size than adults. Therefore, allocate the reproducing ewe lambs to the smaller paddocks.
- The optimum mob size for ewe lambs when using permanent fencing is between 42 and 59 head for twins and 77 to 125 head for singles which relates to an optimum paddock size of between 6 & 90 hectares (depending predominantly on stocking rate).
- The optimum mob size for Merinos is 10 to 20% larger than the corresponding mob size for maternal/shedding breeds.

What are the best-practice recommendations?

- Survival of lambs born from ewe lambs is typically lower than lambs born from adult ewes,
- Reducing mob size at lambing increases the survival of lambs from ewe lambs and they are at least 3-times more sensitive to mob size at lambing than adult ewes,
- The optimum mob size at lambing varies depending on enterprise-specific factors such as the target return-on-investment, stocking rate of the ewes, breed and lamb price,
- The optimum mob size for ewe lambs is approximately 50% that for adult ewes if ewes are allocated to existing paddocks,
- Hence, ewe lambs give a bigger return on subdivision and have smaller optimum mob size than adults- therefore, allocate the reproducing ewe lambs to the smaller paddocks,
- The optimum mob size for single bearing ewe lambs is between 77 and 125 ewes when paddocks are subdivided using permanent fencing with lamb price at $7/kg and a target return-on-investment of 5%, depending on breed type, and
- The optimum mob size for twin bearing ewe lambs is between 42 and 59 ewes when paddocks are subdivided using permanent fencing with lamb price at $7/kg and a target return-on-investment of 5%, depending on breed type.

SECTION 7 – Summary of the Ewe Lamb BPG and next steps

The findings from recent research conducted in the More Lambs from Ewe Lamb Project show that the attention to detail when mating ewe lambs must improve for the production, profit and welfare outcomes from ewe lambs to be improved simultaneously. Especially in the aspect of lamb survival from ewe lambs, where on-farm trial data collected in this project, shows that only two-thirds of the lambs conceived by ewe lambs make it alive to lamb marking. This wastage is compromising ewe lamb performance and is the primary limitation to yield (lamb marking) increases from this cohort of ewes. The key is employing much more stringent policies prior to mating ewe lambs, where it appears from the biological research undertaken that minimum joining weights of 45kg are required, along with at least 10-15kg of total pregnancy weight gain. Together this ensures the ewe lamb is adequately grown to bear a lamb of sufficient birth weight to survive and the ewe subsequently produces enough colostrum and milk to grow her progeny. This development of the ewe lamb and her progeny, coupled with smaller mob sizes at lambing has potential to profoundly increase the performance of Australian ewe lambs. These key messages have been captured in this best practice guide for ewe lambs and are summarised below.

What are the best-practice recommendations for ewe lambs?

Scanning for litter size (empty, single, twin and triplet) in ewe lambs;

- Scan joined ewes to determine pregnancy status- empty, single, twin,
- Remove empty (non-pregnant) ewe lambs from the mob immediately at scanning to sell or retain, due to the pregnant ewe lambs have escalating nutritional requirements compared to the empty ewe lambs,
- The improvements in survival of pregnant ewe lambs and their lambs is achieved through both better nutritional management and better paddock allocation for lambing,
- Pregnancy scanning is a high value practice, increasing profit by $5.75 per ewe scanned, and given the optimum mob size for ewe lambs is much lower than for adults, this indicates there is a higher value from identifying the non-pregnant ewes and differentially managing paddock allocation at lambing, and
- There are social license, animal welfare and potential market access benefits from improving management of ewes lambs and their lambs and these benefits need to be considered.

Ewe lamb liveweight targets at joining and during pregnancy;

- Current practice of joining the majority of your ewe lambs and letting the rams do the drafting must change,
- Joining weight of ewe lambs is the primary driver of their lambs birth weight and subsequent survival rates,
- The late pregnancy nutrition of ewe lambs is very often compromised because they are lambing after the main flock, and in tight seasonal conditions producers allocate most of their feed (pasture and supplement) to the adult lambing ewes, which can severely affect pregnancy weight gain of ewe lambs with dire effects,
- Minimum liveweight targets at joining for ewe lambs should be 45kg,

- Minimum liveweight gains during pregnancy should be at least 10kg for singles and 15kg for twins,
- Hence minimum liveweights of at lambing should be 55kg for singles and 60kg for twin bearing ewe lambs.

Ewe lamb mob size at lambing;

- Survival of lambs born from ewe lambs is typically lower than lambs born from adult ewes,
- Reducing mob size at lambing increases the survival of lambs from ewe lambs and they are at least 3-times more sensitive to mob size at lambing than adult ewes,
- The optimum mob size at lambing varies depending on enterprise-specific factors such as the target return-on-investment, stocking rate of the ewes, breed and lamb price,
- The optimum mob size for ewe lambs is approximately 50% that for adult ewes if ewes are allocated to existing paddocks,
- Hence, ewe lambs give a bigger return on subdivision and have smaller optimum mob size than adults- therefore, allocate the reproducing ewe lambs to the smaller paddocks,
- The optimum mob size for single bearing ewe lambs is between 77 and 125 ewes when paddocks are subdivided using permanent fencing with lamb price at $7/kg and a target return-on-investment of 5%, depending on breed type, and
- The optimum mob size for twin bearing ewe lambs is between 42 and 59 ewes when paddocks are subdivided using permanent fencing with lamb price at $7/kg and a target return-on-investment of 5%, depending on breed type.

Next steps;

- Identify your future management strategies and targets that will improve ewe and lamb survival from ewe lambs that will deliver production, profit, and welfare benefits for your sheep enterprise.

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10. Publications and presentations of the project outcomes

10.1 Two industry facing articles

Once MLA has approved the final report, then the key findings from the More Lambs from Ewe Lambs project will be compiled into an industry facing article to be published in the Prograzier Magazine and rural press. Given the sensitivities of some of the outcomes of this research and honouring the approval process from MLA, little mass communication of the project has been done to date. These industry facing articles will be important for raising awareness of best practices for mating and lambing ewe lambs.

10.2 Presentation at two industry facing events

The findings from the More Lambs from Ewe Lambs project will be presented at two significant industry forums in the next few weeks. First Dr Jason Trompf is scheduled to present the findings at the BESTWOOL BESTLAMB conference in Ballarat of June 19th. This conference consistently has over 300 delegates attending and has a reputation for delivering information that producers can take home and implement, and the adoption process is subsequently supported by over 40 facilitated groups.

Dr Jason Trompf is also scheduled to present the project findings at the LambEx Conference is Adelaide on August 7-9 2024. LambEx is Australia's largest sheep conference and attracts over 1,000 delegates. Presenting More Lambs from Ewe Lambs at LambEx will profoundly lift industry awareness and understanding of the opportunity to improve ewe lamb performance.

10.3 Peer review journal paper

A complete draft of journal paper titled 'Increasing joining weight and weight gain during late pregnancy improves the survival of maternal ewe lambs and their progeny' has been included below. The draft has been prepared for submission to Animals. Animals is a peer-reviewed open-access scientific journal that covers all areas of animal biology, including behavior, physiology, genetics and ecology. It is published by MDPI and was established in 2011.

Increasing joining weight and weight gain during late pregnancy improves the survival of maternal ewe lambs and their progeny

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Keywords: nutrition, growth, heavier, management, single, twin, mortality

Abstract

The reproductive performance of ewe lambs is much lower than that achieved by mature ewes and is highly variable. Whilst increasing weight at joining and growth rate during joining have been identified as strategies to improve the conception and reproductive rates of ewe lambs, there remains a gap in knowledge around nutritional management of ewe lambs during pregnancy to optimise survival of the ewe and her lambs. We hypothesised that (i) improving the nutrition of ewe lambs during pregnancy will increase ewe and lamb survival, and (ii) that the effects on ewe and lamb survival will be greater when liveweight at the start of joining is optimal. Research was conducted using maternal ewe lambs at 12 sites/reps across New South Wales and Victoria, Australia, in 2023. Ewes were randomly allocated into one of two treatments after pregnancy scanning: 'High' or 'Low' nutrition. Ewe weight was recorded at joining, pregnancy scanning and pre-lambing. Ewe and lamb survival were recorded to lamb marking. Single-bearing ewes in the High nutrition treatments gained significantly more weight during late pregnancy than those in the Low nutrition treatments (12.3 vs 5.2 kg; P=0.001), as did the twin-bearing ewes (14.0 vs 7.8 kg; P<0.001). Ewe mortality was significantly lower when ewes were managed at the High compared to the Low nutrition, with mortality of single-bearing ewes of 1.8% vs 3.8% (P<0.01) and mortality of twin-bearing ewes of 1.2% vs 3.4% (P<0.001). Survival of single-born lambs (82.8% vs 74.8%; P<0.01) and twin-born lambs (66.0% vs 57.8%; P<0.001) was significantly higher when ewes were managed at the High nutrition compared to the Low nutrition. There was a significant quadratic effect of joining weight and a linear effect of liveweight change during pregnancy on the mortality of single- and twin-bearing ewes, and the probability of the ewes rearing a lamb to marking.

Introduction

Joining ewes to lamb at 12 to 15 months of age is an effective option to rapidly build ewe numbers and increase lamb supply. However, the reproductive performance of ewe lambs is much lower than that achieved by mature ewes and is highly variable (Rosales Nieto *et al.* 2013; Rosales Nieto *et al.* 2015; Thompson *et al.* 2019). This has hindered adoption of joining ewe lambs by producers in Australia. Research has shown that improved nutrition pre- and post-weaning to achieve heavier liveweights of ewe lambs at the start of joining improve conception and reproductive rates (Paganoni *et al.* 2014a; Corner-Thomas *et al.* 2015; Thompson *et al.* 2024). Furthermore, increased growth rates during joining irrespective of liveweight at the start of joining also improve reproductive rates in ewe lambs (Rosales Nieto *et al.* 2013; Paganoni *et al.* 2014a; Rosales Nieto *et al.* 2015; Thompson *et al.* 2019; Thompson *et al.* 2024). Hence, producers can now utilise strategies to increase joining weight and growth rate during joining to improve conception and reproductive rates. There however remains a gap in knowledge around nutritional management of ewe lambs during pregnancy to optimise survival of the ewe and her lambs.

Thompson *et al.* (2021) analysed data collected over 8 years from two flocks of maternal composite ewe lambs and reported that mortality of the ewe lambs between pregnancy scanning and weaning ranged from 1.3% to 6.3%. Ridler *et al.* (2022) reported similar mortality of 2.5% during the lambing period for Romney and Coopworth-cross ewe lambs in New Zealand. However, Flay *et al.* (2021) and Flay *et al.* (2023) reported higher mortality of maternal ewe lambs in New Zealand, which ranged from 4.4% to 13.4% across three commercial farms. Survival of progeny from ewe lambs can also be poor. Thompson *et al.* (2021) reported survival over 8 years averaged 69.5%, 67.8% and 48% for single-, twin, and triplet-born lambs from maternal composite ewe lambs at two farms in Australia. Similarly, Clune *et al.* (2021a) reported average survival of 75.5% for single-born lambs and 68.8% for multiple-born lambs from maternal ewe lambs from 19 flocks across southern Australia. However, overall lamb survival was as low as 28.9% in one flock and up to 50% of ewes aborted their lambs, with an average abortion rate of 5.7% of ewes. Slightly higher average survival of 78.0-80.8% for single-born and 71.3-71.5% for multiple-born lambs from maternal ewe lambs have been reported in New Zealand (Schreurs *et al.* 2010a; Ridler *et al.* 2022). There is therefore significant scope to increase the survival of ewe lambs and their progeny.

Limited studies have investigated factors which influence the mortality of ewe lambs during pregnancy and lactation. Liveweight and age at breeding were found to affect the mortality of maternal composite ewe lambs in Australia, with a quadratic effect of liveweight and linear effect of age (Thompson *et al.* 2021). However, these effects were small. Flay *et al.* (2023) found that higher liveweight at pregnancy scanning and higher condition score pre-lambing reduced the mortality of maternal ewe lambs in New Zealand. Therefore, increasing weight gain during pregnancy may increase ewe survival.

Birthweight is well recognised to be a key determinant of lamb survival and is heavily influenced by ewe nutrition during pregnancy. A quadratic relationship between birthweight and lamb survival has been reported for progeny of maternal ewe lambs (Thompson *et al.* 2021). Birthweights have also been reported to be lower for multiple than single lambs born to ewe lambs of maternal and Merino breeds (Schreurs *et al.* 2010a; Paganoni *et al.* 2014a; Thompson *et al.* 2021). The quadratic relationship between birthweight and lamb survival and effect of birth type on birthweight are well known for progeny of adult maternal and Merino ewes (Oldham *et al.* 2011; Paganoni *et al.* 2014b; Hocking Edwards *et al.* 2018; Behrendt *et al.* 2019). Thompson *et al.* (2021) also found that at the same birthweight, single lambs born to ewe lambs of maternal composite breed were 4% more likely to survive than their twin counterparts and twin-born lambs were 7% more likely to survive than their triplet counterparts. Similar effects have been reported for progeny born to adult Merino ewes (Oldham *et al.* 2011), but not for those born to adult maternal ewes (Lifetime Maternals Phase II).

Some studies have reported that progeny of ewe lambs have higher birthweights when ewes are joined at heavier weights (Schreurs *et al.* 2010b; Thompson *et al.* 2021). However, another study found minimal to no effect of the liveweight and condition score of ewe lambs at joining on the weight of their lambs from birth to weaning Corner-Thomas *et al.* (2014). Thompson *et al.* (2021) reported that there were minimal differences in the survival of the single- and twin-born lambs when maternal composite ewe lambs were the same liveweight at joining. Similarly, Griffiths *et al.* (2016) studied maternal ewe lambs on two commercial farms in New Zealand and observed no effect of weight at joining on the risk of failure to rear a lamb. However, they found that ewes that were in greater condition score or heavier at pregnancy scanning and pre-lambing, or that gained more liveweight between joining and pregnancy scanning or between pregnancy scanning and lambing were more likely to successfully rear a lamb. In contrast, Corner-Thomas *et al.* (2014) found little to no effect of the liveweight or condition score of ewe lambs during pregnancy on lamb birthweight. Similarly, Morris *et al.* (2005) reported no difference in birthweight or survival of progeny born to ewe lambs offered different levels of nutrition during pregnancy in New Zealand. These findings contradict those from studies using adult maternal and Merino ewes in Australia, where increasing liveweight gain during pregnancy improves the survival of their single- and twin-born lambs, noting that single-born maternal lambs are less responsive (Hatcher *et al.* 2009; Kenyon *et al.* 2011; Oldham *et al.* 2011; Paganoni *et al.* 2014b; Behrendt *et al.* 2019). The findings of Thompson *et al.* (2021) and Griffiths *et al.* (2016) also suggest that nutritional management of ewe lambs during pregnancy is a more important determinant of progeny survival than liveweight at joining. Differential management of single- and twin-bearing ewe lambs during pregnancy and lambing also appears to be effective at reducing the difference in progeny survival that is normally observed when single- and twin-bearing ewes are managed together, regardless of age and breed (Thompson *et al.* 2021). It would be assumed that this is due to improved ewe nutrition. We therefore hypothesise that (i) survival of ewe lambs and their progeny will be greater when ewes are managed to gain more liveweight during pregnancy, and (ii) that the effects on ewe and lamb survival will be greater when liveweight at the start of joining is optimal.

Methodology

This experiment was approved by the Animal Ethics Committees of Murdoch University (R3203/19). All procedures were performed in accordance with the guidelines of the Australian Code of Practice for the Use of Animals for Scientific purposes.

Animals and experimental design

Research was conducted using maternal ewe lambs at 12 sites/reps across New South Wales and Victoria, Australia, in 2023. Ewes were randomly allocated into one of two treatments after pregnancy scanning: 'High' or 'Low' nutrition. The aim was for ewes in the 'Low' nutrition treatment to be managed to gain about 5kg total weight, including the foetus, between pregnancy scanning and lambing whereas ewes in the 'High' nutrition treatment were managed to gain about 15kg total weight between pregnancy scanning and lambing. The target weight gains were achieved by altering the rate of supplementary feeding with grain or pellets and/or allocating ewes to paddocks with differing feed-on-offer (kg DM/ha) and/or pasture composition.

Animal measurements

Ewes were weighed at the start joining (-7 to 0 days from the start of joining), pregnancy scanning (approximately 50 days from the end of joining) and pre-lambing (130-140 days from the start of joining). Details of supplementary feeding were recorded for each mob between pregnancy scanning and lamb marking. The characteristics of each lambing paddock were recorded pre-lambing. The average mob size at lambing was 163 ewes for single-bearing ewes and 109 ewes for twin-bearing ewes. Ewes were assessed for lactation status at lamb marking, at approximately 160 days from the end of joining. Ewes were recorded as lactating, and therefore rearing at least one lamb, or not lactating, and therefore not rearing any lambs. Ewe and lamb survival were recorded to lamb marking. Lamb survival was calculated based on the number of foetuses and the number of live lambs at marking per mob.

Statistical analysis

Data were analysed by the following methods using GENSTAT (Edition 23). For each measure single and twin bearing ewe experiments were examined separately.

Mob means of lamb survival, ewe mortality, ewe liveweight (joining, pregnancy scanning and pre-lambing), ewe liveweight change between scanning and pre-lambing and ewe wet-dry status at weaning were examined separately by the Method of Restricted Maximum Likelihood for the effect of treatment fitted as a fixed effect while farm, replicate (nested within farm) and paddock (nested within replicate) were fitted as random effects.

After treatment effects were determined, estimates of ewe mortality and ewe wet-dry status at weaning were separately assessed by fitting Generalized Linear Mixed Models using individual ewes. The approach used a logit transformation and binomial distribution. Using additive models, logits were predicted as a function of liveweight at joining and liveweight change during pregnancy (between liveweight at joining and pre-lambing but not adjusted for conceptus) fitted as a fixed effect while farm, replicate (nested within farm) and paddock (nested within replicate) were fitted as random effects. The ewe liveweight variates were tested for quadratic effects.

Results

Ewe weight gain

Table 1. Average weight (kg) of maternal ewes at joining, pregnancy scanning and pre-lambing, and weight gain (kg) between pregnancy scanning and pre-lambing for the Low and High nutrition treatments at 12 research sites across New South Wales and Victoria in 2023. Weights are not adjusted for weight of the conceptus.

			Low	High	l.s.d.	*P*-value
Weight	Joining	Single	43.7	43.8	0.24	0.392
		Twin	46.2	45.9	0.93	0.533
	Pregnancy scanning	Single	50.7	49.9	1.25	0.155
		Twin	54.9	54.7	0.59	0.439
	Pre-lambing	Single	55.8	62.1	1.78	<0.001
		Twin	62.2	68.3	1.38	<0.001
Weight gain		Single	5.2	12.3	1.84	0.001
		Twin	7.8	14.0	1.24	<0.001

The weight of single- and twin-bearing ewes did not differ significantly between treatments at joining or pregnancy scanning. However, ewes in the High nutrition treatments gained significantly more weight between pregnancy scanning and pre-lambing and were significantly heavier pre-lambing than their counterparts in the Low nutrition treatments (Table 1).

Ewe and lamb survival

Single- and twin-bearing ewes and their lambs in the High nutrition treatments had significantly higher survival to marking than their counterparts in the Low nutrition treatments (Table 2).

Table 2. Average mortality of maternal ewe lambs and survival (%) of their lambs to marking for the Low and High nutrition treatments at 12 research sites across New South Wales and Victoria in 2023

		Low	High	l.s.d.	*P*-value
Ewe mortality	Single	3.8	1.8	0.68	<0.01
	Twin	3.4	1.2	0.66	<0.001
Lamb survival	Single	74.8	82.8	2.24	<0.01
	Twin	57.8	66.0	2.67	<0.001

There was a significant quadratic effect of joining weight ($P<0.05$) and a linear effect of liveweight change during pregnancy ($P<0.001$) on the mortality of single- and twin-bearing ewes. The combined effects of joining weight and liveweight change during pregnancy on the mortality of single-bearing ewes are shown in Table 3 and the impact on the mortality of twin-bearing ewes are shown in Table 4.

Table 3. Effects of weight at joining and liveweight change between pregnancy scanning and pre-lambing on the mortality of single-bearing maternal ewes at 12 research sites across New South Wales and Victoria in 2023. Weights are not adjusted for weight of the conceptus.

		Liveweight change						
		0	**5**	**10**	**15**	**20**	**25**	**30**
Joining weight	**33**			44.7	19.3	6.6	2.1	
	35		48.7	21.9	7.7	2.4	0.7	
	40	22.7	8.0	2.5	0.8	0.2	0.1	0.0
	45	3.8	1.1	0.3	0.1	0.0	0.0	0.0
	50	0.7	0.2	0.1	0.0	0.0	0.0	100.0
	55		0.1	0.0	0.0	0.0		
	60			0.0	0.0	0.0		

Table 4. Effects of weight at joining and liveweight change between pregnancy scanning and pre-lambing on the mortality of twin-bearing maternal ewes at 12 research sites across New South Wales and Victoria in 2023. Weights are not adjusted for weight of the conceptus.

		Liveweight change					
		5	**10**	**15**	**20**	**25**	**30**
Joining weight	**35**			32.6	15.6	6.6	2.6
	40	26.2	11.9	4.9	1.9	0.7	0.3
	45	5.6	2.2	0.9	0.3	0.1	0.0
	50	1.5	0.6	0.2	0.1	0.0	0.0
	55		0.2	0.1	0.0	0.0	0.0
	60		0.2	0.1	0.0	0.0	
	65		0.2	0.1	0.0		

Probability of ewes rearing at least one lamb

The proportion of single-bearing ewes that were lactating at marking, i.e. reared their lamb to marking, was greater for those managed at the High compared to the Low nutrition (86.1% vs 76.3%; *P*=0.05). A greater proportion of twin-bearing ewes were also lactating at marking, i.e. reared at least one lamb to marking, when managed at the High versus the Low nutrition (88.0% vs 77.2%; *P*<0.001). There was a significant quadratic effect of joining weight (*P*<0.001) and a linear effect of liveweight change during pregnancy (*P*<0.001) on the probability of single- and twin-bearing ewes rearing at least one lamb to marking. The combined effects of joining weight and liveweight change during pregnancy on the probability of ewes rearing at least one lamb to marking are show in Table 5 for single-bearing ewes and Table 6 for twin-bearing ewes.

Table 5. Effects of weight at joining and liveweight change between pregnancy scanning and pre-lambing on the probability (%) of single-bearing maternal ewes rearing at least one lamb to marking at 12 research sites across New South Wales and Victoria in 2023. Weights are not adjusted for weight of the conceptus.

		Liveweight change						
		0	**5**	**10**	**15**	**20**	**25**	**30**
Joining weight	**33**			36.4	45.1	54.2	62.9	
	35			48.1	57.1	65.6	73.3	79.7
	40	56.1	64.7	72.5	79.1	84.4	88.6	91.8
	45	74.4	80.6	85.7	89.6	92.5	94.7	96.2
	50	84.1	88.4	91.6	94.0	95.7	97.0	
	55		91.7	94.1	95.8	97.0		
	60			94.9	96.4	97.5		

Table 6. Effects of weight at joining and liveweight change between pregnancy scanning and pre-lambing on the probability (%) of twin-bearing maternal ewes rearing at least one lamb to marking at 12 research sites across New South Wales and Victoria in 2023. Weights are not adjusted for weight of the conceptus.

		Liveweight change					
		5	**10**	**15**	**20**	**25**	**30**
Joining weight	**35**			28.3	40.6	54.2	67.2
	40	37.3	50.7	64.1	75.5	84.2	90.3
	45	65.8	76.9	85.2	90.9	94.5	96.8
	50	81.7	88.5	93.0	95.9	97.6	98.6
	55	88.1	92.7	95.7	97.5	98.5	99.1
	60		93.8	96.3	97.8	98.7	
	65		92.8	95.7	97.5		

Discussion

Ewe lambs managed in the High nutrition treatments gained more weight during late pregnancy and this increased the survival of the ewes and their lambs to marking. Ewe mortality was impacted by both joining weight and liveweight gain during late pregnancy. The quadratic relationship between joining weight and ewe mortality shows that there was an optimum joining weight in our study. This finding aligns with that of Thompson *et al.* (2021). Overall, our findings support our hypotheses.

The average weight of ewe lambs at joining was about 45kg, which appears to be near optimal for reproductive rate based on the findings of Thompson *et al.* (2021). This demonstrates the best-practice management of these ewes for joining. Ewes managed in the High nutrition treatments gained about double the amount of weight as those in the Low nutrition treatments between pregnancy scanning and pre-lambing. Subsequently, survival to marking was about 8% higher for single and twin lambs born to ewes managed in the High compared to the Low nutrition treatments. Mortality was also about 2% lower for single- and twin-bearing ewes when managed at the High compared to the Low nutrition.

The average mortality of ewe lambs between pregnancy scanning and marking was similar to that reported by Thompson *et al.* (2021). Less than 1% ewe mortality is considered industry best-practice in Australia whilst mortality above 3% is considered unacceptable. Mortality of less than 1% was achieved when ewes were joined at 50kg or greater for single-bearing ewe lambs and 55kg or greater for twin-bearing ewes, regardless of their weight gain during pregnancy. Ewes in the High nutrition treatment gained about 12-14 kg during late pregnancy. It could therefore be assumed that maternal ewes managed according to best-practice nutrition are unlikely to gain more than about 15kg during late pregnancy. Thus, our results indicate that single-bearing ewes joined at 40kg that do not gain at least 10kg during late pregnancy and those joined at less than 40kg will have unacceptable ewe mortality. For twin-bearing ewes, unacceptable mortality is expected if ewes are joined at 45kg and do not gain at least 5kg during pregnancy or if ewes are joined at less than 45kg. Very high mortality of ewes was observed when ewes were joined at less than 35kg and thus producers should not join maternal ewe lambs at less than 35kg.

The average survival of single- and twin-born lambs in our study were similar to that reported previously for lambs born to maternal ewe lambs (Clune *et al.* 2021b; Thompson *et al.* 2021; Ridler *et al.* 2022). Lamb survival was significantly greater when ewes were managed to gain more weight during pregnancy. Given that survival of lambs to individual ewes was unknown in this study, lactation status was used as a proxy for lamb survival to compare with the weight of ewe lambs during pregnancy. More than 10% of single-bearing ewes did not rear a lamb to marking when they were joined at 45kg and did not gain 15kg during pregnancy or when joined at less than 45kg. Hence, survival of single-born lambs is expected to be less than 90% when ewes are below these weights. Given that lactating twin-bearing ewes may be rearing one or both lambs, it is difficult to relate the weight of twin-bearing ewe lambs to the survival of their progeny. Nevertheless, our findings suggest that more than 10% of twin-bearing ewes would not rear any lambs when joined at 50kg if they do not gain at least 12-15kg or if they are joined at less than 50kg.

Combined, our findings suggest it is unlikely that acceptable levels of ewe and lamb mortality will be achieved if ewes are joined at less than 45kg, as the required weight gain to achieve acceptable levels of mortality is unrealistic unless perhaps ewes were managed in confinement with *ad libitum* supplementary feeding. It is unclear if there is an optimum weight gain during pregnancy for ewe lambs, above which over-fatness could compromise ewe and lamb survival. However, given that ewe lambs are still growing, it would be expected that this risk would be relatively small in most cases. Producers that join their ewe lambs later than their main flock should be particularly vigilant about managing nutrition of ewe lambs given that, especially under tight seasonal conditions with limited pasture availability, they may need to allocate most of their pasture and supplementary feed to the adult lambing ewes. This could compromise weight gain in the ewe lambs in late pregnancy and therefore increase the risk of ewe and lamb mortality. Overall, our findings will contribute to the development of best-practice guidelines for the management of ewe lambs during pregnancy and lactation to optimise reproductive outcomes and profitability.

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11. Conclusion

11.1 Key findings

The project commenced with consultation with advisors and leading producers to identifying their research priorities, which include;

- impact of growth rate and flushing with green fed or lupins during joining on ewe lamb reproductive rate,
- pregnancy weight/condition score profile management and its impacts of ewe and lamb survival and lamb growth rates,
- impact of mob size at lambing on lamb survival from ewe lambs, and
- management guidelines for ewe lambs on their first lactation and recovery period to enhance subsequent reproduction rates.

Subsequently a national survey was conducted on Australian producers to baseline the performance, practices, attitudes and barriers to adoption of ewe lambs on commercial farms. From the survey of 500 producers, it was found that 23% of producers had joined ewe lambs in 2019. In addition, there were a further 10% of producers that join ewe lambs when conditions are suitable and another 1% of the producers who had never joined ewe lambs, intend to do it from now on. Hence, in a year with suitable conditions, the estimate of the maximum number of Australian sheep producers currently mating ewe lambs would be 34%.

Almost three quarters of the ewes joined by the producers interviewed were Merino, but two thirds of the ewe lambs joined were Maternal/Cross-bred/Meat breeds. Hence, joining ewe lambs is a lot more prevalent with Maternals, crossbreds, meat breeds and shedding sheep, than in Merinos.

The average lamb marking rate from ewe lambs was 76% marked to ewe lambs joined and the average ewe lamb mortality annually was 5.9%. The indicative estimate of overall lamb survival rates out of ewe lambs was 77% (76% lambs marked out of 98% overall scanning rate). However gathering accurate lamb survival data was compromised by the fact that only one-third of the producers that mate ewe lambs scanned for multiples, around one-quarter scan wet-dry only and 40$ of producers who mate ewe lambs don't scan at all. Furthermore, only 71% of producers run ewe lambs separately from other age groups of ewes.

The barriers to mating ewe lambs were also documented. These include; ewe lambs not being big enough or mature enough to join successfully, it is not economically viable and/or not suitable in their region, they will have too many lambing difficulties, be poor mothers and their will be high losses of ewe lambs themselves. Also, the potential negative aspects associated with joining ewe lambs including the long-term impact on their reproductive performance and longevity, out way the limited benefits by mating them as ewe lambs to only achieve low lambing percentages.

In conjunction with the understanding from consultation with leading producers and sheep advisors and the national survey of 500 producers, a review of the literature was undertaken by Professor Paul Kenyon from Massey University, as a gap analysis on what's known and not known with breeding ewe lambs, to ultimately determine the highest research priorities for ewe lambs. The summary of the research priorities identified through this process are in Table 11.1 below.

Table 11.1. Research priorities for ewe lambs.

	Stage of ewe lamb reproduction cycle			
	Joining	**Pregnancy**	**Lambing**	**Lactation/recovery**
Research priority 1	Impact of growth rate during joining on reproductive rate	Impact of live-weight change in late pregnancy on lamb survival and lamb growth rate	Impact of mob size during lambing on the survival of lambs from ewe lambs	Impact of weaning age during first lactation on subsequent reproductive rate
Research priority 2	Impact of short-term flushing on lupins and/or Lucerne on reproductive rate	Impact of live-weight change in late pregnancy on ewe survival and subsequent reproductive rate	Examine the impact of ewe lamb joining weight on ewe and lamb survival rates	Examine the impact of ewe lamb joining weight on subsequent reproductive rate and longevity
Research priority 3	Identifying the relationship between live weight and BCS at joining and reproductive rate			
Research priority 4	Identifying relationship between percentage of mature weight at joining and reproductive rate			

Research priorities 1 and 2 are to be addressed by interventions/treatments imposed in this project during the relevant stages of the ewe lamb reproduction cycle. Whereas Research priority 3 will be addressed by connective analysis of data across numerous data sets that have recorded ewe lamb live-weight and condition score at joining and subsequent conception and reproductive rate. The priority of 'identifying the relationship between percentage of mature weight and reproductive performance' was beyond the scope/time-frame of this current project as waiting for the ewes to mature takes years- this has been detailed as future research opportunities to follow on from this project.

Key results from the experimental work undertaken in this project showed that;

- For Maternal ewe lambs the response to weight gain during joining, where increasing weight gain by 100 g/day, equates to around an 8% lift in reproductive rate ($p<0.001$),
- Flushing ewe lambs with Lupins, fed at a rate of 500g/day for 14 days, had no significant impact on their conception or reproductive rate ($p>0.05$) and the breed of the ewe lamb had no significant bearing on the response to flushing,
- The effect of the late-pregnancy growth treatment (+156 g/day between low and high growth) on lamb survival was around 8% ($P<0.001$) with low and high growth treatments having a lamb survival of 66.5% and 74.6%, respectively. The effect on ewe mortality was around 2% ($P<0.001$) with low and high growth treatments having ewe mortality rates of 3.58% and 1.46%, respectively. Both singles and twins had similar effect.
- For ewe lambs, their joining weight had a significant quadratic effect on the mortality of single and twin bearing ewes and their lambs, while liveweight change during pregnancy had a linear effect on the mortality of single and twin bearing ewes and their lambs ($P<0.001$, $P<0.05$, highest P given for any term fitted).

- Treatment of pregnant ewe lambs with Regulin (melatonin) post-pregnancy scanning, had no discernible influence on lamb survival (P=0.974) or ewe mortality (P=0.530) of either single or twin bearing ewe lambs,
- Mob size at lambing has a significant effect on lamb survival from both single and twin bearing ewe lambs but there was no effect of breed (Merinos, Maternals or Shedders), which is consistent with research done on adult ewes. For single bearing ewe lambs, every 100 less ewes in the mob at lambing, lamb survival increases by around 3.9%, while for twin bearing ewe lambs, lamb survival improved by around 6.3% per 100 less ewes at lambing,
- Significantly more ewe lambs have lambing difficulties at lighter joining weights than ewe lambs with heavier joining weights (P=0.014),
- Lambing difficulties have direct consequences on lamb survival, with a much greater proportion (10-fold increase) of thebewe lambs that have lambed and lost experiencing lambing difficulties than ewes that have reared a lamb(s),
- There were significant curvilinear relationships between liveweight ($p < 0.001$) or condition score ($p < 0.001$) prior to breeding and reproductive rate for both Merino and non-Merino ewe lambs. It was concluded that liveweight is a more effective method than condition score for selecting ewe lambs for breeding,
- The relationship between hogget joining weight and hogget reproductive rate appears to differ, in that for Maternals it's a quadratic relationship, whereas for Merinos its linear, where for every 1 kilogram of Merino hogget joining weight, reproductive rate increases by 1.84% (p<0.001). For Maternals between 45 and 65 kg at hogget joining every 1 kilogram of Maternal hogget joining weight, increases reproductive rate increases by almost 2%, whereas between 65 and 85 kg at hogget joining every 1 kilogram of Maternal hogget joining weight, increases reproductive rate increases by less than 1%.
- Examination of the impact of parity as a ewe lamb on reproductive rate on the subsequent hogget joining, shows that for Maternals, conceiving twins as a ewe lamb results in about a 14-17% increase in reproductive rate as a hogget over and above single bearing or dry ewe lambs, whereas for Merinos, conceiving twins as a ewe lamb, results in about a 9% increase in reproductive rate as a hogget over and above single bearing and dry ewe lambs.

The benefit-cost analysis of management strategies when mating ewe lambs revealed that;

- Based on an increase in reproductive rate of 8% for a flock gaining an extra 100 g/hd/d for the duration of joining (35 days), it only pays to feed the extra grain to ewe lambs to drive this increase in weight during joining to increase reproductive rate and weaning rate, if the price of lamb was at least $9/kg and the cost of supplement was no greater than $200/t.
- A flock of ewe lambs that gain 100 g/hd/d for a 35-day period prior to the start of joining will be 3.5kg heavier at the start of joining, the predicted increase in reproduction rate averages 14% (at 4% per kg LW). This is 6% greater than the increase in reproduction rate predicted for a flock that starts the joining period lighter but utilises the feed saved to gain 100 g/hd/d during joining. As such temporal reallocation of feed to boost the rate of liveweight gain during joining is not expected to improve flock profitability.
- Updated ewe mortality relationships discovered in this project predict high mortality for ewes that are mated at light weights and gain little weight during pregnancy. The increased mortality reduces the profitability of mating the lighter ewe lambs and the optimal management will be to implement a higher LW for joining and leave a greater proportion unmated. This is likely to be combined with increasing the nutrition of the ewe lambs during either pre-joining or pregnancy. To some extent the increased mortality predicted from joining light ewe lambs can be mitigated if the ewes gain weight during pregnancy. However, to compensate for being 5 kg lighter at joining requires gaining an extra 10 to 15kg during pregnancy, so this is only likely to be feasible for flocks that are lambing in spring rather in autumn or winter, so that there is sufficient green feed available for liveweight gain.
- Updated lamb survival relationships are – similar as for the ewe lamb dam mortality – much more sensitive to ewe LW at joining than the previous research. The increased sensitivity compared to the relationships measured in adults is up to 8 times the impact on survival for a given change in ewe liveweight at joining and 2 to 3 times the impact of LW change during pregnancy. The increased sensitivity increases the financial importance of achieving the target liveweight change during pregnancy and is also likely to increase the target LW gain during pregnancy.

- The most economic pathway to increasing reproductive success in ewe lambs is through focusing on improving lamb survival, indicating that emphasis should be placed on improved pregnancy nutrition prior to emphasising the benefits of better pre-joining nutrition.
- If is increasing LW at joining is achieved by feeding extra supplementary feed the increased cost of increasing LW at joining by 1kg is between $2.00 and $3.60/ewe. This cost is partly offset by the increased reproductive rate achieved by joining at a heavier weight. The net value of the supplement cost versus the extra lambs weaned due to the higher reproductive rate for the Merino ewe lambs is a cost of between $0 and $3/ewe lamb and for Maternals is between a cost of $2.50 and a benefit of $1/ewe lamb, with the range dependent on the price of grain and the lamb value.
- Increasing LW at joining is most valuable for ewes that are joined at lighter weights and have a lower growth expectation during pregnancy. The benefits of higher joining targets are greater for the portion of the flock that conceive twins because the twin bearing ewes are more sensitive for both ewe mortality and lamb survival than the singles, furthermore the benefit of the improved survival is achieved for 2 lambs, although each lamb is less valuable.
- For a flock in which 80% of the pregnant ewe lambs have conceived singles (approx. reproductive rate 110%) it will be profitable to feed grain to increase LW at joining if the expected LW of the ewes is less than 42kg, and to feed to reduce weight loss if less than 47kg. This indicates that the target for minimum LW at joining is 42kg and that the ewes joined in the range 42 to 47kg should be fed extra grain during pregnancy to increase pregnancy weight gain. This aligns with acceptable levels of reproductive success if the single bearing ewes are gaining at least 10kg during pregnancy and the twins are gaining at least 15kg.
- If increasing LW during pregnancy is achieved by feeding extra supplementary feed the increased cost of gaining extra weight during pregnancy by 1kg is between $1.75 and $3.20/ewe depending on the cost of supplementary feed.
- Increasing LW gain during pregnancy is most valuable for ewes that are joined at lighter weights and for twin-bearing ewes rather than single-bearing ewes. If ewes are joined at 40kg or less, then it will be profitable to feed grain to increase LW gain during pregnancy. If joining at 50kg or more then it is unlikely to be profitable to feed grain to increase LW gain. In the range 40 to 50kg then it will be profitable to feed the multiple bearing ewe lambs but not the single-bearing ewe lambs.
- Ewe lambs give a bigger return on subdivision and have smaller optimum mob size than adults. The optimum mob size for ewe lambs is approximately 50% of the optimum mob size for adults. Therefore, allocate the reproducing ewe lambs to the smaller paddocks.
- The optimum mob size for ewe lambs when using permanent fencing is between 40 and 60 head for twins and 80 to 125 head for singles, with he optimum mob size for Merinos is 10 to 20% larger than the corresponding mob size for maternal/shedding breeds.

11.2 Benefits to industry

The findings of this research project provide the basis for changing the current rules of engagement for mating ewe lambs in the Australian sheep industry. Currently a maximum of 34% of Australian producers mate ewe lambs with varying results. The industry focus has been to encourage the adoption of mating ewe lambs to lift lamb production, especially whilst the national flock has struggled to sustain itself or the turn-off of sheep meat demanded globally or both. However, the findings of this project clearly show that the attention to detail when mating ewe lambs must improve in order for the production, profit and welfare outcomes from ewe lambs to be improved simultaneously. Especially in the aspect of lamb survival from ewe lambs, where on-farm trial data collected in this project, shows that only two-thirds of the lambs conceived by ewe lambs make it alive to lamb marking. This wastage is compromising ewe lamb performance and is the primary limitation to yield (lamb marking) increases from this cohort of ewes. The key is employing much more stringent policies prior to mating ewe lambs, where it appears from the biological research undertaken that minimum joining weights of 45kg are required, along with at least 15kg of total pregnancy weight gain. Together this ensures the ewe lamb is adequately grown to bear a lamb of sufficient birth weight to survive and the ewe subsequently produces enough colostrum and milk to grow her progeny. This development of the ewe lamb and her progeny, coupled with smaller mob sizes at lambing, has the potential to profoundly increase the performance of ewe lambs in Australia.

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13. Appendix

13.1 Appendix 1- Questionnaire for consultation with stakeholders

The following survey relates to the management of ewe lambs that are mated to lamb at 12-15 months.

The purpose of this interview is to identify the R,D&E that is needed to produce more lambs out of ewe lambs in the Australian flock. Outcomes of this R, D & E will formulate and validate management guidelines for Merino, Maternal and shedding ewe lambs. As an experienced advisor and/or producer your perspective on the existing challenges and gaps would be most appreciated.

Name:

Location:

1. Do you mate ewe lambs or recommend the mating of ewe lambs? (why/why not)

Maternal- Yes/No/NA Merino- Yes/No/NA Shedders- Yes/No/NA

…….

2. How many ewe lambs do you mate to lamb at 12-15 months? ……………………………….

3. What proportion of ewe lambs breed to be retained are joined to lamb as a ewe lamb?.................

4. What basis are the ewe lambs that are mated selected? ……………………………………………………….

   (visual draft, weight, weight and condition score, born early, born as a multiple)

5. Do you have a minimum joining weight, below which they are not mated? Yes/No …………………kg

6. Is the balance retained to be joined next year or sold as a lamb? ………………………………………………….

7. What age are the ewe lambs at start of joining or age recommended for joining? ……………months

   Why?...

8. Do you use or recommend the use of teasers prior to joining ewe lambs? Yes/No, Why/Why not

9. Do you use or recommend use of Campy Vaccine prior to mating ewe lambs? Yes/No, Why/Why not

10. What % of rams do you use or recommend for mating ewe lambs? ……………………………………………

11. What joining length do you use or recommend for mating ewe lambs? ……………………………………..

12. Do you use or recommend specific low birth weight rams to join ewe lambs? Yes/No, Why/Why not

13. Do you pregnancy scan or recommend pregnancy scanning ewe lambs mated?

    Don't scan Wet/dry scanning only Scan for multiples Plus scan early/late

14. What do you do or recommend to do with ewe lambs that scan dry?..

    Why?..

15. Typical percentage of ewe lambs that get pregnant each year? ………………………………………………….

16. Typical scanning rate of ewe lambs (total foetuses to ewes joined)?..
17. Typical lamb marking rates out of ewe lambs (lambs marked to ewe lambs joined)?.....................
18.
19. What is your biggest challenge with ewe lambs?
    (a) low conception in ewe lambs (ie. too many dries)
    (b) poor overall scanning rate (total foetuses to ewes joined)
    (c) dystocia (lamb difficulties with ewe lambs)
    (d) poor lamb survival out of ewe lambs (big gap between scanning rates and marking rates)
    (e) getting ewe lambs to recover from weaning first lamb(s) to next joining
    (f) poor weaning weights of lambs born from ewe lambs
    (g) low scanning rates on the second joining
    (h) other:…………………………………………………..
20. What aspects of mating ewes to lamb at 12-15 months do you want further investigated (R&D)?
    (a) impact of growth rate during joining on scanning rates
    (b) weight and condition score profile management in pregnancy on ewe and lamb survival
    (c) impact of mob size at lambing on lamb survival from ewe lambs
    (d) impact of feed on offer during lambing on lamb survival and lamb growth rates from ewe lambs
    (e) impact of birth weight and lambing ease ASBVs of the sire mated to ewe lambs on survival rates

13.2 Appendix 2- National Survey Questionnaire

The following questionnaire was used to determine the national baseline of prevalence, performance, practices and attitudes associated with ewe lambs.

Introduction

Identify if a commercial sheep breeder (filter question), if so, how many breeding ewes

S1) This year or in your last normal season, would you have joined 500 or more ewes in total (including adults, maidens and ewe lambs)?

1. Yes, this year
2. Yes, in my last normal season
3. No **THANK AND TERMINATE**

Q1) **S1 = 1:** How many ewes in total did you join this year? Were they …?
S1 = 2: In that normal season, how many ewes did you join? Were they …?

A. Merino type ewes Number __________
B. Maternal/crossbred type ewes Number __________
C. Shedding type ewes Number __________
D. All other breeds
(Please specify) _________________________ Number __________

Ewe Lamb questions

Q2) **S1 = 1:** Did you join ewe lambs (ewes less than 12 months of age?) this year?
S1 = 2: In that last normal season, did you join ewe lambs?

1. Yes
2. No - **SKIP TO Q12** *{Did NOT join ewe lambs this year/last normal season}*

Q3) **S1 = 1:** How many ewe lambs did you join this year? Were they …?
S1 = 2: In that last normal season, how many ewe lambs did you join? Were they …?

A. Merino ewe lambs ___________
B. Maternal/crossbred ewe lambs ___________
C. Shedding ewe lambs ___________
D. Other ______________________________________

Q4) How did you choose which ewe lambs to join?

1. I joined them all.
2. I only joined those above a minimum weight. (Ask what weight) ____________
3. I have a target condition score. (Ask what condition score) ____________
4. I only join some breeds. (Ask which breeds) ____________
5. I only join early born ewe lambs as they are more sexually mature.
6. Other (Ask how) ____
(weight/condition score/breeds/…)

Q5) Did you pregnancy scan your ewe lambs?

1. No **– SKIP TO Q7** *{did NOT scan}*
2. Yes, scanned for pregnant or dry
3. Yes, scanned for Dry/Single/Twin

Q6) **Q5 = 2**: {scanned for pregnant/dry only}
What proportion of the ewe lambs you joined were pregnant?

A. Merino ewe lambs ___________ %
B. Maternal/crossbred ewe lambs ___________ %
C. Shedding ewe lambs ___________ %
D. Other ___________ %

Q5 = 3: *{scanned for dry/single/twin}*
What was your overall scanning rate, total foetuses to ewe lambs joined?

A. Merino ewe lambs ___________ %
B. Maternal/crossbred ewe lambs ___________ %
C. Shedding ewe lambs ___________ %
D. Other ___________ %

Q7) Did you run those ewe lambs separately for lambing?

1. Yes
2. No **– SKIP TO Q14** *{Can only get a sensible marking rate if they are run separately}*

Q8) What marking rate did you achieve from those ewe lambs?

A. Merino ewe lambs ___________ %
B. Maternal/crossbred ewe lambs ___________ %
C. Shedding ewe lambs ___________ %
D. Other ___________ %

Q9) Is that marking rate as a percent of …?

1. … the ewe lambs run with rams.
2. … the ewe lambs that were pregnant.
3. … the ewe lambs that were wet at marking.

Q10) What would you estimate was the mortality rate in those ewe lambs during pregnancy/lambing? What percentage die? ___________ %

Q11) Was the mortality rate among those ewe lambs higher than among older lambing ewes?

1. Yes - What was the main reason for the higher death rates in ewe lambs?
2. No

SKIP TO Q14 *{they have joined ewe lambs}*

Q12) *{Q12 asks those who did NOT join ewe lambs this year/last normal year}*
Have you ever joined ewe lambs?

1. Yes **– CONTINUE WITH Q13**
2. No and I would never consider doing so **– SKIP TO Q15** *{have NEVER joined ewe lambs}*
3. No but I might consider it in the future **– SKIP TO Q15** *{have NEVER joined ewe lambs}*
4. No but I intend to do it from now on **– SKIP TO Q15** *{have NEVER joined ewe lambs}*

{Q13 asks those who did NOT join ewe lambs this year/last normal year, but have previously}

Q13) Which of the following best describes your approach to joining ewe lambs?

1. I usually join ewe lambs but didn't because of the season.
2. I usually join ewe lambs, but I didn't think they were in good enough condition this year.
3. I have tried joining ewe lambs, but the results were too poor or too variable.
4. I have tried joining ewe lambs, but they required too much effort for the reward.
5. I have tried joining ewe lambs, but it was not economically viable.

{Q14 for those that have joined ewe lambs on some occasion}

Q14) On a scale of 1 to 9, where 1 is strongly disagree and 9 is strongly agree, please score these statements.

A. Joining ewe lambs is my usual practice. ____
B. I join ewe lambs because I am trying to rebuild my flock. ____
C. I joined my ewe lambs because it improves the ewe's lifetime reproductive performance. ____
D. I joined my ewe lambs because lamb prices make it worth the additional effort. ____
E. I join ewe lambs because I am trying to accelerate genetic gain. ____
F. I join ewe lambs in order to reduce the age of my flock ____

THANK AND TERMINATE

Q15) *{Q15-16 for those who have never joined ewe lambs}*
What are the key reasons you do not join ewe lambs?

____

____

Q16) On a scale of 1 to 9, where 1 is strongly disagree and 9 is strongly agree, please score these statements.

I don't join ewe lambs because;

A. They are not big enough to get into lamb. ____
B. There are too many difficulties lambing ewe lambs. ____
C. They are not good mothers and will wean poor lambs. ____
D. They will grow less wool. ____
E. It is not economically viable in my operation. ____
F. It is not suitable for my area/climate. ____
G. I've seen poor results elsewhere. ____
H. I buy in ewes more (older) than 1 year old. ____
I. It would lead to an unacceptable increase in ewe lamb losses. ____

THANK AND TERMINATE

13.3 Appendix 3: Journal paper- Additive Impacts of Liveweight and Condition Score at Breeding on the Reproductive Performance of Merino and non-Merino Ewe Lambs

Article

Additive Impacts of Liveweight and Condition Score at Breeding on the Reproductive Performance of Merino and non-Merino Ewe Lambs

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Simple Summary: Fatness is linked to reproductive performance in sheep and its realistic to expect that higher body condition scores at breeding would have positive effects on reproductive rate of ewe lambs over and above liveweight. Data were analysed from over 17,000 records from Merino and non-Merino ewe lambs from 22 different flocks from across Australia. There were significant curvilinear relationships between liveweight or condition score prior to breeding and reproductive rate for both Merino and non-Merino ewe lambs. When analysed together, there was a significant quadratic effect of body condition score on reproductive rate independent of correlated changes in liveweight. The results indicated that if only a proportion of ewe lambs were selecting for breeding, selection based on both liveweight and condition score may only improve overall reproductive rate by 1 to 2% compared to selection on liveweight alone.

Abstract: Ewe lambs that are heavier due to improved nutrition pre- and post-weaning achieve puberty at a younger age, are more fertile and have a higher reproductive rate. Fatness is intimately linked to reproduction, and we hypothesized that higher body condition scores at breeding would have positive effects on reproductive rate of ewe lambs over and above liveweight. We also expected that if only a proportion of ewe lambs were presented for breeding then it would be more effective to select these on both liveweight and condition score. To test these hypotheses, we analysed data from over 17,000 records from Merino and non-Merino ewe lambs from 22 different flocks from across Australia. Non-Merino ewe lambs were more fertile (69.4% vs 48.7%) and achieved a higher reproductive rate than Merino ewe lambs (96.9% vs 60.7%). There were significant curvilinear relationships between liveweight ($p < 0.001$) or condition score ($p < 0.001$) prior to breeding and reproductive rate for both Merino and non-Merino ewe lambs. For both breeds there was a significant ($p < 0.001$) quadratic effect of condition score prior to breeding on reproductive rate independent of the correlated changes in liveweight, and even at the same liveweight an extra 0.5 of a condition score up to 3.3 improved reproductive rate by about 20%. Nevertheless, the results indicated that if only a proportion of ewe lambs were selecting for breeding, then selection based on both liveweight and condition score may only improve overall reproductive rate by 1 to 2% compared to selection on liveweight alone. We conclude that liveweight is a more effective method than condition score for selecting ewe lambs for breeding.

Keywords: ewe lamb, fertility, genetics, reproductive performance

1. Introduction

Breeding ewe lambs at 7 to 10 months of age can increase the profitability of sheep enterprises depending on their reproductive performance [1-3]. The reproductive performance of ewe lambs is highly variable and multiple factors contribute to this variability [reviewed by 4,5]. Merino ewe lambs that are heavier due to improved nutrition pre- and post-weaning consistently achieve puberty at a younger age, are more fertile (percentage of ewes pregnant per 100 ewes exposed to fertile rams) and have a higher reproductive rate (number of fetuses per 100 ewes exposed to fertile rams) [6-9]. This work using Merino ewe lambs with similar genetic background indicated that the relationship between liveweight prior to breeding and reproductive rate was linear over the range 35 to 50 kg and reproductive rate typically increased by about 4% per 1 kg increase in liveweight. Less is known about these responses for different genotypes of Merinos or non-Merino ewe lambs managed in different environments. Thompson et al. [10] and Corner-Thomas et al. [11] analyzed much larger data sets and reported curvilinear relationships between liveweight prior to breeding and reproductive rate for non-Merino ewe lambs that suggested little gains in reproductive rate from increasing liveweight above 45 to 50 kg. The relationship between liveweight and reproductive rate will influence the target liveweight at breeding for ewe lambs and potentially the minimum liveweight when deciding which ewe lambs are suitable for breeding.

Genetic factors influence the reproductive performance of ewe lambs [12-14] and are also likely to influence the average and minimum liveweight targets for ewe lambs at breeding. Puberty and fertility are intimately linked to body fatness, possibly via the actions of leptin [15-19], and in some studies Merino ewe lambs with higher phenotypic or genetic fat depth measured at post-weaning age achieved a higher reproductive performance than those with lower fat depth [8]. More recently, Thompson *et al*. [9] reported that Merino ewe lambs from sires with higher Australian breeding values for fatness achieved a higher reproductive rate than ewe lambs from sires with lower values for fatness and this effect was additive to the effects of liveweight prior to breeding. Indeed, Merino ewe lambs from genetically fatter sires could achieve comparable reproductive rates despite being mated lighter than those from genetically leaner sires, suggesting that ewe lambs with greater fat reserves are physiologically more mature at the same liveweight. Most commercial sheep producers in Australia do not have breeding values for individual animals, but there are strong phenotypic and genetic correlations between fat depth measured by ultrasound at the site used to generate breeding values for fat and condition score at least in adult sheep [20,21]. We therefore expect that a higher condition score will be positively related to the reproductive performance of ewe lambs. The effect of condition score and liveweight are often confounded and difficult to separate, but we hypothesized that a higher condition score at breeding would have an additional positive effect on reproductive rate of ewe lambs over and above liveweight. It would also follow that if only a proportion of ewe lambs were selected for breeding, then it would be more effective to select these ewe lambs based on both liveweight and condition score compared to liveweight alone.

2. Materials and Methods

2.1. Farms and animals

The current study collected data from 22 commercial and research farms across Australia representing a range of production environments, sheep breeds, and genotypes within breed (Figure 1). This included data from the Sheep CRC Information Nucleus Flock [22,23], MLA-funded Producer Demonstration Sites [24], and research or commercial flocks in Victoria (A. Kennedy, unpublished data) and Western Australia (6-9). The combined data included about 10,200 records for Merino ewe lambs and 7,700 records for non-Merino ewe lambs (Table 1). Dohnes and SAMMS from the Information Nucleus Flock were categorised as Merinos, and all records were not available for some ewe lambs.

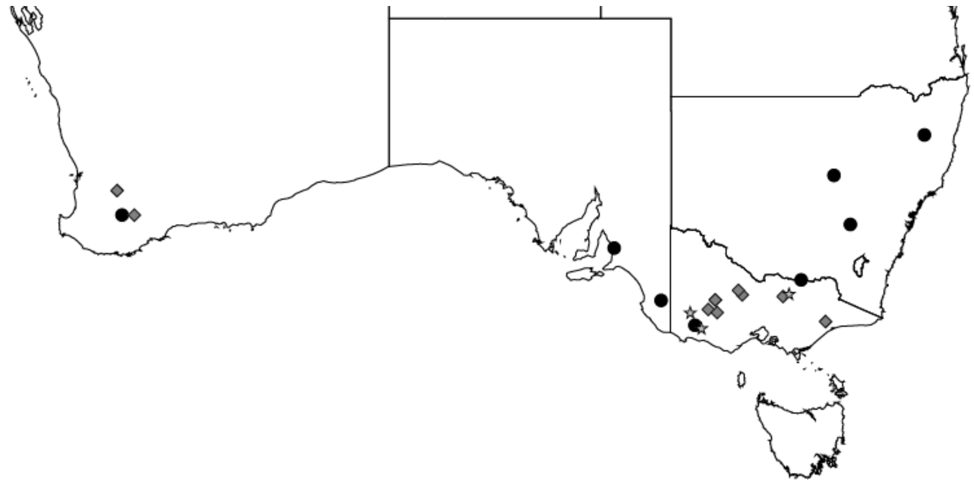

Figure 10. The locations of farms across southern Australia that provided data relating to the reproductive performance of ewe lambs for Merino (grey diamond), non-Merino (grey star), or both breeds (black circle).

Ewe lambs on all farms were managed under commercial farming conditions, and those from each farm were generally managed together from prior to breeding until at least pregnancy scanning. Ewe lambs were naturally mated between February and April with rams for an average of 40-days (range 21 to 74 days) using an average ewe:lamb ratio of 50:1 (range 25:1 to 100:1). Teasers (castrated rams or testosterone treated castrated males) were used at some farms for 15-17 days prior to introduction of entire rams.

2.2. Data collection

Liveweight of all ewe lambs was recorded at the start of breeding, and condition score was assessed at the same time for some flocks or individuals within flocks. Body condition score was assessed using 0.2 to 0.3 increments by a single operator on each farm using a 1 to 5 scale [25]. The pregnancy diagnosis at each farm was conducted by a commercial technician using transabdominal ultrasonography 50-60 days after removal of entire rams. These data were used to calculate fertility (percentage of ewes pregnant per 100 ewes exposed to fertile rams) and reproductive rate (number of fetuses per 100 ewes exposed to fertile rams).

2.3. Statistical analysis

Merino and non-Merino ewe lamb data were analysed separately by the following methods using GENSTAT (Edition 19 [26]). Reproduction rate was analysed as various functions of different variables (separately or together), including liveweight, and condition score prior to breeding, using the method of generalised linear model with a multinomial distribution and logit link function and adjustment for location by year. Data from the eight separate flocks from the Information Nucleus Flock were combined given the ewe lambs at all sites were generated from common sires. All 2-way interactions among the fixed effect and covariates were included in each model, and non-significant ($p > 0.05$) interactions were removed from the model. Liveweight was also examined by the method of restricted maximum likelihood (REML) for the effect of condition score fitted as a fixed effect while year was fitted as a random effect.

3. Results

3.1. Liveweight and condition score at the start of breeding

The average liveweight and condition score at the start of breeding varied widely between farms and years (data not shown) and between individual ewe lambs within farms. On average, non-Merino ewe lambs were slightly heavier (42.1 kg vs 40.4 kg; Table 1), but with similar condition score prior to breeding compared to Merino ewe lambs (3.2 vs 3.1; Table 1). The average standard deviation for liveweight and condition score within farm and year was 5.2 kg and 0.27 units of a condition score for Merino ewe lambs and 5.7 kg and 0.33 units of a condition score for non-Merino ewe lambs. Across all ewe lambs, only 5.3% of Merinos and 11.2% of non-Merinos were greater than 50 kg and only 4.6% and 9.2% were greater than condition score 3.5 at the start of breeding.

Across all farms and years, liveweight and condition score at the start of breeding were moderately correlated for both Merino (slope = 8.8 ± 0.21 kg per condition score; $r^2 = 25$; p <0.001) and non-Merino ewe lambs (slope = 9.2 ± 0.17 kg per condition score; $r^2 = 0.31$; p <0.001). At a given liveweight, the upper and lower 90% confidence interval was 0.9 and 1.0 condition score units either side of the mean for Merino and non-Merino ewes lambs, respectively.

3.2. *Fertility and reproductive rate*

Fertility and reproductive rate varied between farms by about 5-fold for Merino ewe lambs and 2-fold for non-Merino ewe lambs (Table 1). There was also considerable variation in fertility and reproductive rate between years within farm (data not shown) regardless of breed type. On average, non-Merino ewe lambs were more fertile (69.4% vs 48.7%) and achieved a higher reproductive rate (96.9% vs 60.7%) than Merino ewe lambs.

Table 1. Summary of data collated on the reproductive performance of Merino and non-Merino ewe lambs from multiple flocks measured across 1 to 8 years and mated at 7 to 8.5 months of age. The data includes the number of records and mean liveweight (kg) and body condition score at the start of breeding and the number of records, average fertility (number of ewes pregnant per 100 ewes mated) and reproductive rate (number of foetuses scanned per 100 ewes mated) for each farm. The data for Flock 1 represents the average of eight separate sites and the Merino data includes Dohnes and SAMMS. The data in brackets represent the 10th and 90th percentiles for liveweight and condition score at the start of breeding for individual flocks.

Flock	Age	Liveweight		Condition score		Pregnancy scanning		
		Records	Mean	Records	Mean	Records	Fertility	Reproductive rate
Merino ewe lambs								
1	8.0	777	39.4 (30.6, 49.2)	764	3.0 (2.5, 3.5)	785	25.5	31.2
2	8.5	389	44.5 (38.5, 50.0)	389	3.1 (2.8, 3.4)	389	74.6	90.2
3	8.5	376	38.0 (30.5, 46.5)	376	3.1 (2.8, 3.3)	384	75.3	90.1
4	8.0	138	35.5 (32.0, 38.9)	192	2.8 (2.6, 3.1)	192	64.6	83.8
5	8.0	1,581	42.0 (36.5, 47.5)	1,475	3.3 (2.9, 3.7)	1,592	57.5	70.7
6	7.0	999	38.2 (32.0, 45.0)	999	3.1 (2.8, 3.4)	999	63.7	81.2
7	7.5	444	39.2 (32.5, 45.5)	444	3.1 (2.8, 3.3)	444	14.0	17.0
8	8.5	680	33.9 (27.7, 41.3)	680	2.8 (2.5, 3.2)	680	20.1	22.1
9	8.0	712	44.9 (38.5, 51.5)	716	3.1 (2.8, 3.4)	719	56.3	73.0
10	8.0	1,436	42.3 (34.5, 50.5)	355	3.3 (2.7, 3.7)	1,466	47.1	56.3
11	8.0	2,349	40.1 (34.3, 47.0)	593	3.1 (2.8, 3.4)	2,543	47.9	61.7
Average	8.0	9,881	40.4	6,983	3.10	10,193	48.7	60.7
Non-Merino ewe lambs								
1	8	1,366	42.7 (32.0, 52.4)	1,142	3.1 (2.5, 3.8)	1,452	43.5	56.0
12	8	1,581	39.5 (33.5, 46.0)	1,581	3.0 (2.5, 3.3)	1,592	74.5	94.5
13	8	3,149	43.8 (37.5, 51.0)	3,151	3.3 (3.0, 3.7)	3,151	83.8	125.9
14	7.5	1,012	39.5 (33.0, 48.0)	1,012	3.0 (2.7, 3.5)	1,014	52.8	73.5
15	7.5	491	41.6 (35.0, 49.5)	491	3.2 (2.7, 3.5)	491	72.3	82.3
Average	7.8	7,599	42.1	7,377	3.17	7,700	69.4	96.9

3.3. *Effects liveweight or condition score at the start of breeding on reproductive rate*

On average, there was a significant (p < 0.001) curvilinear relationship between liveweight at the start of breeding and reproductive rate for both Merino and non-Merino ewe lambs (Figure 2). The relationship with reproductive rate for both breed types were essentially linear up to about 50 kg, and a kilogram increase in liveweight between 30 and 50 kg was associated with a 3.9 and 4.7% increase in reproductive rate for Merino and non-Merino ewe lambs, respectively. If ewe lambs achieved 50 kg at the start of breeding their reproductive rate was 90% and 98% of the predicted maximum for Merino and non-Merino ewe lambs, respectively.

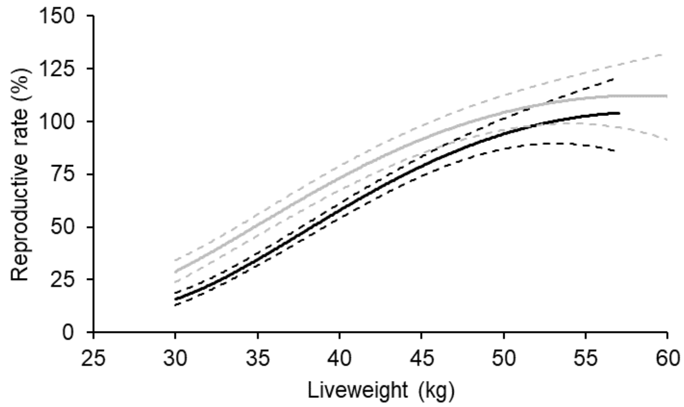

Figure 2. The effect of liveweight at the start of breeding at 7 to 8.5 months of age on the reproductive rate (foetuses scanned per 100 ewes exposed to fertile rams) of Merino (black) and non-Merino (grey) ewe lambs. The Merino data represents 9,881 records from 11 flocks and the non-Merino data represents 7,599 records from 5 flocks. The dotted lines represent the upper and lower 95% confidence intervals.

On average, the relationship between condition score at the start of breeding and reproductive rate was also curvilinear for both Merino and non-Merino ewe lambs (Figure 3). The relationship with reproductive rate for both breed types were essentially linear between condition score 2.5 and 3.5 and over this range reproductive rate increased by 64% and 66% for Merino and non-Merino ewe lambs, respectively. If ewe lambs achieved a condition score of 3.5 at the start of breeding their reproductive rate was 90% and 96% of the predicted maximum for Merino and non-Merino ewe lambs, respectively.

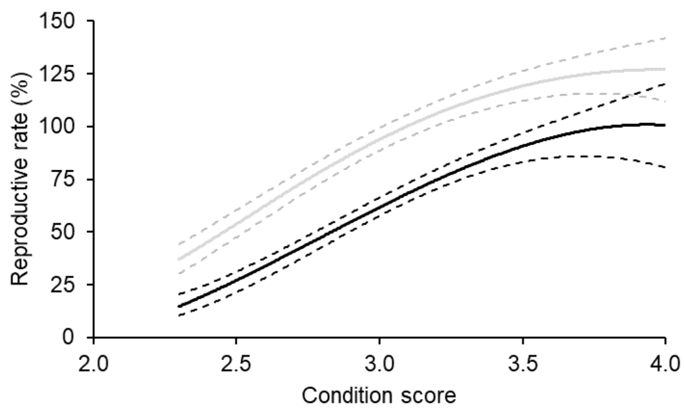

Figure 3. The effect of condition score at the start of breeding at 7 to 8.5 months of age on the reproductive rate (foetuses scanned per 100 ewes exposed to fertile rams) of Merino (black) and non-Merino (grey) ewe lambs. The Merino data represents 6,983 records from 11 flocks and the non-Merino data represents 7,377 records from 5 flocks. The dotted lines represent the upper and lower 95% confidence intervals.

3.4. Effects liveweight and condition score at the start of breeding on reproductive rate

There was a significant ($p < 0.001$) quadratic effect of condition score at the start of breeding on reproductive rate independent of the correlated changes in liveweight (Figure 4). The effects of increasing condition score at a given liveweight on reproductive rate for both Merino and non-Merino ewe lambs were most evident below condition score 3.3. When ewe lambs weighed more than 35 kg at the start of breeding, an extra 0.5 of a condition score up to 3.3 improved the reproductive rate for both Merino and non-Merino ewe lambs by about 20%. There were no significant differences in reproductive rate between Merino or non-Merino ewe lambs that were condition score 3.3 or more at the start of breeding after adjustment for liveweight.

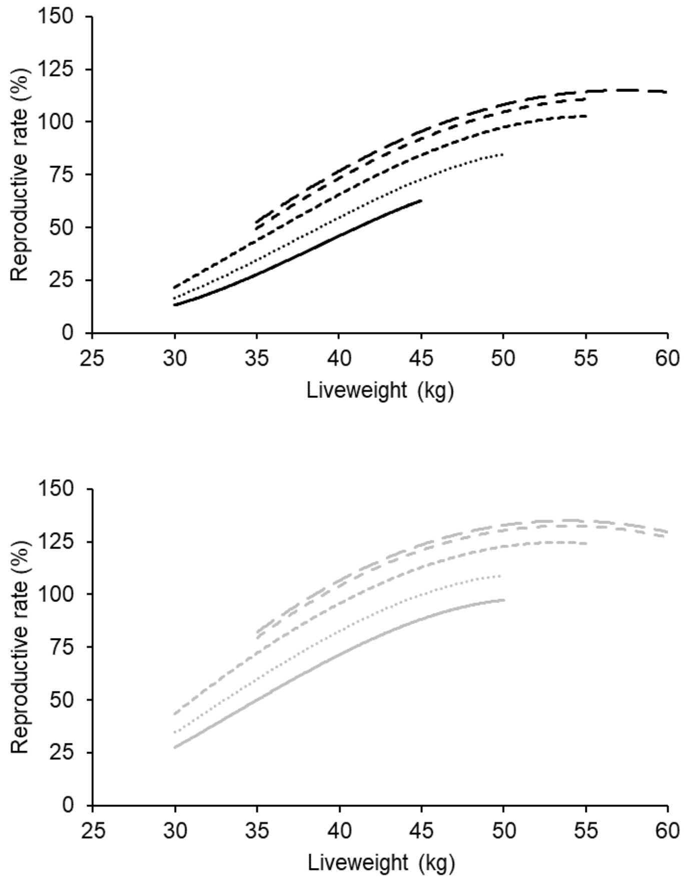

Figure 4. The effect of liveweight and condition score at the start of breeding at 7 to 8.5 months of age on the reproductive rate (foetuses scanned per 100 ewes exposed to fertile rams) of Merino (top) and non-Merino (bottom) ewe lambs. Within each figure, the condition score responses are 2.5 (bottom), 2.7, 3.0, 3.3 and 3.5 (top). The Merino data represents 6,919 records from 11 flocks and the non-Merino data represents 7,375 records from 5 flocks. The average 95% confidence intervals were ± 4.9% for Merino ewe ewes and ± 6.2% for non-Merino ewe lambs.

3.5. Selecting ewes for breeding based on liveweight and condition score

As expected, if only a proportion of ewe lambs are selected for breeding, as the minimum liveweight increases fewer lambs are retained and the average liveweight, condition score and predicted reproductive rate of those retained increases (Table 2). Above 35 kg, a one-kilogram increase in minimum liveweight would reduce the proportion of ewe lambs retained by about 6% and increase the average liveweight and predicted reproductive rate of those retained by about 0.6 kg and 1.9%, respectively.

To assess the effectiveness of selecting a proportion of ewe lambs for breeding based on liveweight and condition score compared to liveweight alone, the reproductive rate of individual ewe lambs was also predicted based on both their liveweight and condition score. When fewer lambs are selected for breeding based on achieving a liveweight threshold, there is more opportunity to identify ewe lambs from below the lightweight threshold but with a higher condition score and predicted reproductive rate. The predicted reproductive rate of this cohort which maybe up to 2.5 kg lighter is typically 12-15% higher than for the lightest ewe lambs initially retained based on liveweight only. However, as selection based on liveweight and condition score only allows for up to 20% of all ewe lambs to be substituted, the predicted improvement in overall reproductive rate compared to selection on liveweight alone was generally less than 2% across all the scenarios for both ewe breeds.

Table 2. The effects of selection based on minimum liveweight (kg) on the proportion of Merino and non-Merino ewe lambs retained for breeding (%) and their average liveweight (kg), condition score and predicted reproductive rate (foetuses scanned per 100 ewes exposed to fertile rams). The effects of replacing varying proportions of ewe lambs that were even lighter than a minimum liveweight threshold but with a higher condition score and predicted reproductive rate on the overall predicted reproductive rate are also shown.

Ewe lambs retained for breeding selected on liveweight only					Ewe lambs retained for breeding selected on liveweight and condition score		
Minimum liveweight	Proportion retained	Average liveweight	Average condition score	Average reproductive rate	Proportion replaced from lighter ewe lambs	Minimum liveweight	Average reproductive rate
Merino ewe lambs							
None	100	40.3	3.10	63.6	-	-	-
≥ 35.0	82	42.3	3.17	71.5	4.7	30.8	72.2
≥ 37.5	69	43.5	3.20	76.0	7.8	35.0	77.1
≥ 40.0	54	44.9	3.23	80.8	10.4	37.5	82.2
≥ 42.5	37	46.6	3.25	85.6	14.9	40.1	87.5
≥ 45.0	23	48.4	3.28	90.1	19.0	43.0	92.4
Non-Merino ewe lambs							
None	100	42.0	3.16	99.7	-	-	-
≥ 35.0	89	43.2	3.21	106.1	2.8	32.0	106.5
≥ 37.5	77	44.3	3.24	110.8	4.6	35.0	111.5
≥ 40.0	62	45.7	3.28	116.0	7.3	37.8	117.1
≥ 42.5	45	47.4	3.33	121.1	10.8	40.4	122.6
≥ 45.0	31	49.3	3.39	125.4	13.8	43.1	127.2

4. Discussion

Reproductive rate of Merino and non-Merino ewe lambs bred at 7 to 8.5 months of age was positively influenced by both liveweight and condition score at the start of breeding. The average reproductive rate of Merino ewe lambs was lower than that of non-Merino ewe lambs, but the impact of increasing liveweight and condition score at the start of breeding on reproductive rate were similar. Across all ewe lambs and regardless of breed, there was a linear effect of liveweight on reproductive rate up to about 50 kg with smaller gains in reproductive rate to increasing liveweight above 50 kg. Similarly, there was a linear effect of condition score on reproductive rate up to 3.3 with smaller gains above condition score 3.3. Increasing both condition score and liveweight at the start of breeding had positive additive effects on reproductive rate, which supported our first hypothesis. However, if only a proportion of ewe lambs were selected for breeding, it was predicted that selection based on both liveweight and condition score typically only improved reproductive rate by 1 to 2% compared to selection based on liveweight alone. Our second hypothesis was therefore not supported, and we conclude that liveweight is a more effective method than condition score for selecting ewe lambs for breeding.

Ewe lambs which were heavier at the start of breeding achieved a higher reproductive rate than lighter ewe lambs. A one-kilogram increase in liveweight at the start of breeding between 30 and 50 kg was associated with a 3.9 and 4.7% increase in reproductive rate for Merino and non-Merino ewe lambs, respectively. These increases in reproductive rate per kilogram of liveweight at the start of breeding were within the range we have previously reported for both Merino ewe lambs [6-9] and non-Merino ewes lambs [10]. However the response to liveweight are greater than the 2.5% reported for maternal composite, Romney and Coopworth ewe lambs by Corner-Thomas et al. [11] and the 3.1% for Border Leicester Merino ewe lambs reported by Paganoni et al. [27]. This variation in responses to liveweight at the start of breeding observed between individual flocks of Merino ewe lambs and Border Leicester Merino ewe lambs suggests that the response varies more between individual flocks within breeds than between breeds. Therefore, in practice, it would be beneficial for individual farmers to quantify the relationship between liveweight and reproductive rate for their specific ewe lambs and management settings.

This is the first study to report a curvilinear relationship between liveweight at the start of breeding and reproductive rate for Merino ewe lambs. This may not have been previously observed due to a limited number of animals above 50 kg in prior studies, whereas in the current study almost 500 Merino ewe lambs (6%) and 850 non-Merino ewe lambs (11%) exceeded 50 kg at the start of breeding. Our study, in conjunction with the findings of Thompson et al. [10], demonstrate that regardless of breed there is a diminishing response in reproductive rate as liveweight increases beyond 50 kg. Moreover, Thompson et al. [9] found no significant effects of liveweight of Merino ewe lambs at the start of breeding on the birth weight or survival of their progeny. Likewise, Thompson et al. [10] observed no benefits in either survival of non-Merino ewe lambs or their progeny when ewe lambs were more than 50 kg at the start of breeding. These results suggest that the potential increase in weaning rates from both Merino and non-Merino ewe lambs weighing above 50 kg at the start of breeding are likely to be minimal. In practice, especially if providing supplements, it is therefore likely to be more cost effective to differentially allocate feed to lighter ewe lambs over the months prior to breeding to increase the proportion of the flock above a minimum liveweight and therefore suitable for breeding.

Ewe lambs with a higher condition score at the start of breeding achieved a higher reproductive rate than those with a lower condition score. The relationships for both Merino and Maternal ewe lambs were essentially linear between condition score 2.5 and 3.5 and over this range reproductive rate increased by more than 60%. This effect of condition score had not been reported previously for Merino ewe lambs and the magnitude of improvement was two to five-fold more than that reported for non-Merino ewe lambs [11,27]. In our study there were minimal gains in reproductive rate with increasing condition score above 3.5, but less than 5% and 10% of Merino and non-Merino ewe lambs were above condition score 3.5 at the start of breeding. Consistent with these findings, Corner Thomas et al. [11] reported that reproductive rate did not differ significantly between ewe lambs that were condition score 3 or more at the start of breeding, whereas Paganoni et al. [27] reported linear relationships. The precise reasons for the differences between studies is not known but could reflect differences in sheep genotypes, subjectivity of condition score assessments, size of data sets or methods for data analysis. Nevertheless, if either Merino or non-Merino ewe lambs are bred between 7.0 and 8.5 months of age it is clear that they should be managing to be as fat as realistically feasible to improve their reproductive rate. In practice, it is important to determine the relative gains in reproductive rate achieved by managing ewe lambs to achieve specific condition score versus liveweight targets at breeding.

Condition score and liveweight at the start of breeding had an additive effect on reproductive rate. Below condition score 3.3 an extra 0.5 of a condition score improved reproductive rate for both Merino and non-Merino ewe lambs by about 20% at the same liveweight. These findings contrast with Paganoni et al. [27] who found no additional effects of condition score on the reproductive performance of Border Leicester Merino ewe lambs in addition to that explained by liveweight. A possible explanation for the differences between studies is that Paganoni et al. [27] analyzed data for single flocks and years comprising an average of 50 ewe lambs (range 40 to 112), whereas the current analysis was across flocks and years involving almost 7,000 ewe lambs for each breed. These additional effects of fatness are not surprising given other studies have highlighted that a particular ratio of fat to lean mass is normally necessary to initiate puberty and for the maintenance of female reproductive ability across a range of species [15-19]. Rosales *et al*. [7,18] reported a linear relationship between leptin concentration and reproductive rate even after including liveweight at the start of breeding in statistical models, and other work reported a linear relationship between Merino ewe lambs own breeding value for fatness and leptin concentration [6,18]. This is also consistent with the positive effect of sire breeding value for fatness at post-weaning age on reproductive rate for Merino ewe lambs over and above the effects of liveweight at breeding reported by Thompson *et al*. [9]. A surprising result was the quadratic effect of condition score such that there were no significant gains in reproductive rate above condition score 3.3 at a given liveweight. This suggests not only a lower fatness threshold to stimulate puberty but also an upper threshold to improving reproductive rate. This would seem biologically sensible but further work is needed to confirm relationships with both phenotypic and genetic differences in fatness to inform both management and selection strategies to optimise reproductive rate in ewe lambs.

Reproductive rate was increased by selecting ewe lambs for breeding based on a higher minimum liveweight and there were minimal additional benefits from selecting these animals on both liveweight and condition score. Breeding from only the heaviest 50% of ewe lambs increased the overall reproductive rate by about 20%. Current industry guidelines regarding minimum liveweights for breeding vary from 40 to 45 kg but to our knowledge there is little economic justification for these liveweight thresholds. In practice, the optimum proportion of ewes mated is likely to vary between enterprises. Young and Thompson [28] reported that the optimum proportion of ewe lambs to mate was consistently higher for non-Merino than Merino ewe lambs. This outcome is not surprising given our data which indicated that non-Merino ewe lambs were heavier at joining and achieved a higher reproductive rate at the same liveweight than Merino ewe lambs. It is also likely that other factors such as length of growing season, seasonal conditions that influence weaning weight and post-weaning growth, date of joining, value of meat, and costs of supplements will influence the optimum proportion of ewe lambs to breed in any given season. Furthermore, it is likely that the adoption of joining ewe lambs could be facilitated by the development of a decision support tool to identify management targets and priorities which reflect the seasonal conditions each year.

5.0 Conclusions

This study has shown that higher body condition scores at the start of breeding had additional positive effects on reproductive rate of both Merino and non-Merino ewe lambs over and above correlated increases in liveweight. Reproductive rate was increased by selecting ewe lambs for breeding based on a higher minimum liveweight and it is possible to identify ewe lambs from below the lightweight threshold but with a higher condition score and predicted reproductive rate. However, it was predicted that selection for breeding based on both liveweight and condition score only improved overall reproductive rate by 1 to 2% compared to selection on liveweight alone.

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Informed Consent Statement: Informed consent was obtained from all producers who volunteered their animals for this study.

Data Availability Statement: The datasets generated and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request pending permission from project funders.

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13.4 Appendix 4- Key reflections survey

Section A – Demographic Information

A1. Your contact details

Company/Business Name: ____________________

Property Address: ____________________
(Incl. Property Name)

Phone Number: __________ **Mobile:** __________

Email Address: ____________________

Postal Address: ____________________

A2. Please tell us about your enterprise

Area Managed: (in hectares)	*Number of beef breeders:*	*Number of cattle turned off per year:*	*Total Number of cattle:*
Number of Ewes:	*Number of lambs turned off each year:*	*Total Number of Sheep:*	*Number of goats turned off per year:*

A3. ***Main type of sheep:*** ***Merinos*** ***Maternals*** ***Shedders***

A4. ***Lambing date for adult ewes (start)?*** ________________________________

A5. ***Lambing date for ewe lambs (start)?*** ________________________________

A6. ***Number of ewe lambs typically joined?*** ________________________________

A7. ***Typical proportion of ewe lambs mated?*** ________________________________

A8. ***Length of joining for ewe lambs?*** ________________________________

A9. ***Breed of ram mated to ewe lambs?*** ________________________________

A10. ***Percentage of rams joined to ewe lambs?*** ________________________________

Section B – Knowledge, Attitude and Skills *(If you do not know, please select the 'Unsure' option)*

B1. Do you normally mate ewe lambs- YES / NO Why or Why Not?

....

....

B2. How would you determine when a ewe lamb is ready to join? *(Tick the answer that applies to you)*

Basis	a) Liveweight	b) % adult weight	c) age at joining	d) joining CS	e) birth type	f) season	g) unsure
Tick what applies							
Target applied							

B3. How much weight gain during pregnancy do your ewe lambs achieve?

a. Just maintain from joining to lambing .... ☐
b. Gain 5 kgs from joining to lambing .... ☐
c. Gain 10 kgs from joining to lambing .... ☐
d. Gain 15 kgs from joining to lambing .... ☐
e. Gain at least 20 kgs from joining to lambing .... ☐
f. Unsure .... ☐

B4. What do you think is the optimal level of weight gain for a single-bearing ewe lamb during pregnancy to increase-?

	Ewe survival	Lamb survival
a. Just maintain from joining to lambing	☐	☐
b. Gain 5 kgs from joining to lambing	☐	☐
c. Gain 10 kgs from joining to lambing	☐	☐
d. Gain 15 kgs from joining to lambing	☐	☐
e. Gain at least 20 kgs from joining to lambing	☐	☐
f. Unsure	☐	☐

B5. What do you think is the optimal level of weight gain for a twin-bearing ewe lamb during pregnancy to increase-?

	Ewe survival	Lamb survival
a. Just maintain from joining to lambing	☐	☐
b. Gain 5 kgs from joining to lambing	☐	☐
c. Gain 10 kgs from joining to lambing	☐	☐
d. Gain 15 kgs from joining to lambing	☐	☐
e. Gain at least 20 kgs from joining to lambing	☐	☐
f. Unsure	☐	☐

B6. How do you rate your current knowledge of managing ewe lambs for good scanning rates?

Please rate out of 10 by marking your choice below, 1 = Very Poor, 5 = average, 10 = extremely knowledgeable

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B7. Please rate your skill level in managing ewe lambs, to achieve good scanning rates?

Please rate out of 10 by marking your choice below, 1 = very low skill, 5 = average, 10 = very high skill level

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B8. How do you rate your current knowledge of managing ewe lambs for good lamb survival rates?

Please rate out of 10 by marking your choice below, 1 = Very Poor, 5 = average, 10 = extremely knowledgeable

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B9. Please rate your skill level in managing ewe lambs, to achieve good lamb survival rates?

Please rate out of 10 by marking your choice below, 1 = very low skill, 5 = average, 10 = very high skill level

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B10. Rate the degree to which you prioritise the management/nutrition of pregnant ewe lambs after pregnancy scanning (during winter) compared to your adult late-pregnant/lambing ewes?

Please rate out of 10 by marking your choice below, 1 = very low priority, 5 = same as lambing adults, 10 = very high priority

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Section C – Confidence and Practices

C1. How confident are you in managing ewe lambs to achieve good pregnancy scanning rates?

Please rate out of 10 by marking your choice below, 1 = Not at all confident, 5 = somewhat confidence, 10 = very confident

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C2. How confident are you in managing ewe lambs to achieve high ewe and lamb survival outcomes?

Please rate out of 10 by marking your choice below, 1 = Not at all confident, 5 = somewhat confidence, 10 = very confident

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C3. Are you already considering making any specific changes within your business relevant to the ewe lambs?

☐ Yes ☐ No **Details of change-**

Please tick how likely you are to make a change in relation to the above question;

Unsure	Very unlikely	Unlikely	Possible	Likely	Very likely
☐	☐	☐	☐	☐	☐

C4. For the key metrics you are seeking to demonstrate in this PDS, please advise what is your current performance;

Metric	**2023**	**2022**
Number of ewe lambs joined		
Pregnancy scanning rates [(foetuses ÷ ewe lambs joined)*100]		
Lamb marking rates [(lambs marked ÷ ewe lambs joined)*100]		
Lamb survival rates [(lambs marked ÷ foetuses scanned)*100]		
Ewe survival rate [(ewes at marking ÷ ewes scanned pregnant)*100]		

C5. Do you currently use the following practices, select the frequency of use?

	Normal prac. (≥ 4/5yrs)	Sometimes (3/5 yrs)	Rarely (1-2/5 yrs)	Never	Any targets
Weigh ewe lambs 1-2 months prior to joining	☐	☐	☐	☐	___________
Weigh ewe lambs at the start of joining	☐	☐	☐	☐	___________
Weigh ewe lambs at end of joining	☐	☐	☐	☐	___________
Pregnancy scan ewe lambs for multiples (0, 1, 2)	☐	☐	☐	☐	___________
Manage singles and twin ewe lambs separately	☐	☐	☐	☐	___________
Weigh ewe lambs at/after pregnancy scanning	☐	☐	☐	☐	___________
Weigh ewe lambs at pre-lambing treatment	☐	☐	☐	☐	___________
Have ewe lamb minimum critical mating weight	☐	☐	☐	☐	___________
Have target pregnancy weight gain for ewe lambs	☐	☐	☐	☐	___________
Vaccinate ewe lambs for Campylobacter	☐	☐	☐	☐	___________
Small mobs (<100) when lambing twin ewe lambs	☐	☐	☐	☐	___________
Calculate lamb survival rates from ewe lambs	☐	☐	☐	☐	___________
Calculate survival rate of pregnant ewe lambs	☐	☐	☐	☐	___________
Budget energy&protein to achieve growth targets	☐	☐	☐	☐	___________
Use teasers prior to joining ewe lambs	☐	☐	☐	☐	___________
Remove teasers prior to putting ram in	☐	☐	☐	☐	___________

Section D – Depth Interview Questions

D1. Tell me about what is working well with joining and lambing ewe lambs in your sheep enterprise?

………

………

D2. Tell me about what needs to improve with ewe lamb performance in your sheep enterprise?

………

………

D3. Tell me about your strategy (keep/sale) with ewe lambs not joined or scanned dry?

Not joined ewe lambs:………

Scanned dry ewe lambs:……

D4. Tell me about the primary causes of lamb loss from ewe lambs in your sheep enterprise?

………

………

D5. Tell me about the primary causes of mortality for late-pregnant/lambing ewe lambs in your sheep enterprise?

………

………

D6. Tell me about the toughest pinch-point/challenge period with ewe lambs in your sheep enterprise and the impact of it?

………

………

D7. Tell me about what worries you the most with joining and lambing ewe lambs, either on your own farm or industry wise?

………

………

D8. What is your typical mob size for single-bearing ewe lambs at lambing? ……………………………………………………………………….

D9. What is your optimum mob size for single-bearing ewe lambs at lambing? ……………………………………………………………………….

D10. What is your typical mob size for twin-bearing ewe lambs at lambing? ……………………………………………………………………

D11. What is your optimum mob size for twin-bearing ewe lambs at lambing? ……………………………………………………………………

D12. Tell me about your main system level questions with ewe lambs?

……

……

……

………