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Improving lamb survival by optimising lambing density and mob size

1. Executive Summary

Lamb mortalities represent a major source of reproductive wastage and are estimated to cost the Australian sheep industry more than $1B each year. Improving reproductive performance is therefore a high priority for AWI and MLA to sustain the national ewe flock and meet domestic and export demand for wool and sheep meat. The National Sheep Reproduction Strategy estimated that improving the survival of single lambs by 5% and twin lambs by 20% would improve farm profit across the industry by $100M and $350M per annum. Participation in Lifetime Ewe Management has improved marking percentage by approximately 10% amongst adopters or 2% across the national flock. It is estimated that about half of these gains have been achieved from improving lamb survival. However, it is evident that additional strategies that will appeal to a much larger proportion of sheep producers are needed to improve marking rates by 5% or more over the next 5 years. There is a major gap in knowledge surrounding the effects of mob size and stocking rate on lamb survival. A limited number of studies conducted on a small, experimental scale have suggested that higher stocking rates or lambing densities increase the risk of mismothering, ewe-lamb separations and lamb mortality. Lambing density is expected to have a greater effect on the survival of multiple-born lambs because more lambs are born per day which presents a greater risk for mismothering. In support, survey data collected from commercial producers in south-east Victoria found that the survival of single- and twin-born lambs decreased by 1.4% and 3.5% per additional 100 ewes in the mob at lambing, regardless of Merino or non-Merino breed. Furthermore, lamb survival decreased by 0.7% for each additional ewe per hectare, regardless of breed and birth type. The existing guidelines of 100 to 250 adult twin-bearing ewes per mob at lambing could therefore represent a range of over 5% in lamb survival or a range in marking rate for twin-bearing mobs of over 10%.

This project therefore aimed to quantify the effects of mob size and stocking rate on the survival of Merino and non-Merino lambs born across southern Australia to deliver improved recommendations for sheep producers regarding the allocation of ewes to mobs and paddocks at lambing. This project also aimed to assist producers to make more informed decisions about the cost-benefit of investing funds in paddock subdivision through permanent or temporary fencing to improve reproductive performance and farm profitability. The research involved three components which were completed across southern Australia; (i) on-farm research at 70 commercial farms to test a 2x2 factorial combination of mob size (high or low) and stocking rate (high or low) on the survival of twin-born lambs of Merino or non-Merino breed; (ii) on-farm research at 15 commercial farms to test the effect of mob size (high or low) on the survival of twin-born Merino lambs at low stocking rates; and (iii) a network of 194 sheep producers who contributed data for 2174 lambing mobs from their own farms to investigate the impacts of mob size and stocking rate on the survival of single- and twin-born lambs of Merino and non-Merino breed across a broad range of management and environmental conditions.

Lamb survival was found to be poorer at higher mob sizes but not stocking rates. A linear relationship between mob size and lamb survival was identified whereby the survival of twin-born lambs decreased by between 2% and 2.5% for each additional 100 ewes in the mob at lambing ($P<0.001$). This effect was consistent across Merino and non-Merino breeds and was not influenced by stocking rate, ewe condition score at lambing, feed-on-offer at lambing or the characteristics of the lambing paddock. Analysis of the data collected from producers across southern Australia showed that the survival of single- and twin-born lambs decreased by 0.3% and 1.1% per additional 100 ewes in the mob at lambing, regardless of Merino or non-Merino breed. The stocking rate of ewes at lambing did not influence lamb survival. Economic modelling showed that reducing mob size at lambing is justified even if paddock subdivision is required. The economic return from reducing mob and paddock size at lambing is greater for twin- compared to single-bearing ewes, with the optimum mob size for twin-bearing ewes being 40% to 50% that for single-bearing ewes. For producers that don't pregnancy scan or only scan wet/dry, the optimum mob size is closer to the mob size for twin- compared to single-bearing ewes. Integrating guidelines for reducing mob size at lambing with current guidelines for the optimisation of maternal nutrition and resource allocation will contribute to improved marking rates within the sheep industry.

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2. Introduction/ Hypothesis

Lamb mortalities represent a major source of reproductive wastage and are estimated to cost the Australian sheep industry more than $1B each year (Trompf *et al* 2018). Improving reproductive performance is therefore a high priority for AWI and MLA to sustain the national ewe flock and meet domestic and export demands for wool and sheep meat. From the analysis that underpinned development of the National Sheep Reproduction Strategy, it is estimated that improving the survival of single-born lambs by 5% and twin-born lambs by 20% would improve farm profit across the industry by $100M and $350M each year (Young *et al.* 2014b). The optimisation of maternal nutrition is key for improving lamb survival (Behrendt *et al.* 2011; Oldham *et al.* 2011; Paganoni *et al.* 2014). Comprehensive recommendations are available for management of ewe nutrition to achieve condition score targets throughout the year (www.lifetimewool.com.au). These guidelines have been widely adopted via participation in Lifetime Ewe Management and have led to improvements in marking percentage of about 10% amongst adopters or 2% across the national flock (Trompf *et al.* 2011). However, approximately 20% of lambs born still die prior to marking even when ewe nutrition is managed according to best practice (Oldham *et al.* 2011). Hence, it is evident that additional strategies that appeal to a large proportion of sheep producers are needed to improve marking rates by 5% or more over the next 5 years.

The allocation of ewes to mobs and paddocks at lambing requires consideration of several factors which influence lamb survival such as ewe condition score, feed-on-offer (FOO) and pasture quality, the availability of shelter and the risk of predation (Hinch and Brien 2014). Guidelines for Merinos lambing in winter-spring recommend ewes are in condition score 3.0 to 3.4 at lambing and FOO is between 1500 kg DM/ha and 2000 kg DM/ha for optimal ewe and lamb survival and performance (Behrendt *et al.* 2011; Curnow *et al.* 2011; Hocking Edwards *et al.* 2011; Oldham *et al.* 2011). High chill conditions at lambing increase the risk of hypothermia in newborn lambs, particularly those of Merino breed (Alexander 1962; Donnelly 1984; Sykes *et al.* 2010). The allocation of twin-bearing ewes to well-sheltered paddocks can reduce the chill index experienced by lambs and improve lamb survival (Broster *et al.* 2012; Donnelly 1984; Lynch *et al.* 1980; Young *et al.* 2014a). However, the effect of shelter on lamb survival is variable and is understood to be related to several factors including the severity of the chill conditions at lambing, topography of the paddock relevant to the prevailing weather conditions, type and thus efficacy of the available shelter, and the proportion of ewes which access the shelter (Bird *et al.* 1984; Broster *et al.* 2012; Lynch and Alexander 1976; Paganoni *et al.* 2008; Robertson *et al.* 2011). Guidelines are available to producers for the nutritional management of lambing ewes and selection of paddocks based on FOO and shelter. However, there is a major gap in knowledge surrounding the effects of mob size and stocking rate on lamb survival and hence there is little evidence to support the recommendations which are currently available to producers.

Limited experimental work has shown that increasing the mob size or stocking rate of ewes at lambing can decrease lamb survival. Kleemann *et al.* (2006) analysed data from commercial Merino flocks in South Australia, where mob size ranged from 119 to 499 ewes (average 326 ewes) and stocking rate ranged from 2.9 to 23.9 ewes/ha (average 8.6 ewes/ha). They observed a quadratic relationship between the mob size of adult ewes and lamb survival and suggested that the survival of single- and twin-born lambs was optimised at mob sizes of 414 and 386 ewes. In contrast, a recent survey of producers in New South Wales by Allworth *et al.* (2017) found that the survival of twin-born lambs tended to be greater when lambs were born at mob sizes of less than 200 ewes compared with 200 ewes or greater. Survey data collected from producers in south-eastern Australia indicated that increasing mob size by 100 ewes at lambing will decrease the survival of single- and twin-born lambs by 1.4% and 3.5%. Furthermore, increasing stocking rate by 1 ewe/ha was shown to decrease lamb survival by 0.7% regardless of lamb birth type (Lockwood *et al.* 2019). These effects were observed to be consistent amongst Merino and non-Merino breeds. Other studies have reported variable effects of stocking rate on lamb survival. For example, Earle *et al.* (2017) found that the number of lambs weaned per ewe was not influenced by stocking rate when ranging from 10 to 14 ewes/ha. In contrast, other researchers have reported an increased risk of ewe-lamb separations and lamb mortality when ewes lambed at high stocking rates in small paddocks (Cloete 1992; Robertson *et al.* 2012; Winfield 1970). It is unclear how other factors such as breed, ewe condition score, FOO and the characteristics of the lambing paddock influence the relationship between lambing density and lamb survival. Hence, experimental research is required to quantify the effects of mob size and stocking rate on lamb survival across different breeds, environments and management conditions on commercial farms.

This research involved three experiments conducted across southern Australia;

i. On-farm research at 70 commercial farms to test a 2x2 factorial combination of mob size (high or low) and stocking rate (high or low) on the survival of twin-born lambs of Merino and non-Merino breed.
   This experiment tested the hypotheses that (i) increasing mob size and stocking rate at lambing will decrease the survival of twin-born lambs and (ii) that this effect will be greater for lambs of Merino compared to non-Merino breed.

ii. On-farm research at 15 commercial farms to test the effect of mob size (high or low) on the survival of twin-born Merino lambs at a low stocking rate.
   This experiment tested the hypothesis that reducing mob size for twin-bearing Merino ewes which lamb at a low stocking rate will increase the survival of their lambs.

iii. A network of 194 sheep producers who contributed data from their own farms to investigate the impacts of mob size and stocking rate on the survival of single- and twin-born lambs of Merino and non-Merino breed across a broad range of management and environmental conditions.
   This experiment tested the hypothesis that reducing mob size and stocking rates at lambing will have a greater impact on (i) the survival of twin-born lambs compared to single-born lambs and (ii) the survival of Merino lambs compared to non-Merino lambs.

3. Project Objectives

1. Quantified the impacts of lambing density on lamb survival and the relative importance of mob size and stocking rate on at least 35 farms throughout Western Australia, Victoria, New South Wales and South Australia in each of two years.

2. Quantified the interactions between lambing density and other factors including feed-on-offer at lambing, ewe condition score at lambing, ewe age, pregnancy status and lambing environment, including chill index.

3. Quantified the impacts of lambing mob size on lamb survival in lower stocking density regions.

4. Quantified the interactions between lambing mob size and other factors including FOO at lambing, ewe condition score at lambing, ewe age, pregnancy status and lambing environment, including chill index.

5. Involved 200 sheep producers directly in the on-farm sites (i.e. a network of at least 5 farms around each site) and collated their data in real time to monitor changes in mob size, paddock size, stocking rate, feed on offer and condition score at lambing and paddock aspects at lambing in relation to lamb survival over 2 years.

6. Completed a comprehensive cost-benefit analysis on strategies that optimise lambing density and survival for different production systems and environments.

7. Developed extension messages for producers for optimum management at lambing, including mob size, paddock size and stocking rate, which lead to a 10% increase in survival of twin born lambs over and above that achieved from adopting existing guidelines for management of ewe nutrition.

4. Success in Achieving Objectives

All 70 on-farm research sites were completed during the lambing seasons of 2016 to 2018 to investigate the impacts of mob size and stocking rate on the survival of twin lambs born on farms across southern Australia. The 15 on-farm research sites to investigate the impact of mob size on the survival of twin lambs born at a low stocking rate in WA and NSW were also completed during 2018. A network of 194 producers across southern Australia were engaged to provide data from their own farms to contribute to understanding the relationship between lambing density and lamb survival. Data were collected for a total of 2174 mobs of ewes which lambed between 2016 and 2018. Significant industry engagement occurred through direct involvement with producers at the research sites, via the producer network and through field days, conferences and industry media. Overall the research has identified that lambing ewes in smaller mobs will increase lamb survival regardless of Merino or non-Merino breed.

5. Experiment One – Decreasing the mob size but not stocking rate of twin-bearing ewes at lambing increases the survival of their lambs to marking at farms across southern Australia

5.1. Methodology

5.1.1. Research sites, animals and experimental design

Research was conducted on 70 commercial sheep farms across Western Australia (WA; *n* = 19), South Australia (SA; *n* = 7) and Victoria (VIC; *n* = 30) during 2016, 2017 and 2018. Research in New South Wales was conducted during 2017 (NSW; *n* = 14). The locations of the research sites are shown in Figure 5.1. The experiment tested a 2x2 factorial combination of mob size (high or low) and stocking rate (high or low). At each farm, adult twin-bearing ewes were randomly allocated into one of four mobs on day 140 from the start of joining with rams. The mean mob sizes and stocking rates for each breed are presented in Table 5.1. A single breed was used at each research site; Merino or non-Merino. Merino refers to joining of Merino ewes to Merino rams. Non-Merino refers to joining of maternal (Corriedale or Coopworth), first cross (Merino x Border Leicester), terminal (Suffolk, White Suffolk, Dorset or Poll Dorset) and composite ewe and ram breeds. Lambs were born in late autumn and/or winter at all sites.

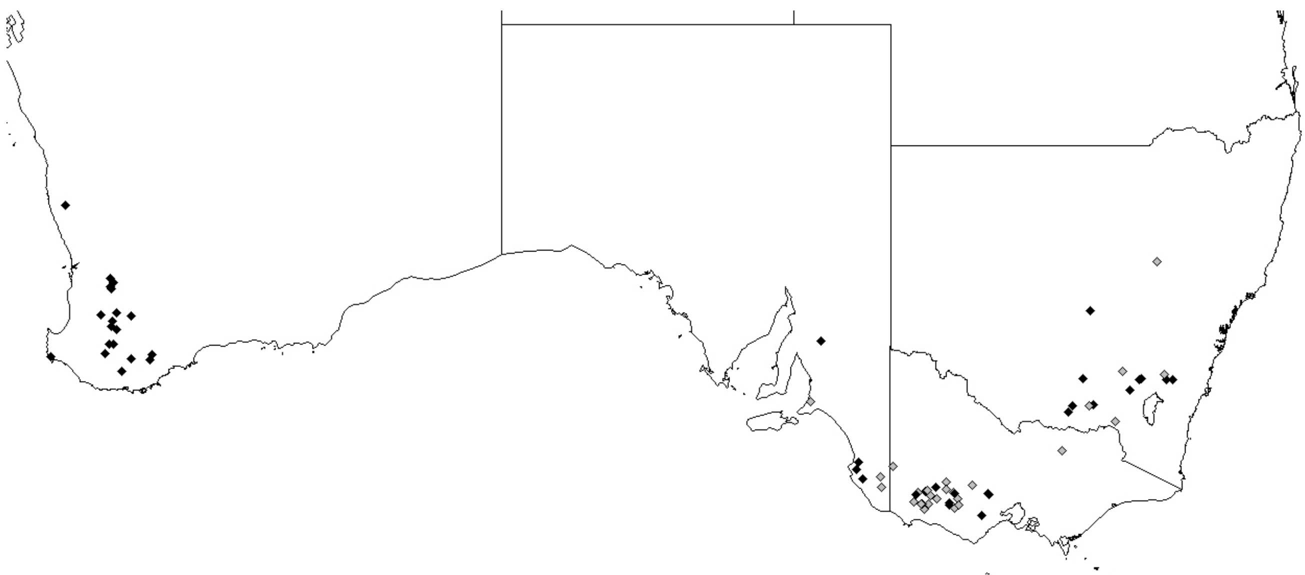

Figure 5.1. The locations of Merino (black) and non-Merino (grey) research sites across southern Australia between 2016 and 2018 for Experiment One

Table 5.1 Mean (± standard error), minimum (min.) and maximum (max.) for the mob size and stocking rate of twin-bearing Merino and non-Merino ewes which lambed at the high and low treatments at research sites across southern Australia between 2016 and 2018 for Experiment One

		Mob size			Stocking rate (ewes/ha)		
		Mean	Min.	Max.	Mean	Min.	Max.
Merino	High	242 ± 5.7	189	432	7.3 ± 0.19	3.9	12.2
	Low	98 ± 3.9	70	261	4.8 ± 0.19	1.7	10.0
Non-Merino	High	243 ± 8.6	188	510	8.1 ± 0.21	5.0	11.2
	Low	97 ± 4.3	70	210	5.9 ± 0.19	3.1	8.1

5.1.2. Animal management and measurements

At allocation, on day 140 from the start of joining, 50 ewes from each mob were randomly selected and condition scored to determine the mean condition score of the mob. Ewes were then moved to their allocated lambing paddocks where they remained until lamb marking, defined as 160 ± 10 days following the end of joining. At lamb marking the number of ewes and lambs in each mob were counted and the same 50 selected ewes in each treatment were condition scored. The mean and range in condition score of ewes at lambing and marking across all research sites are shown in Table 5.2. Entry of farm personnel into the lambing paddocks was limited over lambing to minimise potential mismothering of lambs. Management aimed for FOO to be similar across all paddocks. Details of supplementary feeding were recorded including the frequency of feeding, rate of feeding and type of feed. Ewes were supplementary fed via trail feeding and/or hay at eight sites for part or all of lambing. Two sites provided ewes with access to ad libitum hay only while three sites provided access to hay and grain. The six sites which fed grain provided ewes with between 100g/hd/day and 1115 g/hd/day of oats, lupins, barley, wheat and mixes thereof.

5.1.3. Assessment of FOO and pasture composition

Visual estimates of FOO (kg DM/ha) were assessed at 25 sites in each paddock on day 140 from the start of joining and at lamb marking by the same assessor at each research site. Pasture composition, including the percentage of dead pasture and grass, legume, broadleaf weeds and other forage species, was also assessed at the same 25 sites at lambing. Calibration of the visual assessments of FOO was undertaken using eight 0.1m^2 quadrat cuts which were taken from across the four paddocks and represented the range of FOO observed. Pasture within each quadrat was harvested to ground level. Soil and foreign matter were removed from the samples. The pasture samples were dried in an oven at 65°C and then weighed to determine the dry matter content. The mean pasture composition at lambing and FOO at lambing and marking across all research sites are shown in Table 5.2.

Table 5.2. Mean (± standard error), minimum (min.) and maximum (max.) for the condition score of mobs of twin-bearing ewes at lambing (day 140 from the start of joining) and marking, feed-on-offer (FOO; kg DM/ha) at lambing and marking, percentage of dead pasture, percentage of grass, legume, broadleaf weed and other species within the pasture and availability of shelter within the lambing paddocks (%) at Merino and non-Merino research sites across southern Australia between 2016 and 2018 for Experiment One

	Merino			Non-Merino		
	Mean	Min.	Max.	Mean	Min.	Max.
Condition score at lambing	3.1 ± 0.02	2.4	3.9	3.2 ± 0.02	2.5	3.8
Condition score at marking	2.8 ± 0.02	2.1	3.4	2.8 ± 0.03	2.2	3.7
FOO at lambing	1525 ± 58	124	4179	1722 ± 55	681	3441
FOO at marking	1804 ± 62	33	4694	1532 ± 46	585	2977
Dead pasture	8 ± 2	0	90	4 ± 1	0	33.4
Grass	40 ± 2	0	100	67 ± 2	19	100
Legume	25 ± 2	0	90	19 ± 2	0	71
Broadleaf weeds	22 ± 2	0	79.2	5 ± 1	0	52
Other pasture species	5 ± 1	0	95	5 ± 1	0	50
Shelter availability	17 ± 1	0	80	7 ± 1	0	30

Table 5.3 Percentage of paddocks for each category of shape, topography and shelter, and the number and type of watering points at Merino and non-Merino research sites across southern Australia between 2016 and 2018 for Experiment One

		Merino	Non-Merino
Paddock shape	Square	18	29
	Rectangular	58	59
	Triangular	3	0
	Irregular	21	12
Paddock topography	Flat	44	26
	Gently undulating	33	41
	Undulating	16	18
	Rolling	7	11
	Steep	0	4
Shelter type [A]	High cover	68	61
	Low cover	6	12
	High and low cover	26	12
	None	0	15
Watering points	0	6	0
	1	73	67
	2	21	26
	3	0	4
	4	0	4
Type of watering point	Dam	50	41
	Trough	1	0
	Creek	2	0
	Multiple[B]	41	59
	None	6	0

[A] High cover includes shelter of greater than 1 metre, including trees and tall shrubs, and low cover includes shelter of 1 metre or less, including low shrubs or scrub, tall forage, rocks and gullies
[B] Includes dams, troughs and creeks

5.1.4. Characteristics of the lambing paddocks

The four lambing paddocks on each farm were selected to have similar characteristics. The characteristics of each lambing paddock were recorded by a single assessor at each research site and included the number and type of watering points (dam, trough or creek), shape, topography, type and proportion of each shelter type within the paddock and the total availability of shelter within the paddock expressed as a proportion of the paddock area (Table 5.3). The mean availability of shelter within lambing paddocks across all research sites is shown in Table 2. Shelter types within the paddock were categorised as high cover of greater than 1 metre, including trees or tall shrubs, or low cover of 1 metre or less, including low shrubs or scrub, tall forage, rocks and gullies. Paddock shape was categorised as rectangular, square, triangular or irregular. Topography was categorised as flat (level; 0° slope), gently undulating (very gentle inclines; ≈1-5° slope), undulating (gentle inclines; ≈5-10° slope), rolling (moderate inclines; ≈10-20° slope) or steep (steep inclines; ≈20-30° slope) according to the main slope/s of the paddock.

5.1.5. Weather conditions during lambing

Daily data for temperature, rainfall and wind speed between day 140 of pregnancy and lamb marking were collected from the Bureau of Meteorology for each research site. Daily chill index was calculated for each research site using the formula described by Donnelly (1984). High chill days were defined as days between day 140 from the start of joining and lamb marking where the mean chill index was at least 1100 kJ/m^2.h. The mean chill index and percentage of high chill days for each year within states are shown in Table 5.4. Across all research sites the mean chill index ranged from 881 to 1134 kJ/m^2.h.

Table 5.4. Mean (± standard error) chill index (kJ/m^2.h) and percentage of high chill days between day 140 from the start of joining and lamb marking (165 days after the end of joining) at Merino and non-Merino research sites in Western Australia (WA), South Australia (SA), Victoria (Vic) and New South Wales (NSW) between 2016 and 2018 for Experiment One. High chill days were defined as days where the average chill index was at least 1100 kJ/m^2.h.

State	Year	*n* sites	Chill index	High chill days
WA	2016	8	1050 ± 7.4	20 ± 3.1
	2017	6	1004 ± 26.9	15 ± 4.8
	2018	5	1040 ± 6.4	18 ± 2.0
SA	2016	3	1080 ± 31.9	35 ± 10.6
	2017	2	1052 ± 34.8	21 ± 13.9
	2018	2	1028 ± 38.4	19 ± 14.5
Vic	2016	11	1073 ± 7.4	32 ± 2.6
	2017	17	1064 ± 4.9	31 ± 2.2
	2018	2	1061 ± 8.3	30 ± 7.4
NSW	2017	14	1045 ± 12.1	21 ± 4.3

5.1.6. Statistical analyses

All statistical analyses were performed using GENSTAT (VSN International 2017). For all analyses, terms were only included if they were statistically significant (*P*<0.05). Lamb survival for each mob was calculated according to the number of fetuses identified at pregnancy scanning and the number of lambs marked.

Feed-on-offer and ewe condition score at day 140 from joining and lamb marking were assessed using the method of restricted maximum likelihood. Mob size (high or low), stocking rate (high or low), breed and interactions thereof were fitted as fixed effects and state, year (nested within state) and farm (nested within year) were fitted as random terms. For analysis of feed-on-offer and ewe condition score at marking, the measurement at lambing was included as a covariate.

Lamb survival was also assessed using the method of restricted maximum likelihood. Mob size (high or low), stocking rate (high or low), mob size by stocking rate, breed, ewe condition score at lambing and marking, FOO at lambing and marking, whether the ewes were supplementary fed (yes or no), the shape, topography category, type of shelter within the paddock (high cover, low cover, mixed or none), total availability of shelter within the paddock (%), and number and type (dam, creek, trough or multiple) of watering points within the lambing paddock were fitted as fixed effects. The linear and quadratic effects of covariates were tested. Interaction of mob size and stocking rate with all fixed effects and covariates were also examined. The random terms fitted were state, year (nested within state) and farm (nested within year). To determine the linear effect of mob size, from the above analysis all significant fixed terms were retained with the actual values for mob size replacing the high or low treatments within the same mixed model structure.

5.2. Results

5.2.1. Ewe condition score and feed-on-offer

The condition score of ewes and FOO did not differ between treatments at lambing (Table 5.5). There were also no effects of mob size or stocking rate. The condition score of Merino and non-Merino ewes did not differ at lambing (3.1 vs 3.2). There was no difference in FOO at lambing between Merino and non-Merino research sites (1474 vs 1571 kg DM/ha). There was no breed by treatment, mob size by breed or stocking rate by breed effects on condition score or FOO at lambing.

The condition score of ewes and FOO did not differ between treatments at marking (Table 5.5). However, FOO at marking was 254 kg DM/ha greater at the low stocking rates compared to the high stocking rates (1804 vs 1550 kg DM/ha; *P* <0.001). The condition of non-Merino ewes did not differ to that of Merino ewes at marking (2.8 vs 2.8). There were no effects of mob size, stocking rate, treatment by breed, mob size by breed or stocking rate by breed on the condition score of ewes or FOO at marking.

Table 5.5 Mean condition score, feed-on-offer (FOO; kg DM/ha) and lamb survival to marking (%) for mobs of twin-bearing Merino and non-Merino ewes which lambed at the high and low mob size (MS) and stocking rate (SR) treatments across southern Australia between 2016 and 2018

		High MS + High SR	High MS + Low SR	Low MS + High SR	Low MS + Low SR	l.s.d.	*P*-value[A]
Condition score	Lambing	3.1	3.1	3.1	3.1	0.03	0.457
	Marking	2.8	2.8	2.8	2.9	0.05	0.680
FOO	Lambing	1524	1527	1551	1487	97	0.338
	Marking	1508	1785	1592	1823	110	0.557
Lamb survival	Merino	68.2	68.9	71.0	71.1	1.77	0.673
	Non-Merino	80.2	80.9	83.0	83.1		

[A] *P*-value corresponds to the effect of mob size by stocking rate

5.2.2. Lamb survival to marking

The survival of non-Merino lambs to marking was greater than that of Merino lambs (69.8% vs 81.6%; $P<0.001$). Lamb survival was 2.5% greater for lambs born at the low mob sizes compared to the high mob sizes (77.0% vs 74.5%; $P<0.001$). The survival of lambs did not differ between the low and high stocking rates (76.0% vs 75.6%; $P=0.52$). There was also no mob size by stocking rate effect on lamb survival (Table 5.5). Similarly, there were no interactions between mob size or stocking rate and breed. Increasing mob size at lambing by 100 twin-bearing ewes decreased the survival of their lambs to marking by 1.9%, regardless of Merino or non-Merino breed (Figure 5.2). The regression coefficients for the prediction of lamb survival from mob size and breed are presented in Table 5.6.

There was no effect of the condition score of ewes at lambing or marking, FOO at lambing or marking, paddock shape, paddock topography, the number or type of watering points, availability of shelter, shelter type or whether the mobs were supplementary fed on lamb survival. Furthermore, there were no interactions of these terms with mob size, stocking rate or breed.

Table 5.6 Regression coefficients (± standard error) for restricted maximum likelihood model which predicts the survival of twin-born lambs to marking (%) from ewe breed (Merino or non-Merino), and mob size of twin-bearing ewes at lambing. All possible models were examined with statistical significance of terms and interactions thereof accepted at *P*<0.05.

	Coefficient	*P*-value
Constant[A]	73.0 ± 1.78	-
Non-Merino ewe breed	11.8 ± 1.72	<0.001
Mob size	-0.019 ± 0.004	<0.001

[A] The survival constant is for a twin-born Merino lamb born to an adult ewe

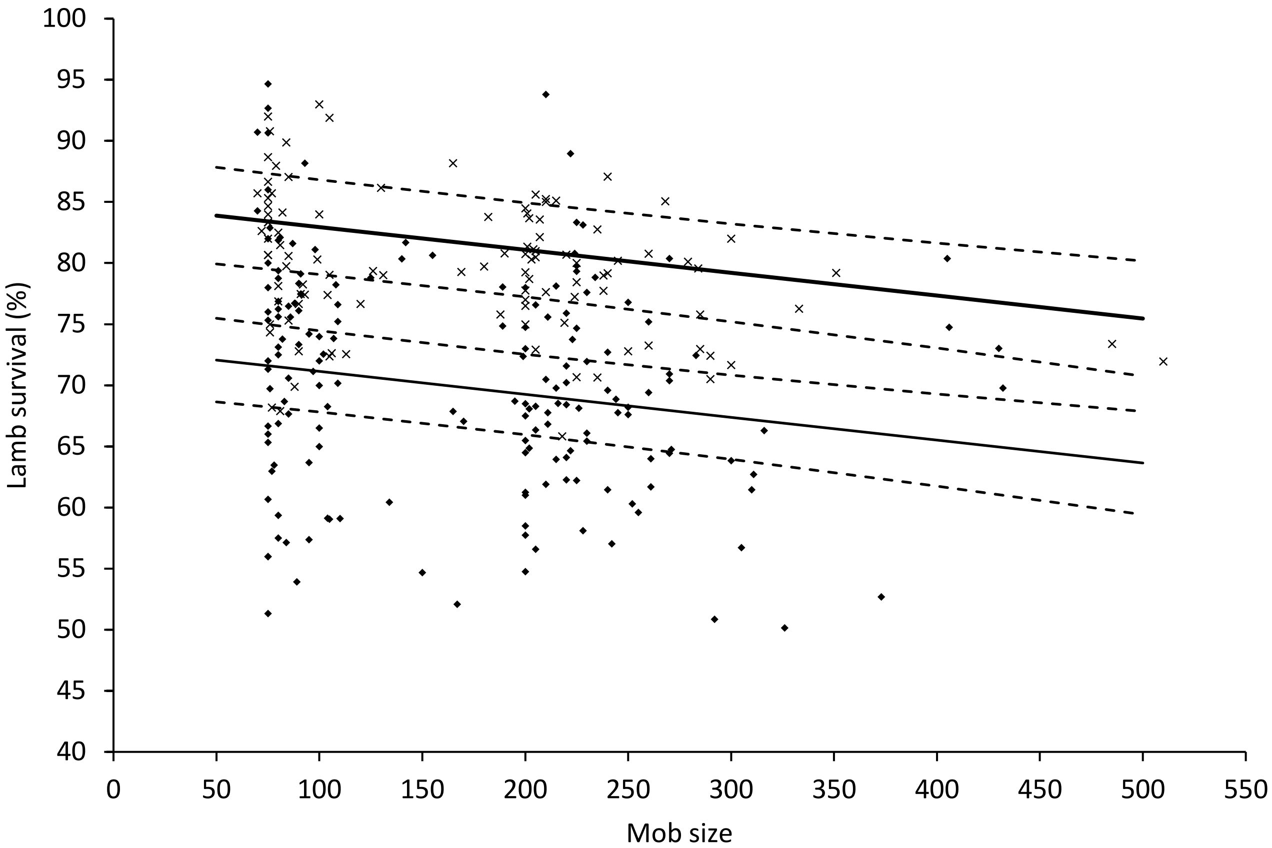

Figure 5.2 The effect (± 95% confidence intervals) of mob size of twin-bearing Merino (thin line) or non-Merino (thick line) ewes at lambing on the survival of their lambs to marking at research sites across southern Australia between 2016 and 2018 in Experiment One. The raw data are shown as diamonds for Merinos and crosses for non-Merinos.

5.3. Discussion

Survival of twin-born lambs was greater at the low compared to the high mob sizes. Reducing mob size at lambing by 100 twin-bearing ewes increased the survival of their lambs to marking by approximately 2%. There was no effect of stocking rate or mob size by stocking rate on lamb survival. Therefore, our first hypothesis was partially accepted. The effect of mob size did not differ between breeds and therefore our second hypothesis was not supported. This result is surprising given Merino ewes are known to have stronger flocking behaviours which could amplify the effects of lambing density on lamb survival (Alexander *et al.* 1990b; Arnold and Maller 1985; Stevens *et al.* 1981). Overall, the findings from this research demonstrate that reducing the number of adult twin-bearing ewes in the mob at lambing will improve lamb survival in both Merino and non-Merino enterprises.

The greater survival of lambs born at the lower mob sizes is similar to the recent survey findings of Allworth *et al.* (2017). These authors reported that lamb survival tended to be poorer when twin-bearing ewes lambed at mob sizes of at least 200 ewes compared with less than 200 ewes on commercial farms in New South Wales. Other survey data collected from producers in south-eastern Australia found that the survival of twin-born lambs decreased by 3.5% per additional 100 ewes in the mob at lambing, regardless of Merino or non-Merino breed (Lockwood *et al.* 2019). This is greater than the linear effect of mob size on lamb survival observed in the current study. The average mob size of twin-bearing ewes amongst the survey data was 197 ewes for Merinos and 163 ewes for non-Merinos. These ewes were stocked at an average of 6.6 ewes/ha and 7.4 ewes/ha, respectively. Mob size in the current study ranged from 70 to 432 ewes for Merinos and 70 to 510 ewes for non-Merinos. These ewes lambed at stocking rates of between 2 and 12 ewes/ha with an average of 6 ewes/ha for Merinos and 7 ewes/ha for non-Merino breeds. Hence the mob sizes and stocking rates were similar between the current study and the survey of producers. The condition score of ewes and FOO at lambing which was reported by producers in the surveys were also similar to those in the current study. It is therefore unclear why the effect of mob size differed between the studies although the subjective nature of some of the survey data may have contributed to this variation.

There was no difference in lamb survival between stocking rates at lambing. Previous studies using small mob and paddock sizes have reported variable effects of stocking rate on lamb survival (Davies and Southey 2001; Donnelly 1984; Kenney and Davis 1974; Langlands *et al.* 1984; Robertson *et al.* 2012). Data collected from producers in south-eastern Australia found that lamb survival decreased by 0.7% per additional ewe/ha regardless of birth type (Lockwood *et al.* 2019). This suggests that reducing mob size by 100 twin-bearing ewes would have a similar effect on lamb survival to reducing stocking rate by at least 3 ewes/ha. However, reducing ewe stocking rate at lambing is unlikely to be a practical or efficient strategy to increase lamb survival as ewes would need to be lambed in much larger paddocks thus displacing other ewes or resulting in ewes being lambed in larger mob sizes. The natural flocking behaviour of domestic sheep breeds results in them maintaining close proximity and few ewes selecting isolated birth sites at lambing (Alexander *et al.* 1990b; Arnold and Maller 1985; Dwyer and Lawrence 1999; Stevens *et al.* 1981; von Borstel *et al.* 2011). Furthermore, Lockwood *et al.* (2018b) found less than 45% of the paddock area was occupied by ewes during lambing. The number of lambs born in the mob per day regardless of paddock size is therefore likely to be the most important factor regarding the relationship between lambing density and lamb survival. Reducing paddock size and mob size at lambing may therefore enhance pasture utilisation whilst improving lamb survival.

Ewe condition score and FOO at lambing were not found to influence the relationship between mob size and lamb survival. Hence, this study indicates that the relationship between mob size and lamb survival is consistent for mobs at an average condition score of 2.4 to 3.9 at lambing and when FOO is between approximately 100 kg DM/ha and 4000 kg DM/ha at the start of lambing. Feed-on-offer varied between states and years, and at some sites was below recommended levels for winter-spring lambing. However, the optimal condition of ewes at most sites and strategic use of supplementary feeding where FOO was very low likely compensated for any adverse impacts on lamb survival. Supplementary feeding of ewes when FOO is limited may further amplify the effects of mob size on lamb survival due to interference which could cause mismothering or ewe-lamb separations. Supplementary feeding was not observed to influence lamb survival in this study, however ewes were only supplementary fed at eight (11%) of the experimental sites during lambing. Other research has suggested that the effect of mob size could be greater when FOO is low (<400 kg DM/ha) and ewes are supplementary fed throughout lambing (Lockwood *et al.* 2018a). The benefit of reducing mob size on lamb survival could therefore be greater when ewes lamb in autumn, close to the break-of-season or when seasonal conditions are poor. Further research is warranted to understand the relationship between mob size, FOO and lamb survival including the effects of supplementary feeding during lambing.

The relationship between mob size and lamb survival was also not influenced by the availability of shelter within the paddock. The risk of lambs dying from hypothermia is high when chill index exceeds 1100 kJ/m^2.h at lambing (Alexander 1962; Broster *et al.* 2012; Oldham *et al.* 2011). The range in the average chill index during the lambing period was small in this study and averaged 1053 kJ/m^2.h. Therefore, on average lambs experienced reasonably high chill conditions during lambing as expected when lambing in winter. At most farms, less than 15% of the paddock contained shelter with this mainly being from trees of sparse to moderate density. Tall, dense windbreaks created by some trees are effective at reducing windspeed, however this is most evident when positioned closest to the windbreak (Bird *et al.* 2007). Similarly, shelter will be more effective when positioned relative to the direction of the prevailing winds. This will also be influenced by paddock aspect and topography. The shelter available within the paddocks in this study may have largely been ineffective and thus had little effect on reducing the chill conditions at lambing. Furthermore, it is unknown whether the ewes utilised the shelter available at lambing, but it is possible that utilisation was poor given the trees at most sites were unlikely to have provided effective shelter. In contrast, congregation of ewes nearby effective shelter could amplify the effects of mob size on lamb survival, particularly under adverse weather conditions.

The relationship between mob size and lamb survival was also not influenced by the number of watering points, topography or shape of the lambing paddocks. Most paddocks in this study were square or rectangular with flat to gently undulating topography. Alexander *et al.* (1990a) found the distribution of birth sites tended to be more scattered in flat paddocks whereas ewes tended to lamb at more elevated areas in sloping paddocks. In paddocks of varying slope, Knight *et al.* (1989) observed a large proportion of lambing ewes were distributed in the flatter areas of the paddock where FOO was also higher. However, the distribution of birth sites and tendency to lamb nearby particular features or areas of the paddock, such as fences, rock piles or shady areas, is variable and may differ between breeds (Alexander *et al.* 1990a; Knight *et al.* 1989; Yamin *et al.* 1995). Given lambing occurred in late autumn and winter-spring, ewes generally had access to green pasture and thus their need to seek water was likely low. When pastures are dry or FOO is limited, the risk of mismothering could be greater due to the need for ewes to seek feed and water. As a result of the complex interactions between paddock characteristics and ewe behaviour, the relationships between the characteristics of the lambing paddock, lambing density and lamb survival remain unclear. Nevertheless, paddock characteristics and seasonal conditions which encourage congregation of lambing ewes and newborn lambs may promote mismothering and therefore poorer lamb survival. Given the variable response in maternal behaviour and lamb survival to the characteristics of the lambing paddock, it is imperative that producers keep annual records for the survival of lambs within paddocks to allow the best lambing paddocks to be identified and prioritised for twin-bearing ewes.

This research has shown that lower mob sizes at lambing increase the survival of twin-born lambs on commercial farms across southern Australia, regardless of ewe stocking rate. Ewes were typically managed according to best-practice guidelines, however approximately 70% to 80% of commercial sheep producers in Australia do not pregnancy scan ewes for multiples and therefore may not manage ewes under optimal conditions (Jones *et al.* 2011). It is unknown whether reducing the mob size of ewes of mixed pregnancy status would significantly improve lamb survival. Although, the ability to optimise the allocation of resources at lambing to mobs of mixed pregnancy status is also compromised and therefore any improvements in lamb survival due to mob size are likely to be diminished by suboptimal ewe nutrition. The mob sizes and stocking rates of ewes in the current study largely reflects enterprises in the high rainfall zones and sheep-wheat zones of southern Australia. Further research to investigate whether the effect of mob size on lamb survival differs when ewes lamb at higher mob sizes and lower stocking rates, typical of the low rainfall zones, would therefore be valuable and assist in developing robust guidelines for producers. Nevertheless, the 2% increase in lamb survival achieved through reducing mob size by 100 twin-bearing ewes is equivalent to increasing ewe condition score at lambing by 0.1 (Lockwood *et al.* 2019; Oldham *et al.* 2011). The on-farm adoption of guidelines related to reducing mob size at lambing together with current guidelines for the management of ewe nutrition and paddock selection will improve the survival of twin-born lambs across southern Australia.

6. Experiment Two – Decreasing the mob size of twin-bearing Merino ewes that lamb at low stocking rates increases the survival of their lambs to marking

6.1. Methodology

6.1.1. Research sites, animals and experimental designs

Research was conducted on 15 commercial sheep farms across Western Australia (*n* = 10) and New South Wales (*n* = 5) during 2018. The locations of the research sites are shown in Figure 6.1. Adult, twin-bearing Merino ewes were randomly allocated into one of two replicates of two mob sizes; high or low, on day 140 from the start of joining. Ewes on each farm lambed at a similar stocking rate. The mean stocking rate of ewes at research sites in WA was 2.9 ± 0.08 ewes/ha and in NSW was 0.5 ± 0.04 ewes/ha. The mean mob sizes for each state are presented in Table 6.1. Lambs were born in late autumn and/or winter at all sites.

6.1.2. Animal and pasture management and measurements

Ewes were condition scored and FOO was assessed at allocation (day 140 from joining) and lamb marking (160 ± 10 days following the end of joining) as described in 5.1.2 and 5.1.3. The mean condition score of ewes and FOO at lambing and marking across all research sites are shown in Table 6.2. Ewes and lambs were counted at marking to determine survival. Entry of farm personnel into the lambing paddocks was limited over lambing to minimise potential mismothering of lambs. Management aimed for FOO to be similar across all paddocks. Ewes were supplementary fed during lambing at nine of the research sites by trail feeding lupins, barley or wheat at between 500 g/hd/day and 1250 g/hd/day. Two of these sites also provided hay to the ewes during lambing.

Table 6.1. Mean (± standard error), minimum and maximum mob size of twin-bearing Merino ewes for the high and low treatments at research sites in New South Wales (NSW) and Western Australia (WA) during 2018 for Experiment Two

State	High mob size			Low mob size		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
NSW	763 ± 35	639	976	435 ± 21	338	554
WA	299 ± 5	255	340	117 ± 7	93	190

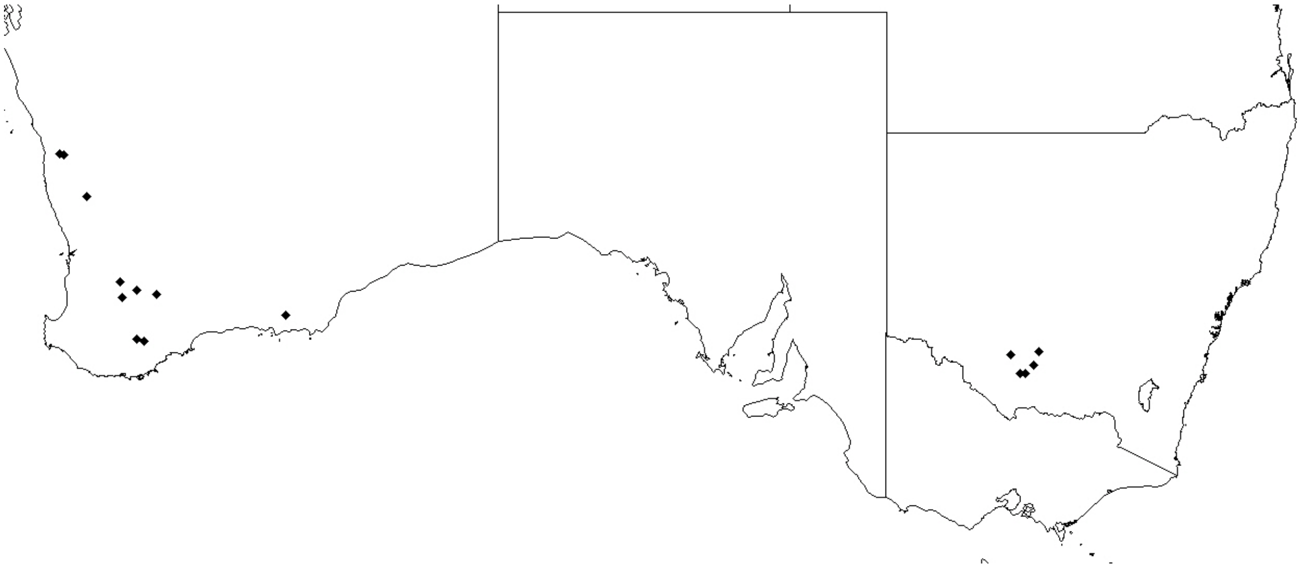

Figure 6.1. Locations of research sites across Western Australia (*n* = 10) and New South Wales (*n* = 5) during 2018 for Experiment Two

Table 6.2. Mean, minimum (min.) and maximum (max.) for the condition score (CS) of mobs of twin-bearing ewes and feed-on-offer (FOO; kg DM/ha) at lambing and marking at research sites in New South Wales (NSW) and Western Australia (WA) during 2018 for Experiment Two

	NSW			WA		
	Mean	Min.	Max.	Mean	Min.	Max.
CS at lambing	3.2	2.9	3.4	3.1	2.5	3.6
CS at marking	2.4	1.9	3.1	2.7	2.1	3.0
FOO at lambing	985	420	2000	552	222	1085
FOO at marking	635	250	1163	817	182	1521

6.1.3. Characteristics of the lambing paddocks

The four lambing paddocks on each farm were selected to have similar characteristics. The characteristics of each lambing paddock were recorded by a single assessor at each research site as described in 5.1.4. The mean availability of shelter within lambing paddocks in NSW was 48%, with a range of 30% to 50%. In WA, the mean availability of shelter within lambing paddocks was 6%, with a range of 1% to 15%. The paddock characteristics are shown in Table 6.3.

Table 6.3. Number and percentage of paddocks for each category of shape, topography and shelter, and the number and type of watering points at research sites in New South Wales (NSW; *n* = 5) and Western Australia (WA; *n* = 10) for Experiment Two

		NSW		WA	
		n	%	*n*	%
Paddock shape	Square	20	100	7	18
	Rectangular	-	-	13	33
	Irregular	-	-	20	50
Paddock topography	Flat	20	100	2	5
	Gently undulating	-	-	24	60
	Undulating	-	-	9	23
	Rolling	-	-	4	10
	Steep	-	-	1	3
Shelter type[A]	High cover	-	-	31	78
	High and low cover	20	100	9	23
Watering points	1[B]	-	-	36	90
	2[C]	9	45	4	10
	3[C]	8	40	-	-
	4[B]	3	15	-	-
Water type	Dam	-	-	28	70
	Trough	19	95	12	30
	Dam and troughs	1	5	-	-

[A] High cover includes shelter of greater than 1 metre, including trees and tall shrubs, and low cover includes shelter of 1 metre or less, including low shrubs or scrub, tall forage, rocks and gullies

[B] Dam or trough

[C] Troughs only

6.1.4. Weather conditions during lambing

Data for temperature, rainfall and wind speed between day 140 of pregnancy and lamb marking were collected via the Bureau of Meteorology. Daily chill index was calculated for each research site using the formula described by Donnelly (1984). High chill days were defined as days between day 140 from the start of joining and lamb marking where the average chill index was at least 1100 kJ/m^2.h. The mean chill index and percentage of high chill days at each research site are shown in Table 6.4.

Table 6.4. Mean chill index (kJ/m^2.h) and percentage of hill chill days between lambing (140 days from the start of joining) and lamb marking (165 days after the end of joining) at research sites in New South Wales (NSW) and Western Australia (WA) during 2018 for Experiment Two

State	Location	Chill index	High chill days
NSW	Conargo	974	2
NSW	Hay	885	2
NSW	Conargo	1002	4
NSW	Carathool	961	3
NSW	Conargo	1011	3
WA	Arino	982	8
WA	Esperance	1006	12
WA	Miling	1008	9
WA	Arino	924	4
WA	Lake Grace	1009	8
WA	Wickepin	1019	13
WA	Yilliminning	1023	10
WA	Harrismith	1022	13
WA	Gnowangerup	1025	17
WA	Tambellup	1031	16

6.1.5. Statistical analyses

All statistical analyses were performed using the method of restricted maximum likelihood in GENSTAT (VSN International 2017). For all analyses, terms were only included if they were statistically significant ($P<0.05$). Lamb survival for each mob was calculated according to the number of fetuses identified at pregnancy scanning and the number of lambs marked.

Ewe condition score, FOO and the effect of mob size treatments on lamb survival were analysed separately for each state. Mob size (high or low) was fitted as a fixed effect and farm was fitted as a random term. Feed-on-offer and ewe condition score at marking were analysed with the measurement at lambing included as a covariate. For analysis of lamb survival, ewe condition score, FOO, shelter availability (%), shelter type, the number of watering points and the type of water were also fitted as fixed effects. Paddock shape and topography were also fitted as fixed effects for the analysis of lamb survival in WA, where there was variation in these measurements.

Data for both states were combined for analysis of the linear effect of mob size on lamb survival. The actual mob size and state along with their interaction were fitted as fixed effects. State and farm (nested within state) were fitted as random terms.

6.2. Results

6.2.1. Ewe condition score and feed-on-offer

There were no differences between treatments in the condition score of ewes at lambing or marking in NSW or WA (Table 6.5). Feed-on-offer did not differ between treatments at lambing or marking in NSW (Table 6.5). The mean FOO at lambing was 82 kg DM/ha lower at the low mob size compared to the high mob size in WA, however FOO at marking did not differ between treatments (Table 6.5).

Table 6.5. Mean mob condition score, feed-on-offer (FOO; kg DM/ha) and lamb survival to marking (%) for mobs of twin-bearing Merino ewes which lambed at the high and low mob sizes at research sites in New South Wales (NSW) and Western Australia (WA) during 2018 for Experiment Two

		High	Low	l.s.d.	*P*-value
Condition score at lambing	NSW	3.2	3.2	0.08	0.592
	WA	3.1	3.1	0.04	0.212
Condition score at marking	NSW	2.4	2.5	0.15	0.731
	WA	2.7	2.6	0.10	0.123
FOO at lambing	NSW	918	1052	182	0.137
	WA	593	511	59	<0.01
FOO at marking	NSW	650	621	90	0.507
	WA	801	833	110	0.550
Lamb survival	NSW	60.2	70.9	5.7	<0.01
	WA	62.8	66.1	3.0	<0.05

6.2.2. Lamb survival to marking

The survival of lambs born in NSW was 10.7% greater at the low compared to the high mob sizes (Table 6.5). Lamb survival was 3.3% greater at the low compared to the high mob sizes in WA (Table 6.5). There was no effect of the stocking rate of ewes, ewe condition score or FOO at lambing or marking, supplementary feeding or the availability of shelter on lamb survival in NSW or WA and there was no interaction with mob size. There were also no effects of paddock shape, paddock topography, shelter type or water type on lamb survival and no interaction with mob size in WA.

There was no interaction between the linear effect of mob size and state. The mean survival of lambs was 11% lower at research sites in WA compared to NSW (61.1 vs 72.1%; $P<0.05$). Increasing mob size at lambing by 100 twin-bearing Merino ewes decreased the survival of their lambs by 2.5% ($P<0.001$; Figure 6.2).

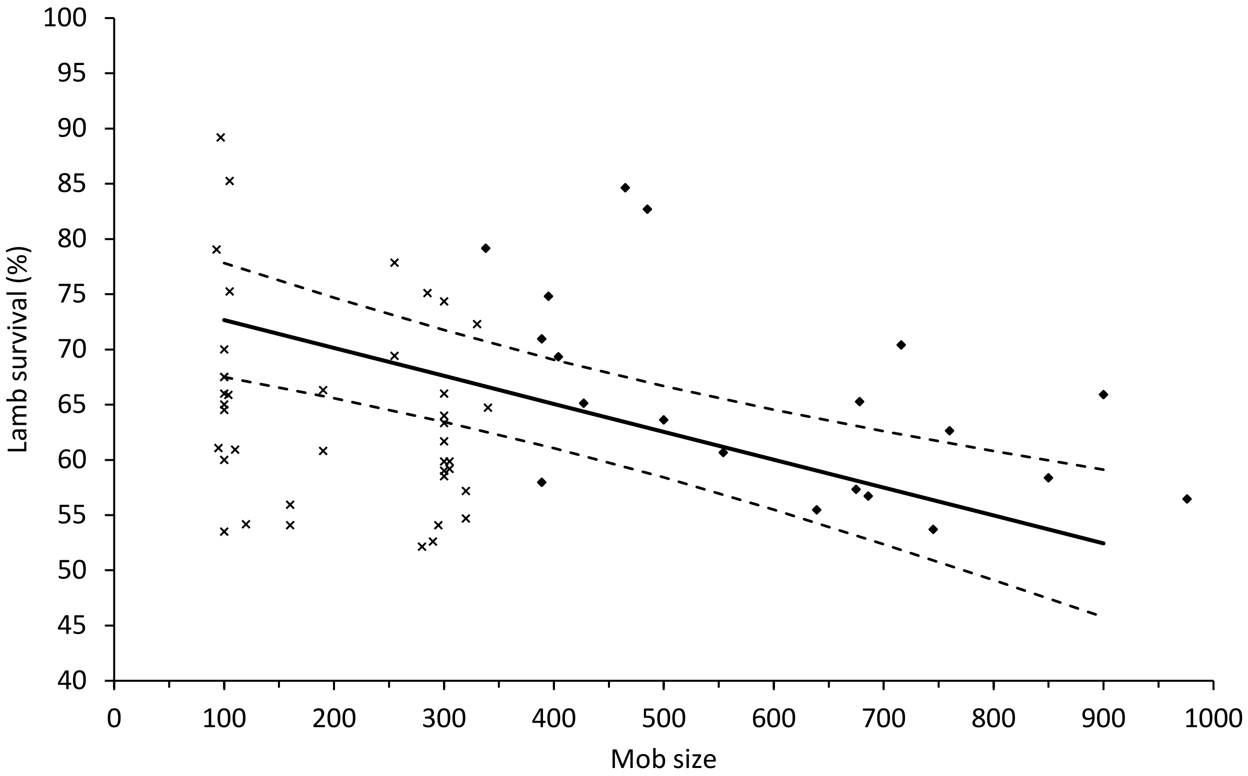

Figure 6.2 The effect (± 95% confidence intervals) of mob size at lambing for twin-bearing Merino ewes that lambed at low stocking rates (≤3.8 ewes/ha) on the survival of their lambs to marking with the mean effect of state for Experiment Two. The crosses and diamonds represent the raw data for mobs in Western Australia and New South Wales, respectively.

6.3. Discussion

The survival of Merino lambs born at stocking rates of between 0.3 and 3.8 twin-bearing ewes/ha was greater when ewes lambed at a lower mob size. The average difference in mob size between the high and low treatments was 328 ewes in NSW compared to 182 ewes in WA. Hence, the greater difference in lamb survival between mob size treatments in NSW is reflective of the greater difference in mob size between the high and low treatments. The linear effect of mob size was not influenced by state and showed that the survival of twin-born lambs decreased by 2.5% per additional 100 ewes in the mob at lambing. This research therefore demonstrates that reducing the mob size of twin-bearing Merino ewes that lamb at low stocking rates will increase the survival of their lambs to marking.

The linear effect of mob size on lamb survival was similar to that observed in Experiment One, where survival of twin-born lambs decreased by 1.9% per additional 100 twin-bearing ewes in the mob at lambing. Consistent with this research, the effect of mob size on lamb survival was not influenced by ewe condition score, FOO or the paddock characteristics. However, most lambing paddocks were comparable other than some variation in shelter availability between states. The repeatable effect of mob size across Experiments One and Two of this project concludes that reducing mob size will increase the survival of twin-born lambs at sheep enterprises in southern Australia regardless of the stocking rate of lambing ewes.

7. Experiment Three – Lambs born in smaller mob sizes have greater survival to marking at commercial farms across southern Australia

7.1. Methodology

Data for lambing during 2016, 2017 and/or 2018 was provided by 194 sheep producers who pregnancy scanned their ewes for multiples. Data were collected for a total of 2174 lambing mobs across Western Australia (WA; *n* = 458), South Australia (SA; *n* = 169), Victoria (VIC; *n* = 1304) and New South Wales (NSW; *n* = 243). Producers provided data for farm location, ewe and ram breed, average ewe age, ewe pregnancy status (single, twin or triplet), time of lambing (month), size of the lambing paddock, mob size at lambing, ewe condition score at lambing (estimated or measured), FOO at lambing (kg DM/ha; estimated or measured), the estimated percentage of legume in the pasture, whether the ewes were supplementary fed during lambing and if applicable the method of feeding, type and number of watering points, and shelter type and availability expressed as the percentage of the paddock containing shelter. The number of lambs marked per mob was provided by producers and used to calculate lamb survival based on lamb losses between pregnancy scanning and lamb marking. Average ewe age was categorised as maiden, being mobs joined as ewe lambs and maiden hoggets, and mixed age, being mobs of various ages ranging between 3 and 8 years. Most mobs (85%) were of mixed age, with the remainder of mobs being for maidens. Shelter type was categorised as high cover, including trees or bush, or low cover, including windbelts, rocks or topography. The mean availability of shelter within the paddock was 16% for Merinos and 20% for non-Merinos. Data for paddock characteristics and supplementary feeding are presented in Table 7.1.

Table 7.1. Number and percentage of paddocks of each shelter type, number of watering points, water source and number of mobs supplementary fed during lambing at farms across southern Australia for Experiment Three

		Merino		Non-Merino	
		n	%	*n*	%
Shelter type	High	514	70	371	70
	Low	113	15	93	18
	Mixed	106	14	67	13
Watering points	0	15	1.5	6	0.7
	1	755	75.0	691	84.0
	2	194	19.3	99	12.0
	3	22	2.2	19	2.3
	4	9	0.9	6	0.7
	5	4	0.4	1	0.1
	6	2	0.2	1	0.1
	7	3	0.3	-	-
	8	1	0.1	-	-
	26	1	0.1	-	-
Water source	Creek	21	2	17	2
	Dam	460	50	208	26
	Trough	352	39	494	62
	Multiple	80	9	81	10
Supplementary fed	Yes	453	55	113	16
	No	378	45	575	84

Data were collected for a total of 1163 mobs of Merino ewes and 1011 mobs of non-Merino ewes. Approximately 76% of Merino ewes were joined to a Merino sire with the remainder joined to a non-Merino sire. Approximately 99% of non-Merino ewes were joined to a non-Merino sire with the remainder joined to a Merino sire. Merino included traditional Merinos, Dohne Merinos, South African Mutton Merinos and Afrinos. Non-Merino included crossbred, composite, maternal and terminal breeds. Most lambs (86%) were born in winter-spring with the remainder (14%) born in autumn or autumn through to early winter. The average mob size, stocking rate, condition score and FOO at lambing are shown in Table 7.2. Boxplots showing the distribution of mob size and stocking rate for Merino and non-Merino ewes are presented in Figures 7.1 to 7.4.

Table 7.2. Number of mobs and mean mob size, stocking rate (ewes/ha), condition score and feed-on-offer (FOO; kg DM/ha) at lambing for maiden and mixed age (MA) Merino and non-Merino ewes of single, twin, triplet and mixed pregnancy status which lambed between 2016 and 2018 in southern Australia for Experiment Three

		n	Mob size		Stocking rate		Condition score		FOO	
			Maiden	MA	Maiden	MA	Maiden	MA	Maiden	MA
Merino	Singles	534	266	271	7.2	7.2	3.0	3.0	1117	1126
	Twins	625	117	173	5.4	6.1	2.9	3.1	1187	1346
	Triplets	4	-	43	-	10.2	-	3.0	-	2500
Non-Merino	Singles	257	215	197	7.8	8.5	3.0	3.2	1566	1565
	Twins	736	152	131	8.1	7.0	3.2	3.2	1906	1808
	Triplets	18	41	58	2.8	5.9	3.2	3.4	2000	2111

7.1.1. Statistical analyses

All statistical analyses were performed using the method of restricted maximum likelihood in GENSTAT (VSN International 2017). For all analyses, terms were only included if they were statistically significant (P<0.05).

Survival of lambs to marking was analysed with mob size, stocking rate, ewe pregnancy status (single, twin, triplet or mixed), ewe breed (Merino or non-Merino), ewe age (maiden or mixed age), season of lambing (autumn, autumn-winter or winter-spring), ewe condition score at lambing, FOO at lambing, the percentage of legume in the pasture, whether or not the ewes were supplementary fed, the method of supplementary feeding, number and type of watering points, type of shelter within the paddock and percentage of the paddock containing shelter fitted as fixed effects. All relevant interactions between fixed terms were also tested. Year of lambing, state (nested within year of lambing), farm (nested within state) and lambing paddock (nested within farm) were fitted as random effects. Data for lamb survival were angular transformed for analysis. Predicted means are presented in the back-transformed state.

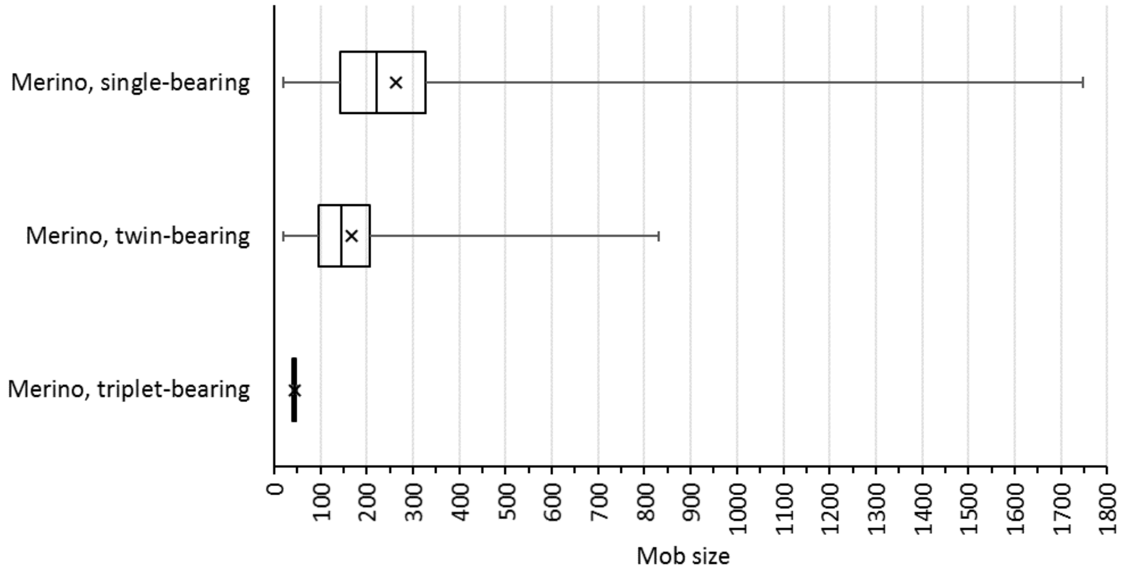

Figure 7.1. Distribution for the mob size of single-bearing, twin-bearing and triplet-bearing Merino ewes at lambing from producer data collected across southern Australia between 2016 and 2018. Mean mob sizes are shown as crosses.

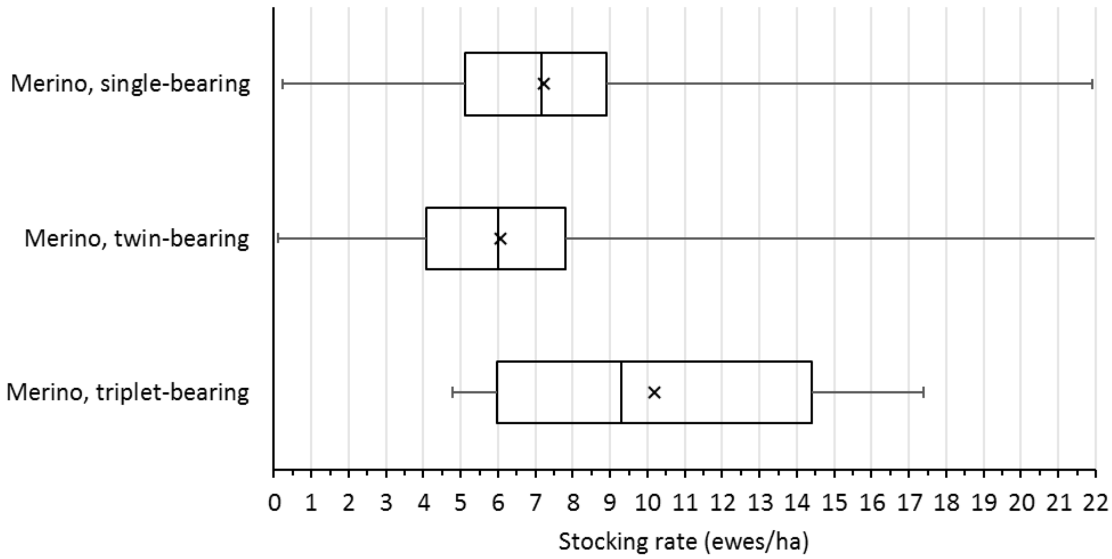

Figure 7.2. Distribution for the stocking rate of single-bearing, twin-bearing and triplet-bearing Merino ewes at lambing from producer data collected across southern Australia between 2016 and 2018. Mean stocking rates are shown as crosses.

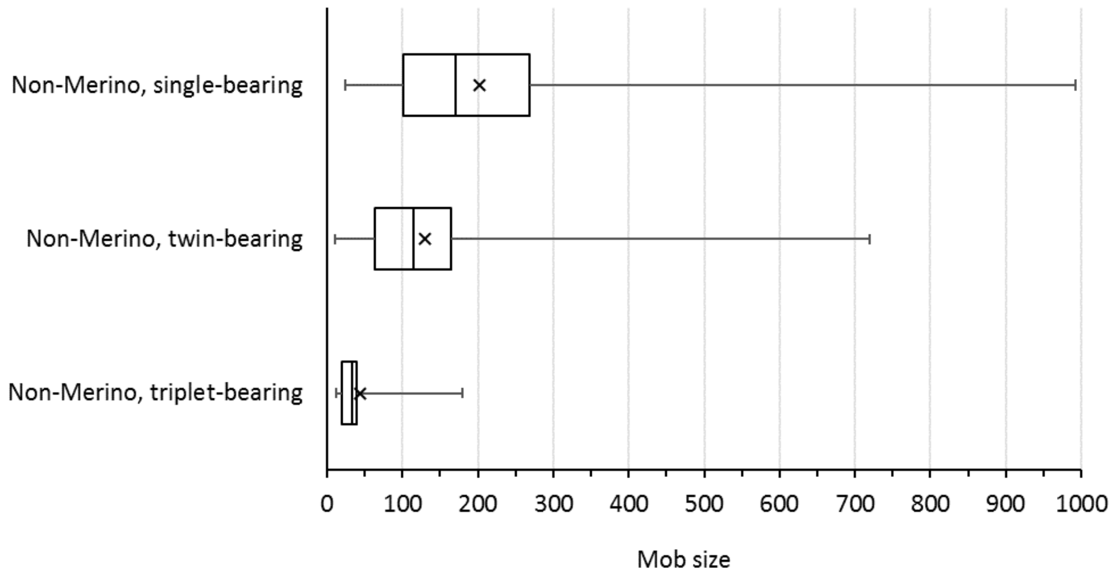

Figure 7.3. Distribution for the mob size of single-bearing, twin-bearing and triplet-bearing non-Merino ewes at lambing from producer data collected across southern Australia between 2016 and 2018. Mean mob sizes are shown as crosses.

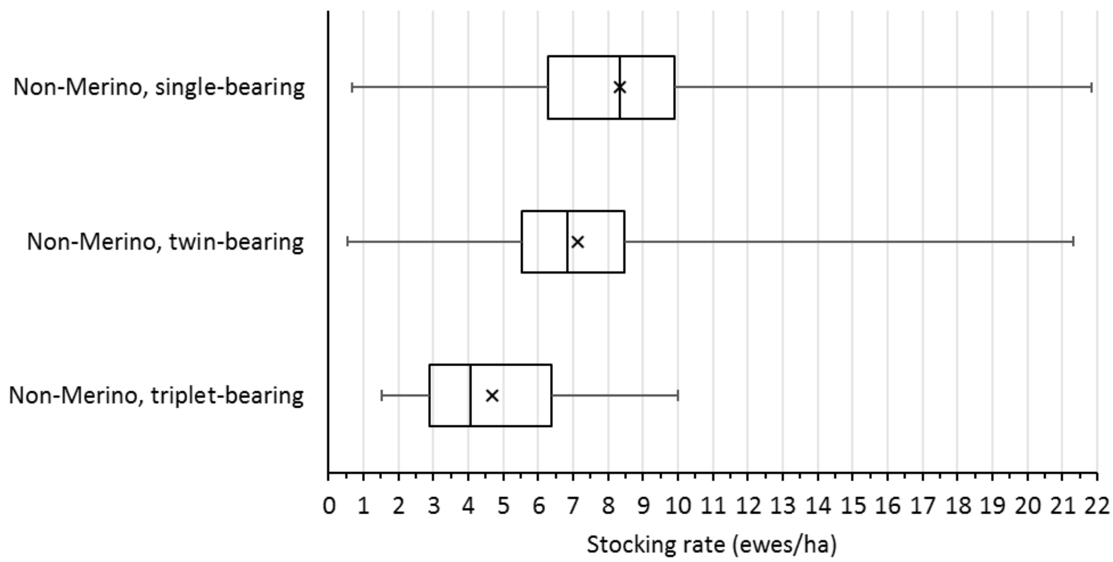

Figure 7.4. Distribution for the stocking rate of single-bearing, twin-bearing and triplet-bearing non-Merino ewes at lambing from producer data collected across southern Australia between 2016 and 2018. Mean stocking rates are shown as crosses.

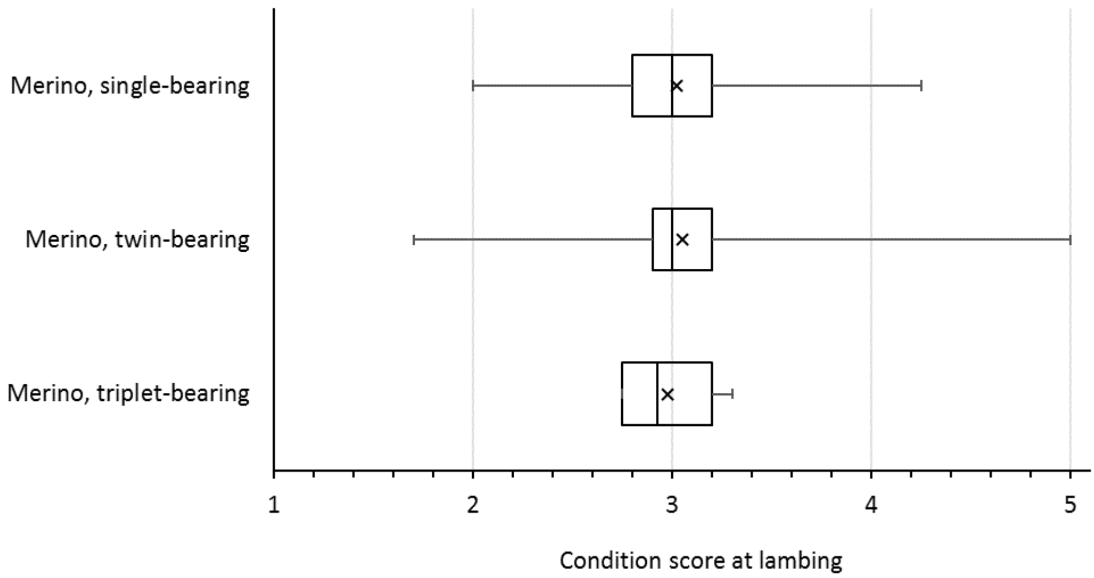

Figure 7.5. Distribution for the condition score of single-bearing, twin-bearing and triplet-bearing Merino ewes at lambing at farms across southern Australia between 2016 and 2018. Mean condition scores are shown as crosses.

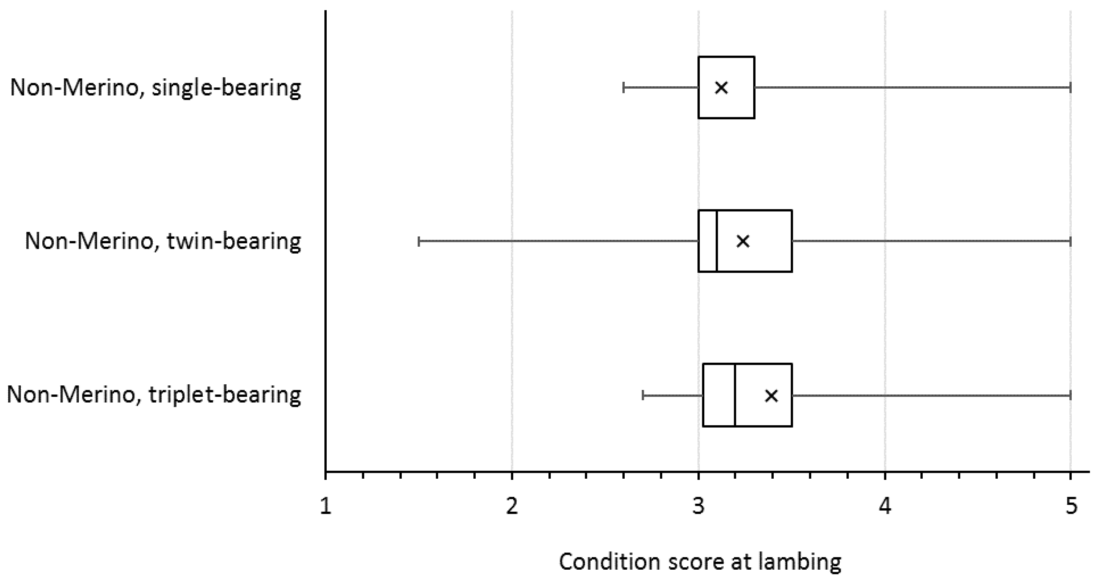

Figure 7.6. Distribution for the condition score of single-bearing, twin-bearing and triplet-bearing non-Merino ewes at lambing at farms across southern Australia between 2016 and 2018. Mean condition scores are shown as crosses.

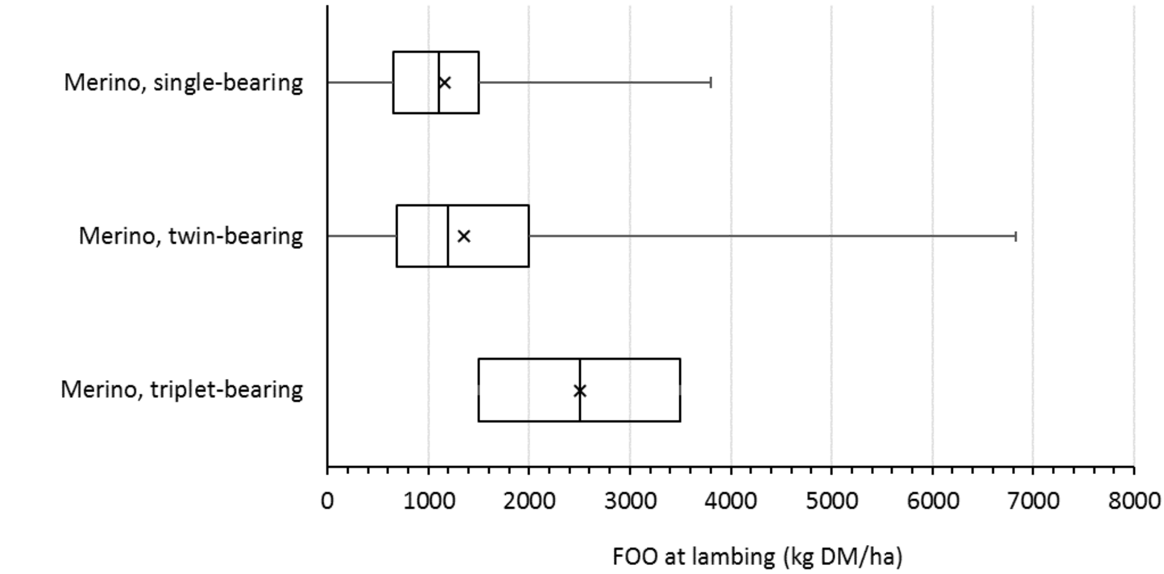

Figure 7.7. Distribution in feed-on-offer (FOO) at lambing for single-bearing, twin-bearing and triplet-bearing Merino ewes at farms across southern Australia between 2016 and 2018. Mean FOO are shown as crosses.

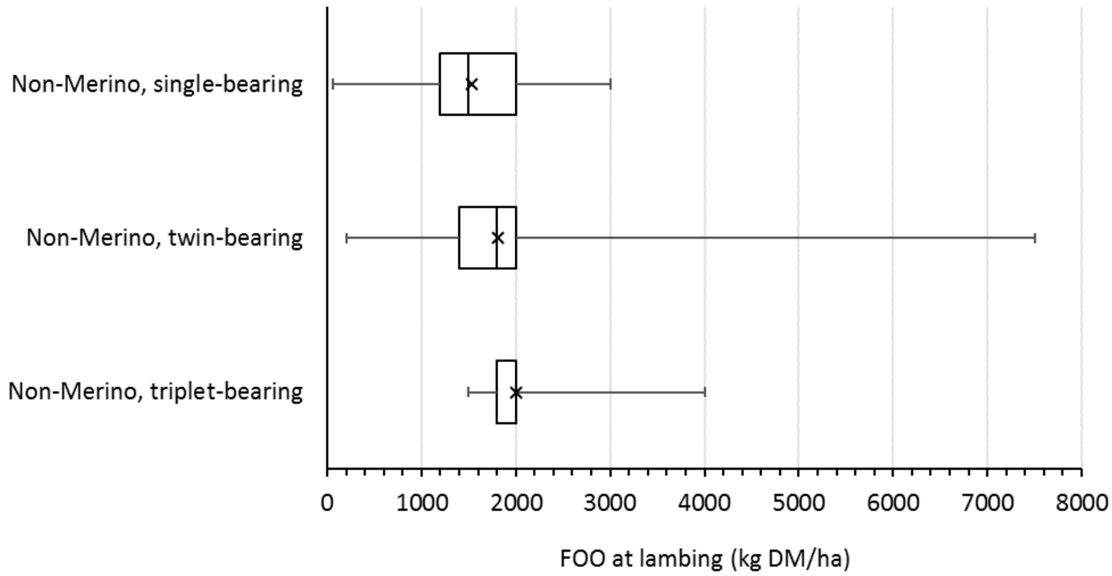

Figure 7.8. Distribution in feed-on-offer (FOO) at lambing for single-bearing, twin-bearing and triplet-bearing non-Merino ewes at farms across southern Australia between 2016 and 2018. Mean FOO are shown as crosses.

7.2. Results

There was a significant effect of ewe breed by pregnancy status on lamb survival (Table 7.3; $P<0.001$). The survival of single (85.7%), twin (64.6%) and triplet (26.5%) lambs born to Merino ewes was lower than that of their non-Merino counterparts (89.4%, 78.3% and 44.3%, respectively). The survival of lambs born to maiden ewes was poorer than that of mixed age ewes (65.5 vs 74.2%; $P<0.001$). Lamb survival increased by 0.2% for each additional 0.1 condition score of ewes at lambing ($P<0.001$). There was a significant mob size by pregnancy status effect on lamb survival (Table 7.3). The survival of lambs born to single-, twin- and triplet-bearing ewes decreased by 0.35%, 1.15% and 5.56% per additional 100 ewes in the mob at lambing, respectively (Figure 7.9; Figure 7.10; Figure 7.11).

There was no effect of ewe stocking rate at lambing, season of lambing, FOO at lambing, the percentage of legume in the pasture, whether or not the ewes were supplementary fed, the method of supplementary feeding, number and type of watering points, type of shelter within the paddock or the percentage of the paddock containing shelter on lamb survival and no interaction with mob size.

Table 7.3. Regression coefficients (± standard error) for restricted maximum likelihood model which predicts lamb survival to marking within mobs (%) from ewe age (maiden or mixed age), ewe condition score (CS) at lambing, ewe breed by pregnancy status and mob size of ewes at lambing by pregnancy status for Experiment three. Data were angular transformed.

	Coefficient	*P*-value
Constant[A]	64.94 ± 1.71	-
Maiden ewe age	-5.43 ± 0.39	<0.001
Ewe CS at lambing	1.99 ± 0.51	<0.001
Twin-bearing	-12.81 ± 0.56	<0.001
Triplet-bearing	-27.07 ± 3.32	
Non-Merino ewe breed	3.25 ± 0.64	<0.001
Non-Merino by twin	5.53 ± 0.57	<0.001
Non-Merino by triplet	7.45 ± 3.52	
Mob size	-0.0035 ± 0.0014	<0.05
Mob size by twin	-0.0080 ± 0.0022	0.001
Mob size by triplet	-0.0522 ± 0.0339	

[A] Survival constant is for a single lamb born to a mixed age Merino ewe

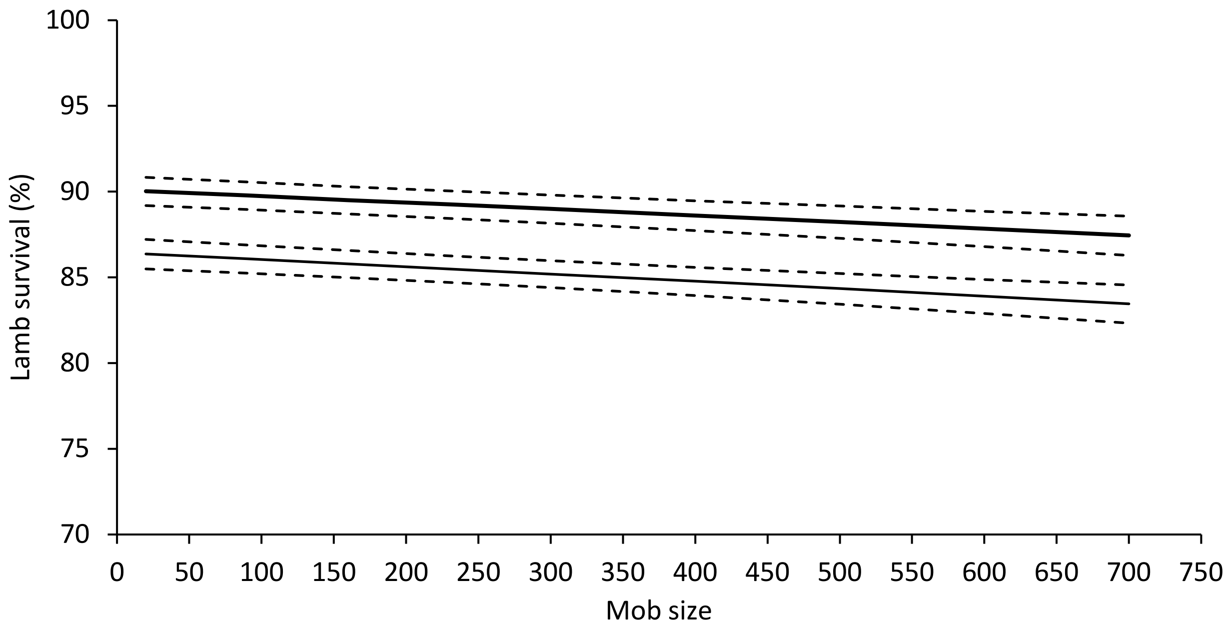

Figure 7.9. Effect (± 95% confidence intervals) of increasing the mob size of single-bearing Merino (thin line) or non-Merino (thick line) ewes at lambing on the survival of their lambs to marking at farms across southern Australia between 2016 and 2018 for Experiment Three

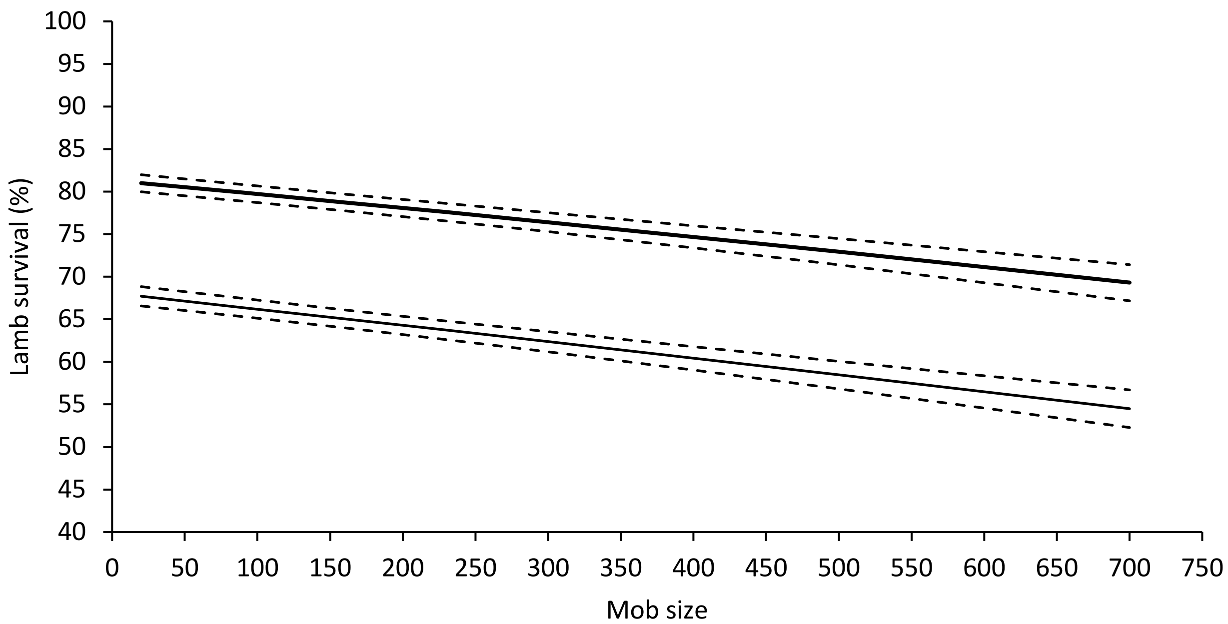

Figure 7.10. Effect (± 95% confidence intervals) of increasing the mob size of twin-bearing Merino (thin line) or non-Merino (thick line) ewes at lambing on the survival of their lambs to marking at farms across southern Australia between 2016 and 2018 for Experiment Three

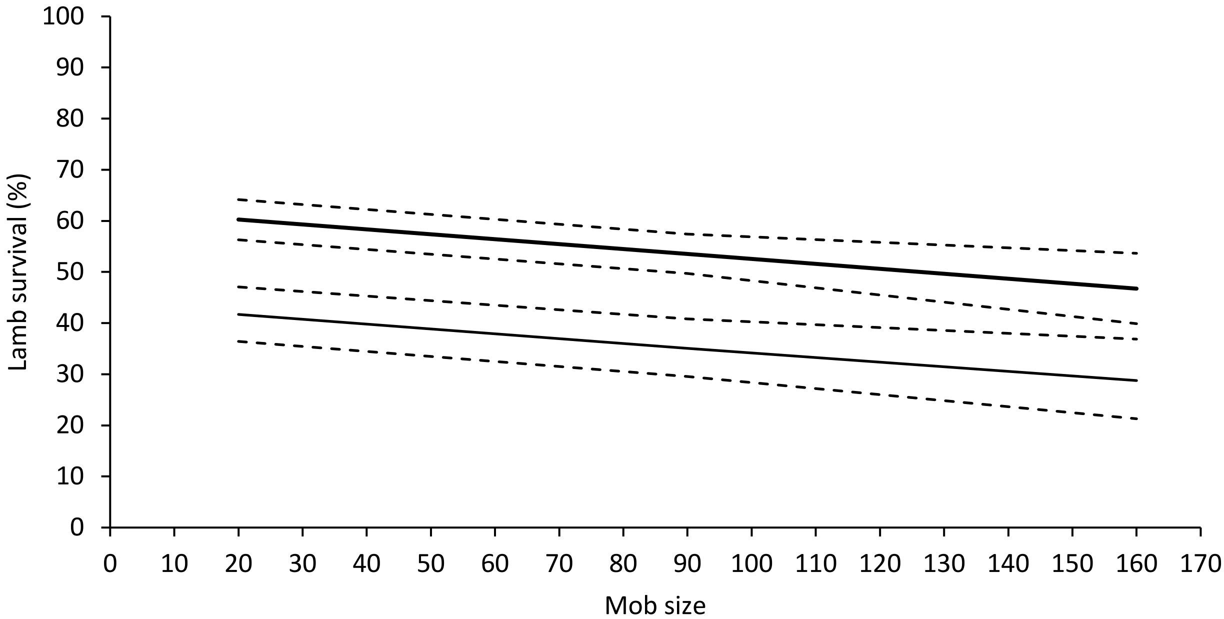

Figure 7.11. Effect (± 95% confidence intervals) of increasing the mob size of triplet-bearing Merino (thin line) or non-Merino (thick line) ewes at lambing on the survival of their lambs to marking at farms across southern Australia between 2016 and 2018 for Experiment Three

7.3. Discussion

Lambing ewes at higher mob sizes reduced the survival of their lambs to marking. The effect of reducing mob size by 100 single-bearing ewes was approximately a third of the effect observed from previous analysis of data collected from producers (Lockwood *et al.* 2019). Similarly, the increase in lamb survival associated with reducing mob size by 100 twin-bearing ewes was lower than that observed in Experiments One and Two and also from the previous analysis of data collected from producers (Lockwood *et al.* 2019). Very few mobs of triplet-bearing ewes were included in this experiment. However, the results suggest that reducing the mob size of triplet-bearing ewes can have a greater effect on lamb survival compared with twin-bearing ewes. The greater effect of mob size on the survival of multiple-born lambs is expected to be due to the greater number of lambs born per day and therefore a greater risk of mismothering (Cloete 1992; Robertson *et al.* 2012; Winfield 1970).

The mob sizes and stocking rates of Merino and non-Merino ewes at lambing were similar in this experiment. Mob sizes typically ranged between approximately 100 – 300 for single-bearing ewes and 60 – 200 for twin-bearing ewes. These ewes generally lambed at stocking rates of approximately 5 – 9 single-bearing ewes/ha and 5.5 – 10 twin-bearing ewes/ha. The relationship between mob size and lamb survival was not influenced by ewe breed, which aligns with the findings of Experiment One. These findings are also consistent with analysis of data from producers within a similar range of mob size and stocking rate (Lockwood *et al.* 2019). This consistent finding highlights that reducing mob size at lambing can be implemented as a strategy to increase reproductive performance from Merino and non-Merino ewes.

The effect of mob size on lamb survival was not influenced by the season of lambing or the condition score of ewes or FOO at lambing as reported by the producer. The number and type of watering points and reported availability of shelter also had no effect on the relationship between mob size and lamb survival. This is consistent with the findings of Experiments One and Two. Similar to these experiments, most paddocks in the current study had limited shelter available from high cover. It is therefore unlikely that the available shelter was effective at reducing the chill index experienced and may have also had no influence on ewe behaviour, including the congregation of ewes near the shelter. The majority of lambing paddocks had one or two watering points, as dams or troughs. Hence, there was typically limited variation in the characteristics of the lambing paddocks recorded in this experiment. Some bias and error would be expected in the data of this study due to the objective nature of some of the measurements. Nevertheless, the results highlight that many lambing paddocks in southern Australia have similar characteristics and these do not appear to influence the relationship between mob size and lamb survival.

The data collected suggests that at least 50% of Merino and 75% of non-Merino producers were managing ewes as per the current condition score and FOO targets described by Lifetime Ewe Management guidelines. Producers typically lambed multiple-bearing ewes at smaller mob sizes compared to single-bearing ewes which aligns with the current industry recommendations. However, until now there has been little credible evidence to support these recommendations for producers. Based on the findings from the collection of work conducted for this project plus the findings of Lockwood *et al.* (2019), reducing mob size at lambing by 100 single- or twin-bearing ewes will increase the survival of their lambs to marking by 0.3% – 1.4% and 1.1% – 3.5%, respectively, regardless of ewe breed. The greater benefit of reducing mob size on the survival of twin-born lambs aligns with the industry's highest priority for improving reproductive performance. To achieve smaller mob sizes at lambing, producers may need to subdivide lambing paddocks or consider lambing single-bearing ewes in larger mobs whilst reducing mob size for multiple-bearing ewes. The following analysis demonstrates the economic pay-off of strategies for reducing mob size to increase lamb survival.

8. Economic analysis

8.1. Background

The experiments conducted for this project aimed to quantify the impacts of the mob size and stocking rate of ewes at lambing on lamb survival. The stocking rate of lambing ewes was not found to influence lamb survival and hence this has not been evaluated in the following economic analysis. However, the project showed that reducing the number of ewes in the lambing paddock increased lamb survival and it was shown to be a linear increase over the range of mob size evaluated.

Two analyses were carried out:

1. To determine if it was profitable for producers to subdivide paddocks to reduce mob size at lambing and to evaluate the optimum mob size. Scenarios have been examined for mobs of twin-bearing ewes, single-bearing ewes and mixed mobs with dry, single- and twin-bearing ewes. This analysis considered the impact of reduced paddock size not only on lamb survival but also on pasture utilisation and stocking rate.
2. To determine the relative mob size for single- and twin-bearing ewes if paddocks are not subdivided and the ewes are just reallocated in the existing paddocks.

8.2. Method

8.2.1. Experimental findings used in the analysis

8.2.1.1. Impact of mob size on lamb survival

Project results from Experiments One, Two and Three, plus the findings from Lockwood *et al*. (2019) have been used in this analysis (Table 8.1).

Table 8.1. Regression coefficients which predict the effect of reducing mob size at lambing by 100 ewes on the survival of single-born and twin-born lambs to marking

Experiment	Singles	Twins	Breeds evaluated
One (2x2)	-	-1.9%	Merino & non-Merino
Two (Expansion)	-	-2.5%	Merino
Three (National survey)	-0.3%	-1.1%	Merino & non-Merino
Lockwood *et al.* (2019) (BWBL survey)	-1.4%	-3.5%	Merino & non-Merino
Average	-0.85%	-2.25%	

In the remainder of this report the results are based on the change in lamb survival based on the average coefficient value. The different data sets provide a slightly different answer for optimum mob size; with the coefficients from Lockwood *et al.* (2019) resulting in the smallest mob size and those from Experiment Three resulting in mobs about twice the size. The range between the results using the coefficients from the experimental work is smaller, varying by less than ±10% (Figure 8.1).

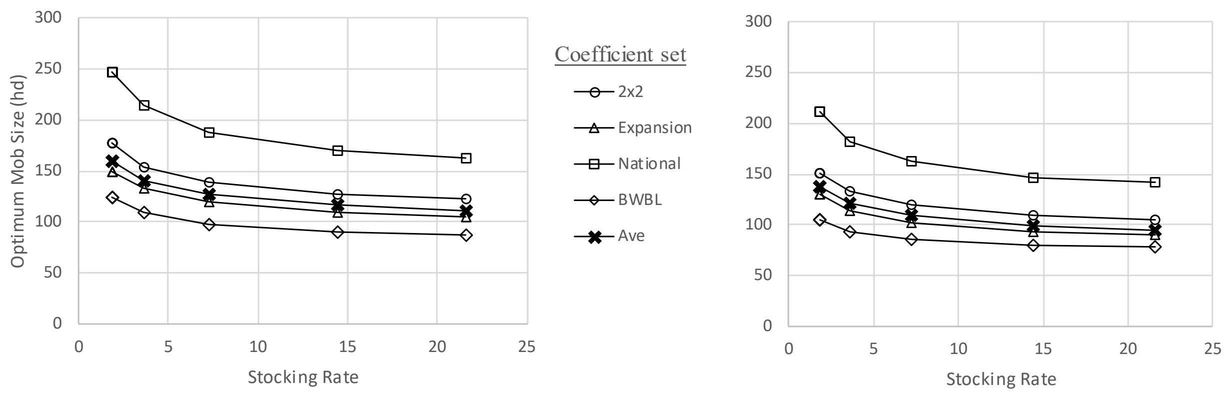

Figure 8.1. Optimum mob size for twin-bearing Merino (left) and maternal (right) ewes when calculated using the different sets of coefficients that describe the effect of varying mob size on lamb survival. The scenario is with lamb price at $6/kg, using permanent fencing, the impact of paddock size on pasture utilisation excluded and target return on investment of 5%.

8.2.1.2. Impact of paddock size on pasture utilisation and stocking rate

Saul and Kearney (2002) fitted the following relationship to data observed in a paired paddock programme carried out in south-west Victoria:

Potential stocking rate = -11.05+ 2.75 (Paddock size < 20 ha) + 3.41 Length of growing season + 0.178 Olsen PO_4

This relationship includes a factor for whether the paddock is greater than or less than 20 ha. They predicted that paddocks less than 20 ha could carry 2.75 DSE/ha more than paddocks greater than 20 ha. This coefficient has been used as the basis for deriving a general relationship between paddock size and variation in carrying capacity in different regions. The derivation included three steps;

1. It was assumed that the Saul and Kearney coefficient of 2.75 related to a change in paddock size from 30 ha (greater than 20 ha in their study) to 10 ha (less than 20 ha in their study). Therefore, stocking rate increases by 0.14 DSE/ha (2.75/20) for each 1 ha reduction in paddock size.
2. For paddock size below 30 ha, it is assumed that the change in stocking rate is linear with a slope of -0.14 DSE/ha. For paddock size above 30 ha, it is assumed that the change in stocking rate is based on the logarithm of the paddock size, such that halving paddock size increases stocking rate by 1.74 DSE/ha (2.75/(log(30)-log(10))*log(2).
3. The change in stocking rate is scaled based on the stocking rate in the target region relative to the stocking rate in the south-west Victorian paired paddock program. If the stocking rate on the property being analysed is half the south-west Victorian stocking rate, then the change in stocking rate due to adjusting paddock size is half that predicted using steps 1 and 2.

The resulting relationship for a specific situation is shown in Figure 8.2.

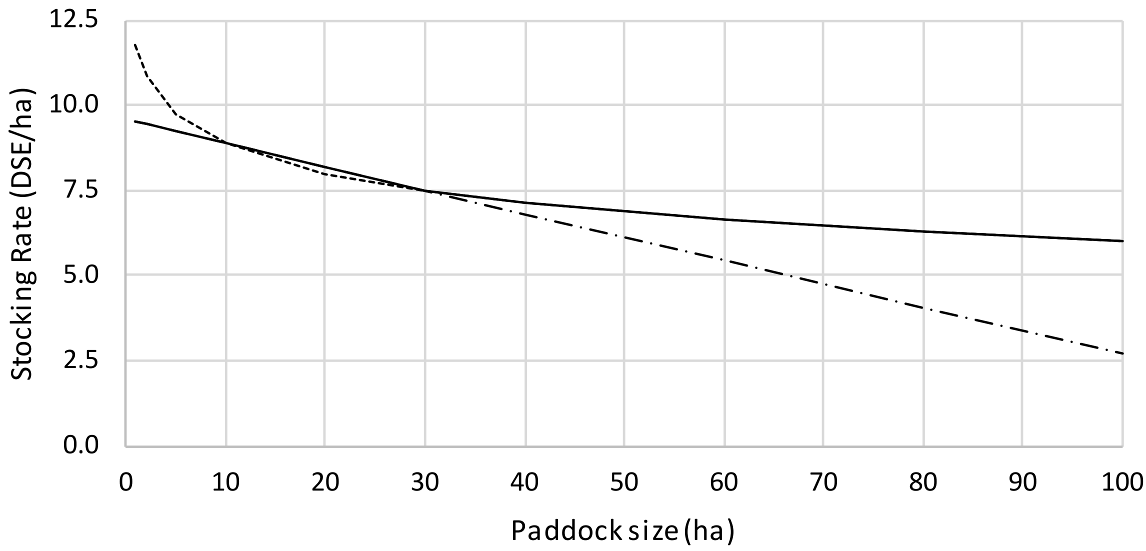

Figure 8.2. Relationship between paddock size and stocking rate for a property that runs 7.5 DSE/ha in a 30 ha paddock. The solid line shows the selected relationship, the long dash is the linear relationship if above 30 ha and the short dash is the log relationship if below 30 ha.

8.2.2. Calculations of profitability

The calculations have three components;

1. The increase in income achieved from increasing lamb survival
2. The cost of subdividing paddocks to reduce mob size
3. The effect of altering paddock size on pasture utilisation and stocking rate
4.

8.2.2.1. Increase in income

The value of increasing lamb survival was calculated using the value of extra lambs surviving that has been calculated using the MIDAS model (Young *et al*. 2014). The MIDAS value 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 lower wool production of lactating ewes and also accounts for the lower wool production expected from twin-born lambs but doesn't account for the lower weaning weight of twins. This will only have a minor effect on the value of extra twin-born Merino lambs because surplus animals are typically sold as hoggets. However, it will be overestimating the value of extra maternal twin lambs which will require more feed to achieve sale weights. This overestimation of the value of a twin-born lamb will reduce the optimum mob size for twin-bearing maternal ewes and will also reduce the optimum relative mob size for maternal twins versus singles.

Three meat price scenarios were evaluated; lamb at \$5/kg, \$6/kg and \$7/kg dressed weight (Table 8.2). Previous analysis showed that wool price did not alter the value of an extra lamb so wool price was not included in the analysis.

Table 8.2. Value of an extra twin lamb surviving at three meat prices for a self-replacing flock based on a Merino and a maternal genotype

Lamb price	Merino		Maternal	
	Single	Twin	Single	Twin
$5/kg	$75	$56	$73	$73
$6/kg	$94	$70	$91	$91
$7/kg	$117	$88	$114	$114

The value of the extra lambs surviving as a result of reducing the mob size of ewes at lambing was calculated using the formulas:

$$Value\ of\ extra\ single\ lambs\ per\ single\ bearing\ ewe$$
$$= 1 * change\ in\ survival\ of\ singles * Value\ of\ extra\ single\ lambs$$
$$Value\ of\ extra\ multiple\ lambs\ per\ multiple\ bearing\ ewe$$
$$= lambs\ per\ ewe * change\ in\ survival\ of\ twin\ lambs * Value\ of\ extra\ twin\ lambs$$

where;

$$change\ in\ survival\ of\ single\ lambs$$
$$= change\ in\ number\ of\ ewes\ in\ the\ lambing\ paddock * singles\ coefficient$$
$$change\ in\ survival\ of\ multiple\ lambs$$
$$= change\ in\ number\ of\ ewes\ in\ the\ lambing\ paddock * twins\ coefficient$$

Notes:

- An alternative approach could have been to calculate the change in survival as a function of the change in the number of lambs born per day rather than the change in the number of ewes. This alternative approach would have no effect on the results for the flocks where singles and twins are scanned and separated, but it would increase the optimum mob size for flocks that don't pregnancy scan.
- Triplets were valued as twin lambs and triplet mob size was not evaluated separately. This is likely to have undervalued the contribution of triplet-bearing ewes because triplet lamb survival is likely to be more sensitive to mob size, although this will be offset to some degree by the lower value of triplet lambs.

8.2.2.2. Cost of subdivision

The cost of subdividing 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.

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

The analysis quantified the following costs of dividing paddocks;

- Both fencing and provision of water
- Cost of materials and labour

- The cost of temporary fencing was calculated assuming that either lambing was in spring and that providing water was not necessary or that lambing was in autumn and water was required
- The cost of providing water included pipe to move the water and a trough
- Life of the fence and watering points were assumed to be 15 years

Costs are detailed in Table 8.3.

Table 8.3. Cost of materials and labour to subdivide paddocks ($/unit).

Item	Unit	Upfront capital cost		Annual maintenance
		Materials	Labour	Labour
Permanent fencing	km	$1990	$1000	
Temporary fencing	km	$600		$75
Pipe	km	$1000	$200	
Trough in a permanent paddock	unit	$2200	$50	
Trough in a temporary paddock	unit	$660	$50	$20

The size of the paddock was calculated from the mob size and stocking rate of the ewes at lambing and their DSE rating (dry 1.0, single 1.5 and twin 1.8 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 half way across the paddock to the newly installed fence that was down the middle of the paddock.

8.2.2.3. Pasture utilisation and stocking rate

The impact of smaller paddocks on pasture utilisation and stocking rate was based on the approach of Saul and Kearney (2002) as previously described. The benefit of increased stocking rate was based on the flock gross margin and the cost of the animals retained or purchased to increase stocking rate was based on the stock value in the gross margin (Table 8.4).

Table 8.4. Gross margin ($/DSE) and value of stock ($/DSE) of the Merino and maternal flock for the range of meat prices evaluated.

	Gross Margin		Value of stock	
Lamb Price	Merino	Maternal	Merino	Maternal
	$/DSE	$/DSE	$/DSE	$/DSE

$5/kg	27.50	29.20	76	72
$6/kg	33.10	39.50	91	86
$7/kg	40.85	50.00	106	101

8.2.3. The analysis

Two analyses were carried out examining;

1. The scenarios where farmers are considering subdividing paddocks and want to know the optimum mob size or return on investment (ROI)
2. The scenario where farmers don't want to re-fence and hence only adjust the mob size of single- and twin-bearing ewes within their current paddocks.

8.2.3.1. Optimum mob size

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 and increased stocking rate) is compared to the annual maintenance costs plus the annuity of the up-front costs (associated with paddock subdivision and retaining extra stock). The result is therefore an equivalent annual value in $/year and has been presented per ewe managed differently.

The analysis evaluated a given flock size with varying stocking rates and varying initial number of ewes per paddock. This structure allows optimum mob size and ROI to be derived. The optimum mob size is a range and if the current paddock size is within or below the range, 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. To simplify the presentation of the results the optimum mob size has been graphed as the mid-point of the upper and lower values. In this case the range can be estimated from the midpoint value as ± ⅓ of the midpoint value. Where a ROI is the return presented, it is the return achieved if a paddock is subdivided to the specified size.

The results have been presented in two different formats to represent different levels of detail required in understanding the results; (1) With less detailed presented in a table format for 19 different scenarios and (2) With more detail in graphical format which includes sensitivity analysis of each factor examining the optimum mob size for a Merino and a non-Merino scenario (Table 8.5).

Table 8.5. Parameters tested in the sensitivity analysis of the optimum mob size. The standard Merino scenario is underlined and the standard non-Merino scenario is bolded.

	Levels evaluated
Stocking rate	1.8 DSE/ha, 3.6 DSE/ha, 7.2 DSE/ha, **14.4 DSE/ha**, 21.6 DSE/ha
Coefficient set	Experiment One, Experiment Two, Experiment Three, Lockwood *et al.* (2019), **Average**

Scanning	All singles, **All twins**, Combined 120%, Combined 150%, Combined 180%
Fencing & water	**Permanent**, Temporary Fencing & water, Temporary fencing w/o water
Lamb price	$5/kg, **$6/kg**, $7/kg
Breed	Merino, **Maternal**
Target return on investment	**5%**, 10%, 20%, 50%
Impact of paddock size on pasture utilisation	**Excluded**, Included

8.2.3.2. Adjust single and twin mob size within current paddocks

This analysis was carried out as a single year analysis because there are no capital costs due to there being no subdivision of paddocks. The change in survival of single- and twin-born lambs was calculated based on reducing mob size for multiple-bearing ewes and increasing mob size for single-bearing ewes. The analysis evaluated the profitability of a flock of 3000 scanned ewes on a farm with a specified number of equal sized paddocks used for lambing ewes. The proportion of the paddocks used for single- and multiple-bearing ewes was varied, which altered the mob size. This was carried out for flocks with varying scanning performance and hence varying proportion of single- and multiple-bearing ewes.

Sensitivity analysis examined the allocation of singles and twins in current paddocks in a range of scenarios (Table 8.6).

Table 8.6. Parameters tested in the sensitivity analysis for adjusting the allocation of singles and twins in current paddocks. The standard Merino scenario is underlined and the standard non-Merino scenario is bolded.

	Levels evaluated
Coefficient set	Experiment Three, Lockwood *et al.* (2019), **Average**
Scanning	120%, **150%**, 180%
Lamb price	$5/kg, **$6/kg**, $7/kg
Breed	Merino, **Maternal**

8.3. Results and Discussion

8.3.1. Scenario results

There are several factors that affect optimum mob size and paddock size. The optimum varies with the type of fencing used to subdivide paddocks, whether the subdivided paddocks require water, the target ROI for the investment, stocking rate of the ewes, breed of sheep, lamb price and whether the advantages of improved pasture utilisation in smaller paddocks will be capitalised. The optimum mob and paddock sizes for a number of scenarios are presented in Table 8.7 and Table 8.8.

8.3.2. Sensitivity analysis results

Two scenarios have been presented for each set of results. Scenario (a) is Merino ewes, stocked at 7.2 DSE/ha and scenario (b) is maternal ewes stocked at 14.4 DSE/ha. Both scenarios are for twin-bearing ewes, with permanent fencing, $6/kg for lamb, 5% interest rate and exclude the impact of pasture utilisation on stocking rate (see Table 8.5).

8.3.2.1. Optimum flock size

The breakeven mob size is calculated as the mob size which results from subdividing a paddock when the increase in annual income is equal to the sum of the annual maintenance costs and the annuity of the upfront costs. This is demonstrated in Figure 8.3.

Splitting a paddock of twin-bearing Merino ewes to result in a mob size of 250 ewes increases income by $8/ewe. The cost incurred depends on the stocking rate in the lambing paddock. At 21.6 DSE/ha (12 twin-bearing ewes per ha) the cost is less than $1/ewe generating a profit of approximately $7/ewe. Whereas at 1.8 DSE/ha (1 twin-bearing ewe per ha) the cost is $2/ewe with a profit of $6/ewe. The cost for maternal ewes is the same, but the income is higher and therefore the optimum mob size is smaller.

Table 8.7 Optimum mob size and paddock size for the Merino scenarios

		Pasture utilisation benefits excluded					Pasture utilisation benefits included				
		Lambing ewe mob type (from scanning/lambing practice)					Lambing ewe mob type (from scanning/lambing practice)				
DSE/ha	Scenario Fence type	Twin	Single	Wet/dry (118%)	No scan (118%)	No scan (150%)	Twin	Single	Wet/dry (118%)	No scan (118%)	No scan (150%)
<u>Optimum Mob Size</u>											
1.8	Permanent	107	240	165	168	142	45	65	62	57	49
3.6	Permanent	94	206	146	148	123	36	43	24	12	5
7.2	**Permanent**	**85**	181	130	132	108	40	50	52	46	38
7.2	Temporary + water	56	120	84	85	72					
7.2	Temporary, no water	28	68	42	44	34					
14.4	Permanent	77	163	118	119	97	47	66	65	60	54
14.4	Temporary + water	52	107	77	78	65					
14.4	Temporary, no water	23	53	31	33	26					
<u>Optimum Paddock Size</u>											
1.8	Permanent	107	200	148	142	128	45	54	56	45	41
3.6	Permanent	47	86	65	63	56	18	18	11	2	1
7.2	**Permanent**	**21**	38	29	28	24	10	10	12	9	7
7.2	Temporary + water	14	25	19	18	16					
7.2	Temporary, no water	7	14	9	9	8					
14.4	Permanent	10	17	13	13	11	6	7	7	6	6
14.4	Temporary + water	6	11	9	8	7					
14.4	Temporary, no water	3	6	4	3	3					

Table 8.8 Optimum mob size and paddock size for the non-Merino scenarios

	Scenario	Pasture utilisation benefits excluded					Pasture utilisation benefits included				
		Lambing ewe mob type (from scanning/lambing practice)					Lambing ewe mob type (from scanning/lambing practice)				
DSE/ha	Fence type	Twin	Single	Wet/dry (150%)	No scan (150%)	No scan (180%)	Twin	Single	Wet/dry (150%)	No scan (150%)	No scan (180%)
<u>**Optimum Mob Size**</u>											
1.8	Permanent	92	243	122	123	101	32	45	30	28	22
3.6	Permanent	81	209	105	106	89	27	38	30	27	20
7.2	Permanent	73	183	93	93	81	33	50	30	27	19
7.2	Temporary + water	49	122	63	63	52					
7.2	Temporary, no water	24	69	28	28	22					
14.4	**Permanent**	**66**	165	87	87	75	41	59	47	45	40
14.4	Temporary + water	45	109	57	57	47					
14.4	Temporary, no water	19	54	21	21	16					
21.6	Permanent	63	156	84	84	73	45	69	53	52	46
21.6	Temporary + water	43	103	54	54	44					
21.6	Temporary, no water	16	47	17	17	13					
<u>**Optimum Paddock Size**</u>											
1.8	Permanent	92	203	113	112	96	32	38	28	25	21
3.6	Permanent	41	87	49	48	42	13	16	15	12	10
7.2	Permanent	18	38	21	21	19	8	12	7	6	5
7.2	Temporary + water	12	25	15	14	12					
7.2	Temporary, no water	6	14	6	6	5					
14.4	**Permanent**	**8**	17	10	10	9	5	6	5	5	5
14.4	Temporary + water	6	11	7	6	6					
14.4	Temporary, no water	2	6	2	2	2					
21.6	Permanent	5	11	6	6	6	4	5	4	4	4
21.6	Temporary + water	3.6	7	4	4	3					
21.6	Temporary, no water	1	3	1	1	1					

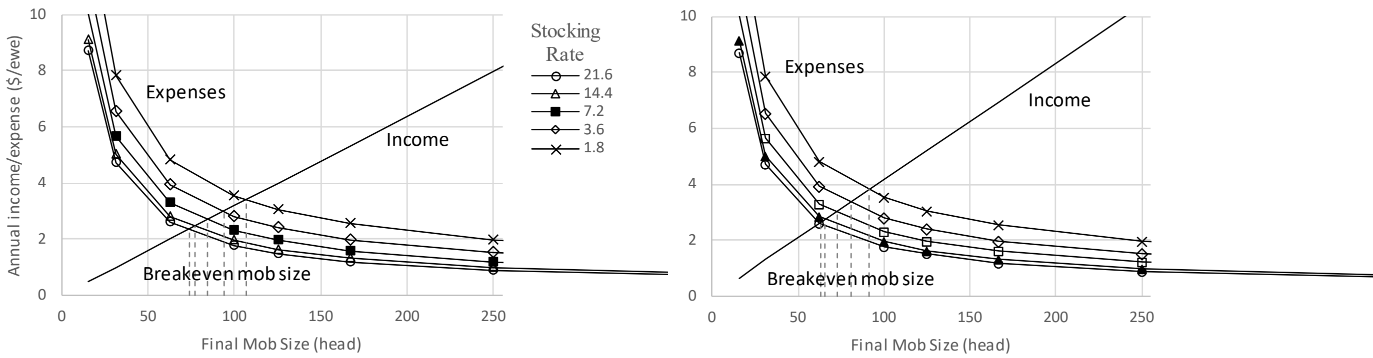

Figure 8.3. Increase in income from improved lamb survival ($/twin-bearing ewe) and the annual equivalent increase in expenses associated with paddock subdivision if the mob size is halved to the 'Final Mob Size' for Merinos (left) and maternals (right). Profit increases if the ‘Final mob size’ is greater than the ‘Breakeven mob size’ for each stocking rate (DSE/ha in the lambing paddock). The scenario is for a lamb price of $6/kg, using permanent fencing, average lamb survival coefficients, the impact of paddock size on pasture utilisation excluded and target return on investment of 5%. The standard scenario is bolded.

Although the above analysis calculates a single value, optimum mob size is actually a range because there is not a single optimum mob size. In a specific situation of existing paddocks, the paddock sizes vary and therefore can’t all be subdivided to the same target size. This analysis calculates the mob size for which having divided the paddock in half has equal profitability to not dividing. Therefore, the final flock size and double the final flock size are equally profitable, and this is the range of optimum flock size. If the paddock is larger than the upper value, then it would increase profit if the paddocks were divided in half. If dividing the paddock will result in mob sizes less than the optimum range, then proceeding with that subdivision will reduce profit. Examples of the optimum range for mob size are shown in Figure 8.4 and Figure 8.5.

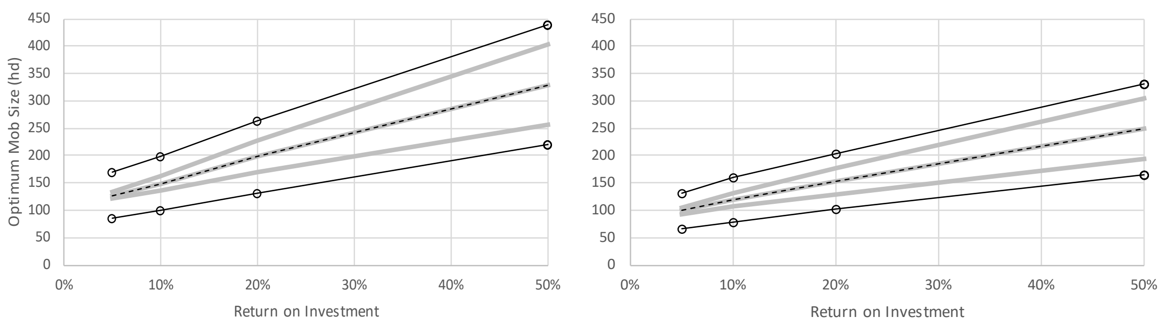

Figure 8.4. The range of optimum mob size for twin-bearing Merino (left) and maternal (right) ewes when the target return on investment varies. The dashed line is the mid-point of the optimum range. The scenario is for a lamb price of $6/kg, using permanent fencing, average lamb survival coefficients and the impact of paddock size on pasture utilisation excluded.

8.3.2.2. Interest rate or target return on investment

The optimum flock size varies with the target ROI from paddock subdivision (Figure 8.4). The higher the target return, the larger the mob size. If the target return is 20%, then the range of optimum mob size is between 130 and 270 twin-bearing ewes per mob, whereas if the target is 10%, then the optimum is between 100 and 200 twin-bearing ewes.

The analysis reported in this document used a default interest rate of 5%. Optimum mob size can be approximated using the mob size scalar in Table 8.9. The increase in optimum mob size with higher target ROI can be calculated by scaling the result presented in this report that are calculated using the default 5% interest rate.

Table 8.9. Scalar for optimum mob size for producers who wish to achieve a higher return on investment

Target return on investment	Mob size scalar
5%	1.0
10%	1.2
20%	1.5
50%	2.5

8.3.2.3. Cost of subdivision

The magnitude of the optimum range increases when the optimum mob size increases. This is demonstrated in Figure 8.5, with the range being much larger when using permanent fencing than using temporary fencing. The range of optimum mob size is ±⅓ of the mid-point (dashed line).

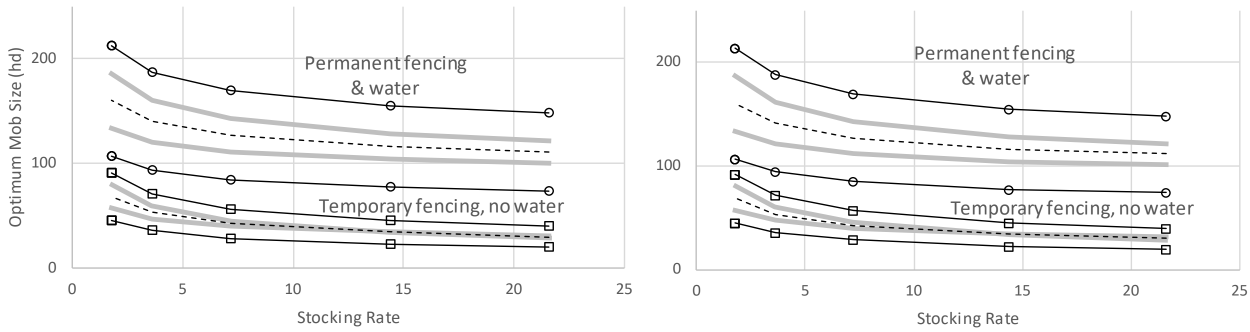

Figure 8.5. The range of optimum mob size for twin-bearing Merino (left) and maternal (right) ewes with varying stocking rate (DSE/ha) when changing the type of fencing and requirement for water in the resulting paddocks. Each scenario is for a lamb price of $6/kg, average lamb survival coefficients, the impact of paddock size on pasture utilisation excluded and target return on investment of 5%.

The optimum mob size is affected by the cost of subdivision and is much smaller if using temporary fencing due to the lower cost (Figure 8.5 and Figure 8.6). In Figure 8.6, only the mid-point of the optimum range is presented to simplify the graph.

The cost of subdivision is also dependent on the shape of the paddock. This analysis was carried out assuming that the original paddock layout was square paddocks with water in the corner. Rectangular paddocks with central water are much cheaper to subdivide and would result in smaller optimum mob sizes. Likewise, fencing with cheaper materials, for example 5 line ringlock® rather than 7 line would reduce costs and reduce optimum mob size.

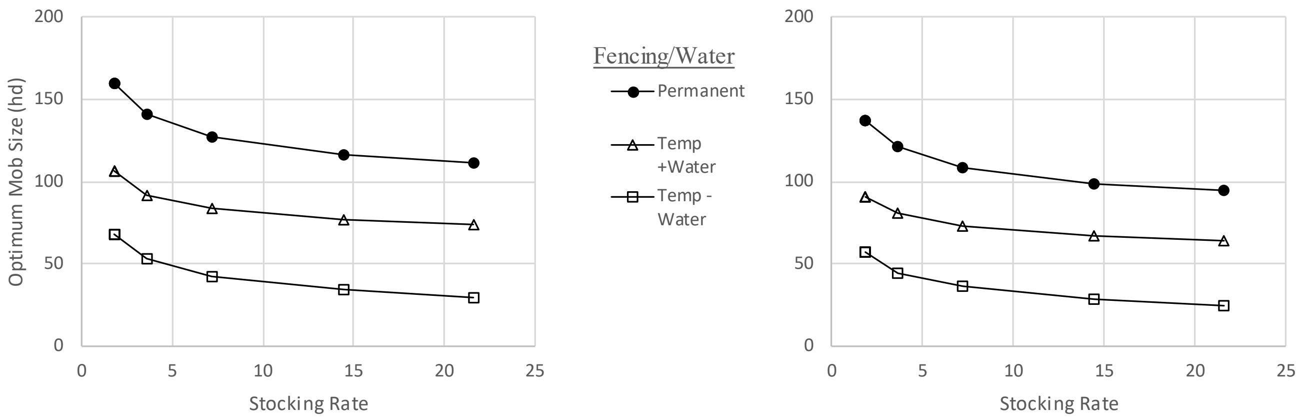

Figure 8.6. Mid-point of optimum mob size for twin-bearing Merino (left) and maternal (right) ewes with varying stocking rate (DSE/ha) for the three fencing and water scenarios examined in the analysis. The scenario is for a lamb price of $6/kg, average lamb survival coefficients, impact of paddock size on pasture utilisation excluded and target return on investment of 5%.

8.3.2.4. Scanning percentage

The optimum mob size for twin-bearing ewes is just less than half the optimum mob size for single-bearing ewes (Figure 8.7). Relative mob size of twins versus singles is discussed in more detail in section 8.3.3.

If ewes are not scanned, then the optimum paddock size is affected by the expected scanning percentage. For a mob that scans 120%, the optimum mob size is 1.6 times the twin mob size. If scanning 150%, then 1.3 times and if 180% then 1.1 times.

The optimum mob size for an unscanned mob is more similar to the optimum mob size for the twin-bearing ewes than it is for the single-bearing ewes (Figure 8.8). This is the case even for mobs that are scanning 120%. Flocks that have been pregnancy scanned for wet/dry have a very similar optimum mob size to flocks that don’t scan (Figure 8.8).

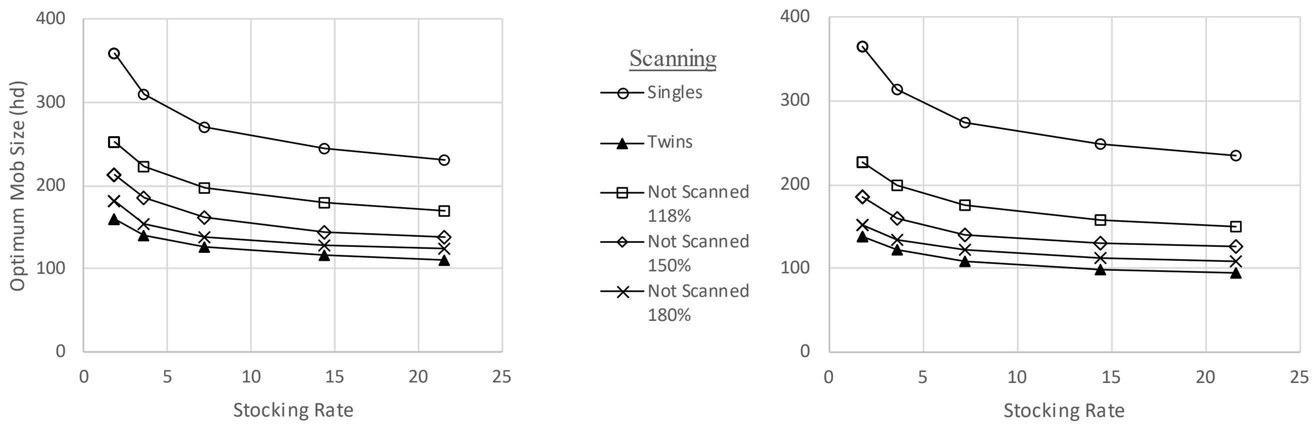

Figure 8.7. Optimum mob size for single- and twin-bearing Merino (left) and maternal (right) ewes and mobs with varying scanning percentages. The scenario is for lamb price at $6/kg, using permanent fencing, average lamb survival coefficients, the impact of paddock size on pasture utilisation excluded and target return on investment of 5%.

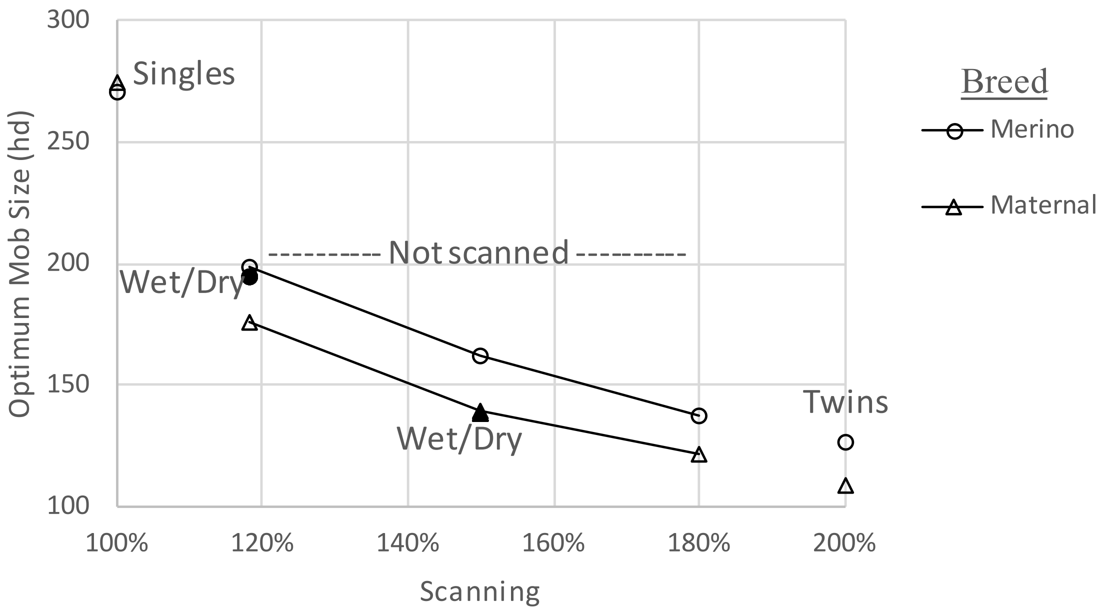

Figure 8.8. Impact of expected scanning performance on optimum mob size for flocks that don't pregnancy scan (open symbols) or only scan for wet/dry (closed symbols), compared with the optimum mob size for single- or twin-bearing Merino and maternal ewes.

8.3.2.5. Breed

The optimum mob size for twin-bearing maternal ewes is approximately 15% smaller than that for twin-bearing Merino ewes when run at the same stocking rate (Figure 8.9).

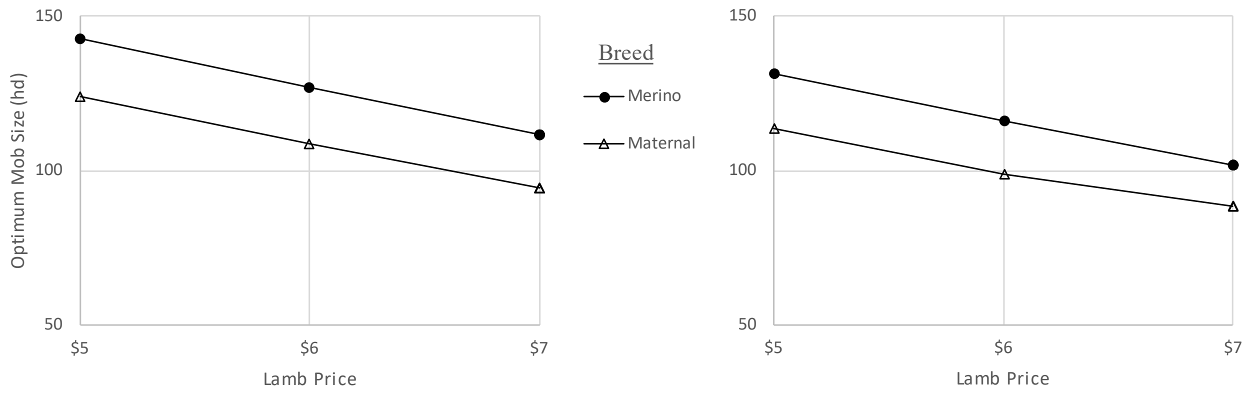

Figure 8.9. Impact of varying lamb price on the optimum mob size for twin-bearing Merino and maternal ewes at a stocking rate of 7.2 DSE/ha (left) and 14.4 DSE/ha (right). With a lamb price $6/kg, using permanent fencing, average lamb survival coefficients, impact of paddock size on pasture utilisation excluded and target return on investment of 5%.

In contrast to mob size for twin-bearing ewes, the optimum mob size for single-bearing ewes is the same for both Merino and maternal ewes (Figure 8.10) and reduces from 275-310 ewes with a lamb price of $5/kg to 210-240 ewes at $7/kg. Relative mob size of singles and twins is discussed in more detail in section 8.3.3.

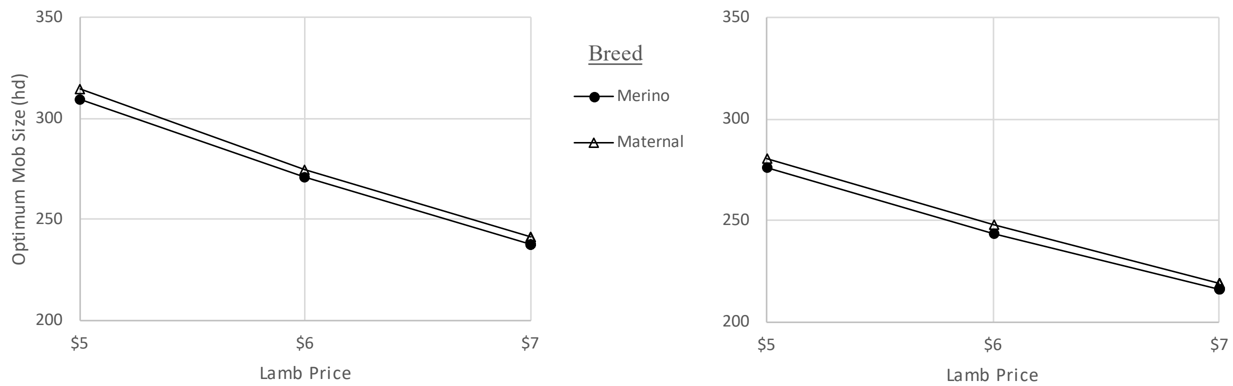

Figure 8.10. Impact of varying lamb price on the optimum mob size for single-bearing Merino and maternal ewes at a stocking rate of 7.2 DSE/ha (left) and 14.4 DSE/ha (right). The scenario is for lamb price at $6/kg, using permanent fencing, average lamb survival coefficients, impact of paddock size on pasture utilisation excluded and target return on investment of 5%.

8.3.2.6. Optimum paddock size and including pasture utilisation

Optimum paddock size can be calculated from the optimum mob size, the stocking rate of ewes at lambing and the DSE/hd for the ewes using the formula:

$$Paddock\ size = \frac{Mob\ size * DSE/hd}{Stocking\ rate}$$

Looking at the results as optimum paddock size is an alternative view of the same information. The best option depends on whether mob size or paddock size is a more familiar metric.

The results presented in the previous sections are only evaluating the impact of mob size on lamb survival. They are ignoring the effect of smaller paddocks on increasing the capacity to utilise pasture and increase stocking rate. Including this effect in the calculations alters both income and expenses. Income increases through the increased profitability of the flock due to the higher carrying capacity. Expenditure increases because of the up-front value of the stock retained or purchased.

The relationship used to relate paddock size to pasture utilisation is not precise and has been extrapolated from another study and the extrapolation is beyond the limits of that study. Even given the above limitation, it is still the best available information but these findings need to be interpreted with caution.

Including pasture utilisation in the calculations reduces optimum paddock size (Figure 8.11). This indicates that reducing paddock size to increase lamb survival is complementary to reducing paddock size to improve pasture utilisation.

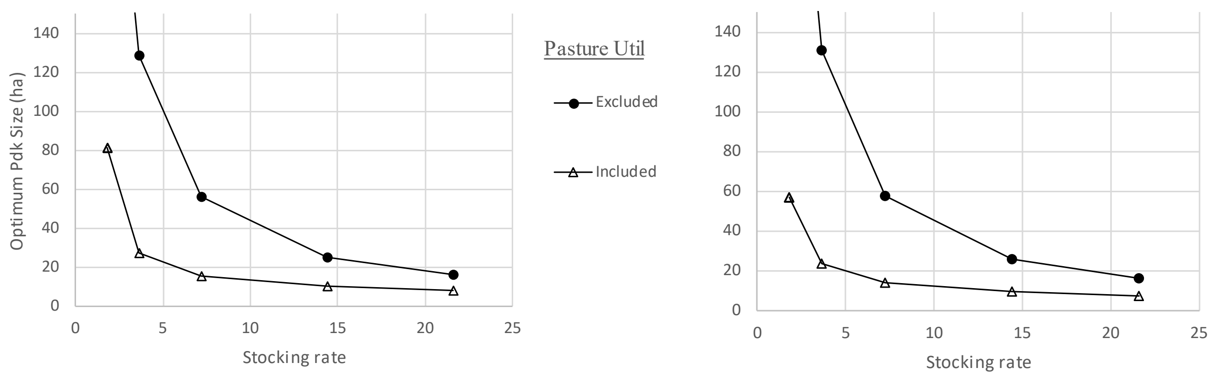

Figure 8.11. Impact of stocking rate on the optimum paddock size (ha) for Merino (left) and maternal (right) ewes when including or excluding the impact of paddock size on pasture utilisation and stocking rate. The scenario is for a lamb price of $6/kg, using permanent fencing, average lamb survival coefficients and target return on investment of 5%.

Including pasture utilisation has a relatively larger effect on optimum paddock size at low stocking rates than at high stocking rates (Figure 8.11). If stocking rate is 1.8 or 3.6 DSE/ha then the optimum paddock size including pasture utilisation in the calculation is 20% of the size if pasture utilisation is excluded. In contrast at 21.6 DSE/ha the optimum is 45% of the value excluding pasture utilisation. This occurs because pasture utilisation level is controlled by change in paddock size and with low stocking rates, at the same mob size, paddocks are larger and therefore the potential to increase stocking rate is greater.

When the results with and without inclusion of pasture utilisation are presented as optimum mob size, it shows that optimum mob size is smaller than if pasture utilisation is excluded (Figure 8.12). However, the optimum mob size increases with increasing stocking rate, although the effect is relatively small.

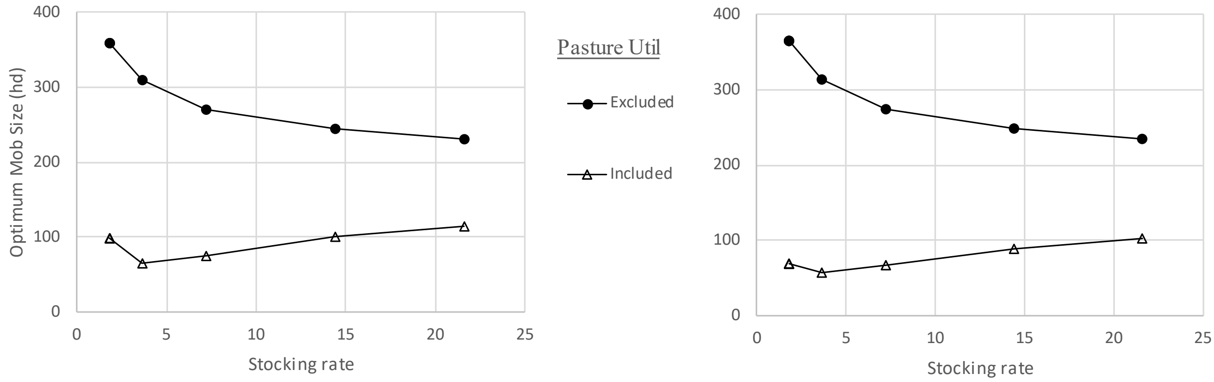

Figure 8.12. Impact of stocking rate on the optimum mob size for Merino (left) and maternal (right) ewes when including or excluding the impact of paddock size on pasture utilisation and stocking rate. The scenario is for a lamb price of $6/kg, using permanent fencing, average lamb survival coefficients and target return on investment of 5%.

8.3.3. Relative mob size using current paddocks

The results from the producer surveys showed that the survival of lambs in mobs of single-bearing ewes is less sensitive to mob size at lambing than mobs of twin-bearing ewes. This indicates that if the existing paddocks are not subdivided, profit could still be increased by altering the allocation of single- and twin-bearing ewes to the existing paddocks.

The experiments did not quantify the impact of mob size on the survival of lambs from single-bearing ewes and therefore this component of the analysis was based on the coefficients derived from the producer surveys in Experiment Three and by Lockwood *et al.* (2019). The BWBL survey (Lockwood *et al.* 2019) indicated that survival was more sensitive to mob size but there was less relative difference between the singles and twins. Therefore, the increase in the value of altering relative mob size is greater ($0.34/merino ewe, $0.70/maternal ewe) than when evaluated using the results of the national survey ($0.15/merino ewe, $0.30/maternal ewe), but the optimum relative mob size is slightly higher (Figure 8.13).

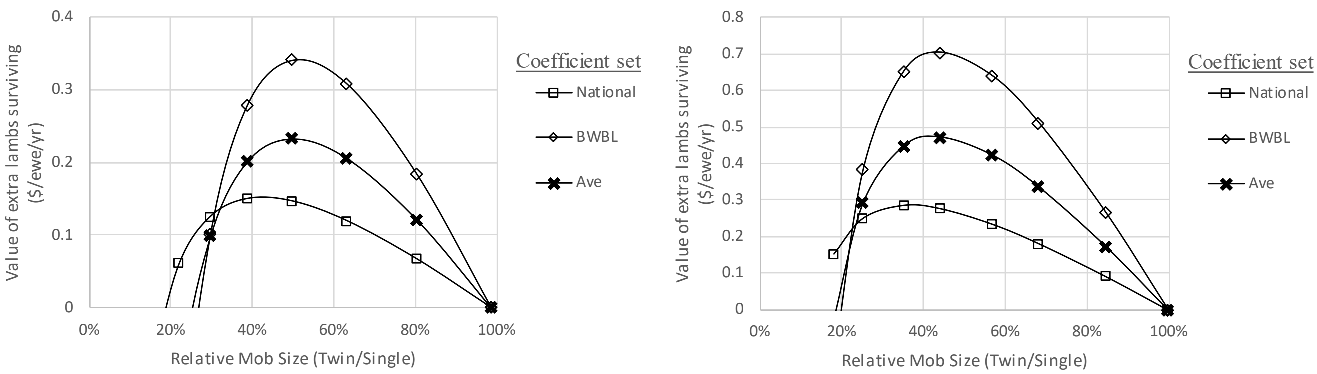

Figure 8.13. Impact of varying relative mob size (twin mob size/single mob size) of Merino (left) and maternal (right) ewes on the value of extra lambs surviving ($/ewe/yr). The scenario is for a Merino flock scanning 118%, maternal flock scanning 150% and a lamb price of $6/kg.

The value of adjusting the relative mob size of twins and singles at lambing depends on the scanning percentage of the flock (Figure 8.14). The value is greatest if scanning percentage is approximately 150% which equates to half the ewes carrying singles and half carrying twins. When the scanning percentage varies either side of this the value diminishes because there is less scope to vary the relative mob size. Although scanning percentage alters the value that can be achieved from altering relative mob size, there is no change in the optimum relative mob sizes (Figure 8.15).

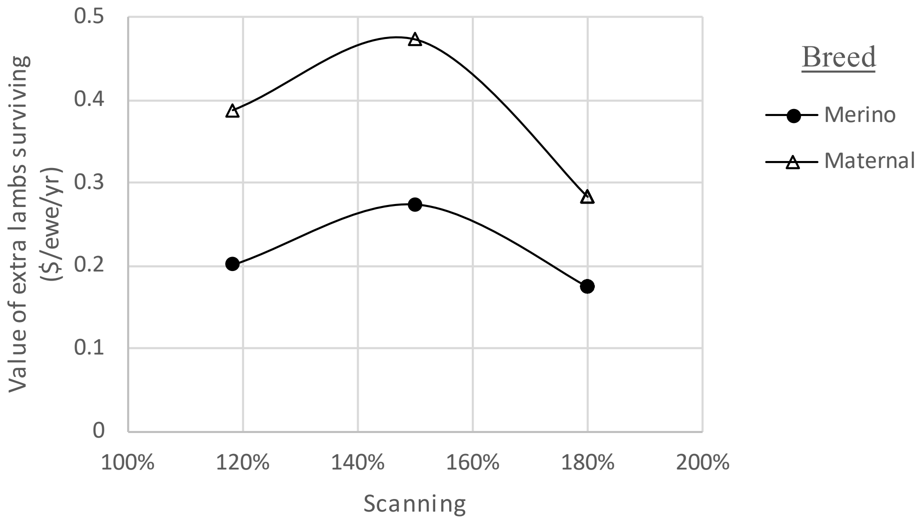

Figure 8.14. Value of extra lambs surviving from reducing relative mob size from 100% to 50% for Merino and maternal ewes with different scanning percentage. The scenario is for a lamb price of $6/kg and with the average lamb survival coefficients.

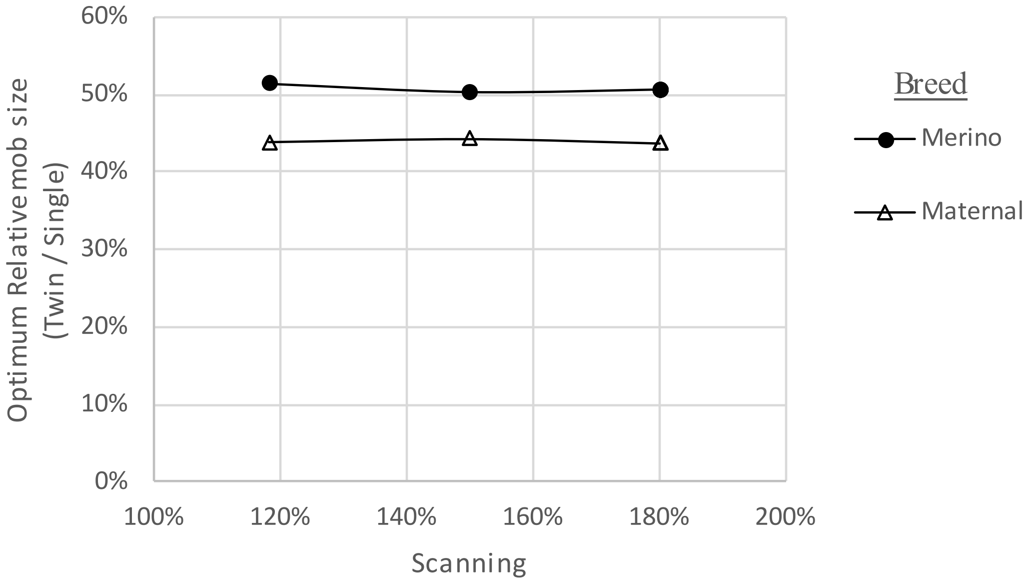

Figure 8.15. Effect of scanning percentage on the optimum relative mob size for Merino and maternal ewes. The scenario is for a lamb price of $6/kg using the average lamb survival coefficients.

8.4. Conclusions

This analysis shows that the range in magnitude of effect of mob size on lamb survival justifies reducing mob size at lambing even if this requires subdividing paddocks.

The optimum mob size is very sensitive to:

- The cost of subdividing the paddocks. Reducing the fencing cost from $3000/km to $600/km reduces the optimum mob size by 40% and removing the cost of providing water reduces the mob size by a further 30%.
- The stocking rate of the ewes in the lambing paddocks. The optimum mob size with a stocking rate at 15 ewes/ha is 35% lower than at 1 ewe/ha.
- The pregnancy status of the ewes. The optimum mob size for twin-bearing ewes is 40-50% of the optimum mob size for single-bearing ewes. Being able to reduce mob size for twin-bearing ewes is a further advantage that can be realised for producers who are scanning and separating twin- from single-bearing ewes. However, the analysis also identified the optimum mob sizes for producers who don’t separate single- and twin-bearing ewes but who can estimate the scanning percentage of their flocks.
- The target ROI and the planning horizon for the money spent on subdivision.

Optimum mob size is also affected by breed and lamb price; however, these have a smaller effect. Producers can also benefit from this research if they don’t wish to invest in subdividing paddocks because the results of the producer surveys showed that survival of single-born lambs is less sensitive to mob size than for twin-born lambs. The optimum allocation of single- and twin-bearing ewes in existing paddocks is for the mob size of twin-bearing ewes to be 40-50% of the mob size of single-bearing ewes. Maternal breeds are on the lower end of the range and Merinos on the upper end. Lamb price and the proportion of singles and twins have little effect on the optimum ratio.

9. Impact on Wool Industry – Now and in 5 years time

This research has demonstrated that lambing ewes in smaller mobs will contribute to improved lamb survival on commercial farms across southern Australia. Data collected from producers suggests this effect is greatest for multiple-bearing ewes which aligns with the industry's highest priority for improving reproductive performance. Implementing reduced mob sizes at lambing may require temporary or permanent fencing to increase paddock availability. Alternatively, the mob size for single-bearing ewes could be increased whilst reducing mob size for multiple-bearing ewes to utilise current lambing paddocks. Managing mob size at lambing is therefore a strategy which can be adopted immediately to increase lamb survival. The 1.1 – 3.5% increase in the survival of twin-born lambs achieved through reducing mob size by 100 twin-bearing ewes will therefore contribute to the industry's target to increase lamb marking rates by 5% over the next 5 years. Preliminary findings from this research have been extended to industry over the past two years through various industry media channels (Beyond the Bale magazine, The Yarn podcast, MLA webinar, MLA Feedback magazine), conferences (BestWool BestLamb 2018, SALC Livestock Advisor Update 2018), field days and rural press.

10. Conclusions and Recommendation

10.1. Conclusions

Lambing ewes in smaller mobs increases the survival of their lambs to marking. In Experiment One, decreasing mob size by 100 twin-bearing ewes increased the survival of their lambs by 1.9%, regardless of Merino or non-Merino breed and ewe stocking rate which ranged between 2 and 12 ewes/ha. In Experiment Two, decreasing mob size by 100 twin-bearing Merino ewes increased the survival of their lambs by 2.5% when ewes lambed at low stocking rates of between 0.3 and 3.8 ewes/ha. The 1.9% to 2.5% increase in twin lamb survival achieved through reducing mob size by 100 twin-bearing ewes is equivalent to increasing ewe condition score at lambing by 0.1 to 0.15.

Analysis of data collected from producers across southern Australia for Experiment Three showed that the survival of lambs born to single- and twin-bearing ewes decreased by 0.35% and 1.15% per additional 100 ewes in the mob at lambing, respectively. The stocking rate of ewes was not found to influence lamb survival, consistent with Experiment One. Reducing the stocking rate of ewes at lambing is therefore unlikely to be associated with significant improvements in lamb survival. The increase in paddock area associated with reducing the stocking rate of lambing ewes is also likely to displace of other sheep on the farm or require them to be managed at higher stocking rates. Lambing ewes in larger paddocks would also be expected to decrease pasture utilisation. Therefore, reducing stocking rate is unlikely to be a practical or efficient strategy for increasing lamb survival.

The relationship between mob size and lamb survival was not influenced by the characteristics of the lambing paddocks in the experiments conducted for this project. Furthermore, the effect of mob size was consistent across breeds. This repeatable effect for Merino and non-Merino ewes managed across a range of sheep producing regions in southern Australia highlights that reducing mob size at lambing can be implemented as a strategy to increase lamb survival across the industry. The relationship between mob size and lamb survival was also independent of ewe condition score at lambing. Therefore, reducing mob size at lambing will contribute to increased survival of lambs above that achieved from adoption of current best practice guidelines for the management of maternal nutrition and resource allocation during pregnancy and lambing.

10.2. Recommendations

Economic analysis has shown that increasing the survival of twin-born lambs is the highest priority for increasing reproductive performance within the Australian sheep industry. This research found that the benefit of reducing mob size at lambing on lamb survival is greater for twin-bearing ewes than single-bearing ewes, regardless of breed. Therefore, to maximise the benefits of reducing mob size on lamb survival, producers must pregnancy scan their ewes for multiples. This is also essential for optimal management and resource allocation for single-, twin- and triplet-bearing mobs at lambing. Hence, the benefit of reducing mob size for ewes which are not pregnancy scanned or managed separately will be counteracted by factors that influence ewe and lamb survival and performance including suboptimal supplementary feeding, the inability to wean lambs early and better performing ewes being in poorer condition at weaning and hence potential carry-over effects on their subsequent joining.

The relationship between mob size and lamb survival was not found to be influenced by FOO in this project. However, variation in the effect of mob size on lamb survival was observed in intensive experimental work conducted in two contrasting seasons. The survival of twin lambs born at a mob size of 55 ewes was 6.2% higher than those lambs born at a mob size of 210 ewes when FOO was below 390 kg DM/ha and ewes were supplementary fed during lambing (Lockwood *et al.* 2018a). If the effect was linear, this is equivalent to a 4% decrease in the survival of twin-born lambs per additional 100 ewes in the mob. In contrast, the survival of single- and twin-born lambs was not observed to differ between mob sizes of 50 and 130 ewes when FOO at lambing exceeded 2400 kg DM/ha (Lockwood *et al.* 2018b). This suggests that the effect of mob size on lamb survival could be influenced by FOO and supplementary feeding. Reducing mob size when ewes lamb earlier in autumn or close to the break of season, or when FOO is limited and ewes are being supplementary fed, may therefore be associated with a greater benefit in lamb survival. Further work is warranted to investigate the magnitude of effect of mob size on lamb survival under varying FOO levels.

Ewes in Experiments One and Two were joined naturally for an average of 35 to 42 days. Given the number of lambs born per day is expected to drive the impact of mob size on lamb survival, reducing the length of lambing could amplify the impact of mob size. Producers who synchronise ewes for artificial insemination or a natural joining or those who pregnancy scan for foetal age and lamb earlies and lates separately may therefore receive additional benefits from reducing mob size at lambing. Hence, the 1.1% to 2.5% increase in survival achieved by reducing mob size by 100 twin-bearing ewes when naturally mated could potentially be doubled when lambing ewes that have been artificially inseminated, synchronised for joining or foetal aged.

11. Key messages

- Reducing mob size at lambing is a management strategy which should be added to existing guidelines for increasing lamb survival. Existing guidelines include;
    - Pregnancy scanning for multiples
    - Managing the nutrition of single- and twin-bearing ewes separately, including assessing condition score plus FOO and pasture quality
    - Access to shelter in lambing paddocks
    - Knowledge of historical lamb marking rates within available lambing paddocks
    - Allocating twin-bearing ewes to the best available paddocks
- The effect of mob size at lambing on lamb survival is greater for twins compared to singles. Reducing mob size at lambing by 100 ewes;
    - Increased the survival of twin-born lambs by 1.1% to 3.5%, regardless of breed, when stocking rate typically ranged from 1.5 to 12.5 ewes/ha
    - Increased the survival of single-born lambs by 0.3% to 1.4%, regardless of breed, when stocking rate typically ranged from 5 to 10 ewes/ha
- The level of return achieved from subdividing paddocks depends on the current mob size. The returns are greater from subdividing larger mobs.
- Greater return on lambing twin-bearing ewes in smaller mobs, including by subdividing paddocks, compared with single-bearing ewes. Therefore, allocate twin-bearing ewes to the smaller paddocks.
- Lamb survival and pasture utilisation both benefit from smaller paddocks and are therefore complementary in decisions about optimum management
- Optimum mob size for twins is approximately half that for singles.
- Temporary fencing is a cost-effective way to reduce mob size, especially if the ewes don't require a water supply in the lambing paddock
- For producers that don't pregnancy scan or only scan wet/dry, the optimum mob size is more similar to the mob size for twin- compared to single-bearing ewes
- Although there are benefits for subdividing non-scanning or wet/dry scanned mobs, in most cases the recommendation is to pregnancy scan and differentially manage single- and twin-bearing ewes. This is because:
    - In most cases it will have a bigger impact on profit
    - It allows the best lambing paddocks to be used for twin-bearing ewes
- If undertaking a fencing program, consider;
    - The impact of paddock size on both mob size and lamb survival as well as pasture utilisation and management.
    - Creating a paddock layout that facilitates subdivision using temporary fences.
- There are several factors that affect optimum mob size and paddock size. The optimum varies with type of fencing used to subdivide paddocks, whether the subdivided paddocks require water, the target ROI, stocking rate of the ewes, breed, lamb price and whether the advantages of improved pasture utilisation in smaller paddocks will be capitalised.

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