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Factors influencing the optimum mob size of ewes at lambing and the economic benefit of lambing ewes in smaller mobs to increase lamb survival across southern Australia

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ABSTRACT

At least 25% of lambs born in Australia die before marking. Research across southern Australia has demonstrated that reducing mob size at lambing by 100 ewes will, on average, increase the survival of single-born lambs by 0.8% and twin-born lambs by 2.2%. In this paper we assessed the economic value of lambing ewes in smaller mobs to improve lamb survival. The analysis considered scenarios for Merino and non-Merino flocks where producers subdivided lambing paddocks using temporary or permanent fencing, or where ewes were reallocated within existing paddocks based on ewe pregnancy status. Optimum mob sizes were most sensitive to the type of fencing used for subdivision, whether ewes were single- or twin-bearing, whether the effect of paddock size on potential stocking rate was included and the target return on investment. Breed, ewe stocking rate, scanning percentage and lamb price also impacted optimum mob size but had a smaller effect. The optimum mob size for twin-bearing Merino and non-Merino ewes was between 34% and 60% that of single-bearing ewes and this was similar for scenarios where paddocks were subdivided or ewes were reallocated within existing paddocks. Permanent subdivision of paddocks also presents an opportunity to increase stocking rate by capitalising on the benefits of improved pasture utilisation in smaller paddocks. The relationship between paddock size and pasture utilisation is not well quantified but it has an important effect on optimum mob and paddock size. The value of reallocating ewes within existing paddocks was greatest at a scanning percentage of 150% as this presents the greatest opportunity to alter mob sizes for single- and twin-bearing ewes. The economic return from adjusting the relative mob size of twin-bearing ewes from 100% to 50% that of single-bearing ewes was up to $0.27/Merino ewe/yr and $0.44/non-Merino ewe/yr with lamb at $6/kg carcass weight. Overall, these analyses demonstrate that reducing mob size at lambing can be a profitable strategy for improving lamb survival depending on the current size of lambing mobs. However, it is difficult to provide generic recommendations to producers for the optimum mob size of ewes and value of paddock subdivision because these are dependent on enterprise-specific factors.

1. Introduction

At least 25% of lambs born in Australia die before marking (Hinch and Brien, 2014; Allworth et al., 2017). Improving lamb survival is a priority for both Merino and non-Merino breeds. The survival of lambs born to Merino ewes is typically 10% lower than that of lambs born to non-Merino ewes despite non-Merino ewes achieving higher scanning percentages (Paganoni et al., 2014; Allworth et al., 2017; Lockwood et al., 2019a). Twin-born lambs are often twice as likely to die than single-born lambs (Hocking Edwards et al., 2011; Oldham et al., 2011). Economic modelling has shown that improving the survival of twin-born lambs is the highest priority for increasing reproductive performance because of the significant scope to improve the survival of twin-born lambs and the high economic value per unit of improvement (Young et al., 2014b). Managing ewe nutrition during pregnancy is vital for optimising the survival of Merino and non-Merino ewes and lambs.

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Table 1
Regression coefficients from four experiments which predict the effect of reducing mob size at lambing by 100 ewes on the survival to marking of single-born and twin-born lambs of Merino and non-Merino breed.

Source	Data	Singles	Twins	Breed/s evaluated
Lockwood et al., 2020 (Experiment one)	National on-farm research sites	–	+1.9%	Merino and non-Merino
Lockwood et al., 2020 (Experiment two)	National on-farm research sites	–	+2.5%	Merino
Hancock et al., 2019 (Experiment three)	Survey data from producers across southern Australia	+0.3%	+1.1%	Merino and non-Merino
Lockwood et al., 2019a (Experiment one)	Survey data from producers in south-eastern Australia	+1.4%	+3.5%	Merino and non-Merino
Average		+0.85%	+2.25%	

The nutritional requirements of single- and twin-bearing ewes are best met by managing them separately from pregnancy scanning (Behrendt et al., 2019; Hocking Edwards et al., 2011, 2019). Differential management after pregnancy scanning also allows resources such as feed and well-sheltered paddocks to be prioritised for twin-bearing ewes (Pollard, 2006; Young et al., 2014, 2016). Despite these advantages only about 30% of producers in Australia pregnancy scan ewes for multiples and differentially manage single- and twin-bearing ewes (Howard and Beattie, 2018). It is estimated that adoption of best practice management and pregnancy scanning for multiples by industry will increase profitability by approximately $1B per year (Young et al., 2014b; Kubeil, 2017).

The allocation of ewes to paddocks for lambing requires consideration of several factors which influence lamb survival. These include pregnancy status, ewe age, the availability of shelter, and the quantity and quality of available feed. Producers could also maintain lambing records for individual paddocks each year so that those which consistently perform better can be prioritised for multiple-bearing ewes. Kleemann et al. (2006) analysed data from 22 flocks in South Australia with mob size ranging between 119 and 499 ewes. They reported a weak quadratic relationship between mob size and lamb survival, with optimum mob sizes of 414 single-bearing ewes and 399 twin-bearing ewes. The authors suggested that larger mobs may reduce predation pressure or the likelihood of ewes moving prematurely from the birth site. In contrast, comprehensive producer and experimental data collected across southern Australia has demonstrated that lambing ewes in smaller mobs will improve lamb survival (Allworth et al., 2017; Hancock et al., 2019; Lockwood et al., 2019a; Lockwood et al., 2020). A linear relationship was observed between mob size and lamb survival where reducing mob size at lambing by 100 ewes increased survival to marking by up to 1.4% for single-born lambs and 3.5% for twin-born lambs of Merino or non-Merino breed, when mob size ranged from about 20–1750 ewes for single-bearing ewes and 10–980 ewes for twin-bearing ewes (Hancock et al., 2019; Lockwood et al., 2019, 2020). However, Lockwood et al. (2019b) observed no difference in lamb survival when single- or twin-bearing Merino ewes lambed in mobs of 50 ewes compared with 130 ewes when feed-on-offer was above 2400 kg DM/ha. In contrast, Lockwood et al. (2019c) found the survival of twin lambs born in mobs of 55 ewes was 6.2% greater than those born in mobs of 210 ewes when feed-on-offer was below 400kg DM/ha at lambing and ewes were supplementary fed via trail feeding. These contrasting results demonstrate that reducing mob size may not always be associated with improvements in lamb survival but suggest that the impact of lambing ewes in smaller mobs on lamb survival could be greater when feed-on-offer is limited at lambing and ewes are supplementary fed.

The impact of ewe stocking rate at lambing on lamb survival is conflicting. Data collected from producers in south-east Australia indicated that increasing stocking rate by 1 ewe/ha would decrease the survival of lambs to marking by 0.7% (Lockwood et al., 2019a). However, other studies found that there was no effect (Earle et al., 2017; Hancock et al., 2019; Lockwood et al., 2020). Reducing stocking rate at lambing is therefore unlikely to significantly improve lamb survival but reducing mob size at lambing is an additional strategy which producers can use to increase marking rates. This paper tests the hypotheses that mob size at lambing affects farm profitability and that there is an optimum mob size for lambing ewes. Furthermore, that there is an optimum ratio of allocating single- and twin-bearing ewes to existing paddocks. An initial report of the analysis described in this paper was published by Hancock et al. (2019).

2. Materials and methods

The analysis reported in this paper evaluated the cost of subdividing paddocks compared with the benefit of reducing mob size to improve lamb survival. It also examined the effect of reducing paddock size on pasture utilisation and potential stocking rate. The response in lamb survival related to varying mob size was based on findings from several studies conducted across southern Australia which quantified the effect of the mob size and stocking rate of ewes at lambing on the survival of their lambs to marking. The analyses were based on the average change in lamb survival from these studies, which found the relationship between mob size and lamb survival to be linear (Table 1). There was no evidence from the studies that the response to mob size at lambing was different between Merinos and non-Merinos.

2.1. Value of an extra lamb surviving

A whole-farm analysis using the MIDAS model (Young et al., 2014b) quantified the increase in income achieved by improving the survival of Merino and non-Merino lambs. For this analysis the value of the extra lambs surviving was evaluated at three meat price scenarios (Table 2). Young et al. (2014b) showed that wool price did not alter the value of an extra lamb, so wool price was not included in this analysis.

2.2. Cost of subdivision

The cost of subdividing paddocks could vary greatly depending on the individual farm layout including the shape of paddocks, location of watering points and local fencing conditions. The cost also depends on whether permanent or temporary fencing is used and whether watering points are required in the new paddocks. Costs could also vary depending on the cost of labour or contractors if they are employed. In this analysis it was assumed that existing paddocks were square with a watering point in the corner of the paddock. Square paddocks with water in the corner are the most expensive to subdivide as they require the longest dividing fence and most pipe for supply of water to a single trough. Hence, the values calculated for the profitability of subdividing

Table 2
Value of an extra single-born or twin-born lamb surviving at three meat prices for self-replacing Merino and non-Merino flocks. Source: Young et al. (2014b) & Young unpublished data.

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

Table 3
Cost estimates for materials and labour used to subdivide and maintain paddocks.

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

Table 4
Gross margin ($/DSE) and value of stock ($/DSE) of the Merino and non-Merino flocks for the range of lamb meat prices ($/kg carcass weight) evaluated.

Lamb price	Gross margin		Value of stock	
	Merino	Non-Merino	Merino	Non-Merino
	$/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

paddocks will be a conservative estimate and optimum mob size will be over-estimated.

The analysis quantified the costs of subdividing paddocks associated with permanent or temporary fencing materials, labour and provision of water via pipe and a trough. Permanent fencing was assumed to be pre-fabricated netting with galvanised posts, and the temporary electric fencing was using poly-wire electric fence wire with plastic 'tread-in' posts (Table 3). It was assumed that pipe was required to get halfway across the paddock to the newly installed fence that was down the middle of the paddock. The life of the fence and watering points were assumed to be 15 years. The size of the paddock was calculated from the mob size and stocking rate of the ewes at lambing and their dry-sheep-equivalent (DSE) rating. Merino ewes were rated at 1.0 DSE/hd for dry ewes, 1.5 DSE/hd for single-bearing ewes and 1.8 DSE/hd for twin-bearing ewes. Non-Merino ewes were rated at 1.1 DSE/hd for dry ewes, 1.6 DSE/hd for single-bearing ewes and 1.9 DSE/hd for twin-bearing ewes.

A potential cost that has not been included in the analysis is the logistics associated with managing the extra mobs of ewes and lambs. Depending on the farm layout there may be extra time required for mustering ewes when allocating to paddocks for lambing and at marking, and this has not been included.

2.3. Stocking rate and pasture utilisation

There is little information available from which to quantify the impact of subdividing paddocks on pasture utilisation and potential carrying capacity. Our approach was based on the results of Saul and

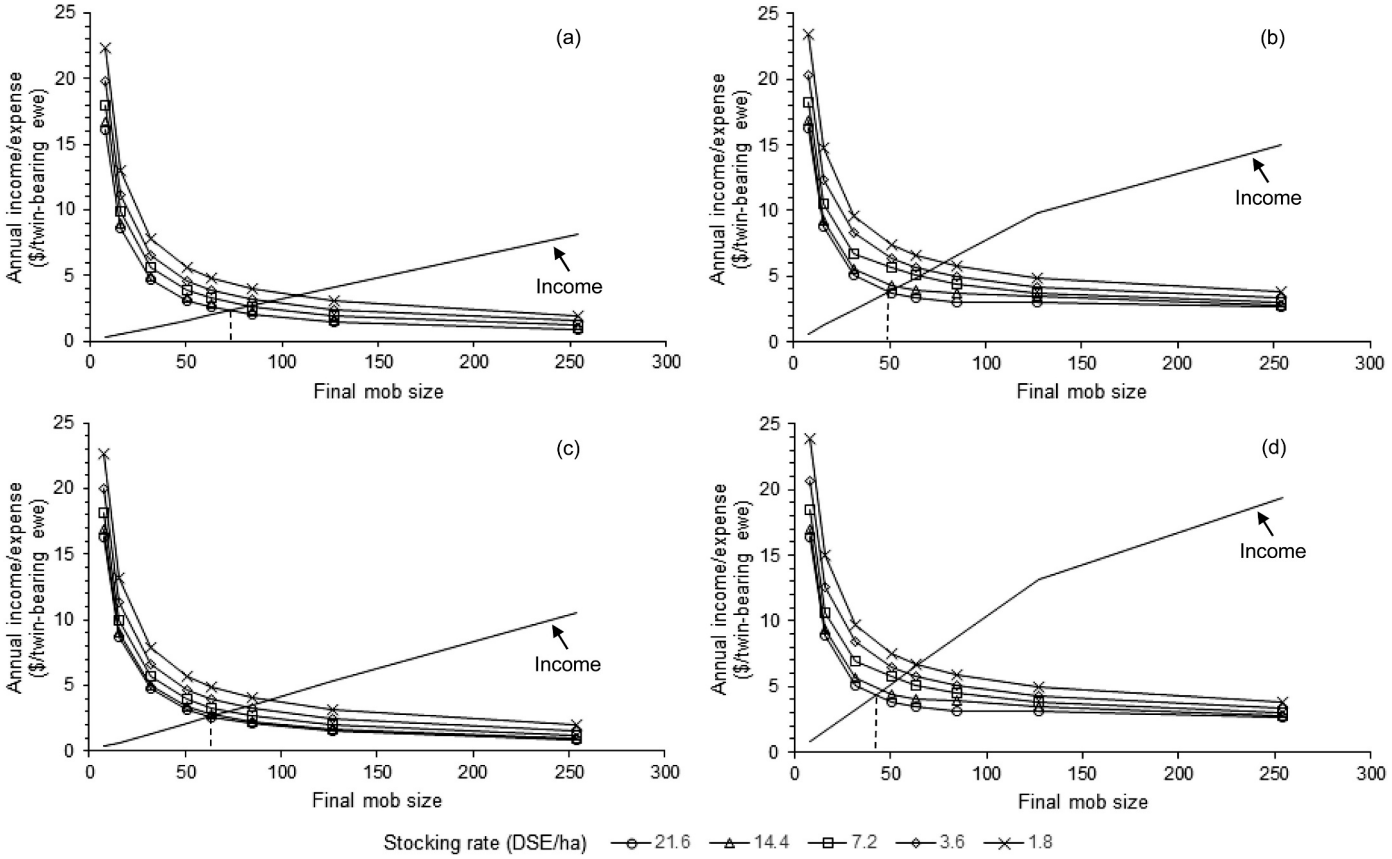

Fig. 1. Increase in income from improved survival of twin-born lambs and the annual equivalent increase in expenses (x, ◊, □, Δ and ○) associated with halving the mob size of twin-bearing ewes to the 'final mob size' where the benefits of pasture utilisation are (a) excluded or (b) included for Merinos and (c) excluded or (d) included for non-Merinos at varying stocking rates. The scenario is for permanent subdivision of paddocks with lamb meat at $6/kg and a target return on investment of 5%.

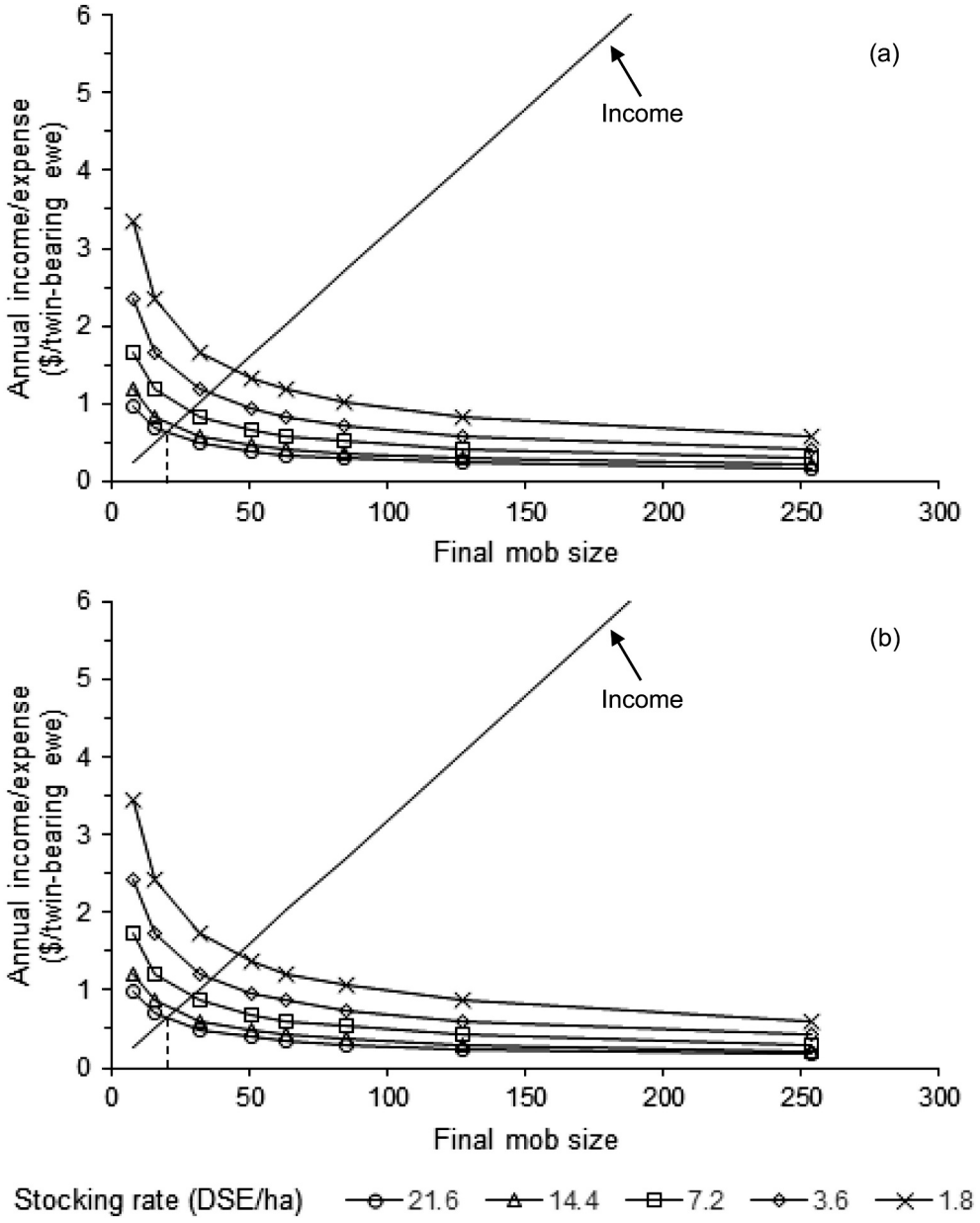

Fig. 2. Increase in income from improved survival of twin-born lambs and the annual equivalent increase in expenses (x, ◊, □, Δ and ○) associated with temporary subdivision of paddocks without supplying a watering point where the mob size of twin-bearing ewes is halved to the 'final mob size' for (a) Merinos and (b) non-Merinos at varying stocking rates. The scenario is for lamb meat at $6/kg and a target return on investment of 5%.

Kearney (2002). They predicted that paddocks less than 20 ha could carry 2.75 DSE/ha more than paddocks greater than 20 ha and fitted the following relationship;

$$\text{Potential stocking rate} = -11.05 + 2.75 * (\text{Paddock size} < 20\ \text{ha}) + 3.41 * \text{Length of growing season} + 0.178 * \text{Olsen } PO_4$$

This relationship includes a factor for whether the paddock is greater or less 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 coefficient of 2.75 reported by Saul and Kearney (2002) 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 will increase by 0.14 DSE/ha for each 1 ha reduction in paddock size.
2. For paddock size below 30 ha, it was assumed that the change in stocking rate was linear with a slope of −0.14 DSE/ha. For paddock size above 30 ha, it was assumed that the change in stocking rate is based on the logarithm of the paddock size such that halving paddock size will increase stocking rate by 1.74 DSE/ha. This value generates an equivalent change in stocking rate when paddock size changes from 30 ha down to 10 ha, but potential stocking rate is less sensitive to paddock size for paddocks greater than 30 ha.
3. The change in stocking rate calculated in steps 1 and 2 was scaled based on the current stocking rate relative to the stocking rate in the south-west Victorian study of Saul and Kearney (2002). This scaling was based on an expectation that paddock size would have less effect on absolute stocking rate in an environment with a low potential carrying capacity, even though this was not the form of the equation fitted by Saul and Kearney (2002).

Table 5
Optimum mob sizes for Merino ewes for scenarios where mobs are subdivided using permanent or temporary fencing, with lamb price at $6/kg and a return on investment of 5%. Optimum mob sizes reflect the breakeven mob size, where the increase in annual income is equal to the sum of the maintenance costs and the annuity of the capital costs. The mob sizes represent the lower value for the optimum range in mob size.

Stocking rate (DSE/ha)	Subdivision type	Pasture utilisation benefits excluded					Pasture utilisation benefits included				
		Single	Twin	Scanned wet/ dry (118%)	Not scanned (118%)	Not scanned (150%)	Single	Twin	Scanned wet/ dry (118%)	Not scanned (118%)	Not scanned (150%)
1.8	Permanent	247	108	166	170	137	62	43	58	54	49
3.6	Permanent	209	94	142	146	119	48	35	48	45	41
7.2	Permanent	181	83	124	126	106	51	38	51	47	43
7.2	Temporary, with water	119	54	81	83	69	–	–	–	–	–
7.2	Temporary, without water	67	28	43	45	36	–	–	–	–	–
14.4	Permanent	164	76	114	116	97	65	46	62	58	52
14.4	Temporary, with water	106	50	74	75	62	–	–	–	–	–
14.4	Temporary, without water	53	23	34	35	29	–	–	–	–	–

The benefit of increased stocking rate was calculated from the flock gross margin minus the cost of the animals retained or purchased to increase stocking rate. The stock value ($/DSE) was the average opening value of stock divided by the opening number of DSE in the gross margin (Table 4).

2.4. The analyses

Two analyses were conducted; the first to determine the optimum mob size for scenarios where producers subdivide paddocks and the second for scenarios where producers adjust the mob size for single- and twin-bearing ewes within their existing paddocks.

2.4.1. Optimum mob size

An investment analysis calculated the benefits and costs of halving paddock size. Subdividing existing paddocks is the relevant decision for producers because this will generate a much greater return on investment than removing existing fences and refencing the whole farm. As an individual paddock analysis, it is independent of region and initial flock size but includes stocking rate and mob size.

In the investment analysis framework, the annual income, associated with increased lamb survival and stocking rate, was compared with the annual maintenance costs plus the annuity of the up-front capital costs. The capital costs are associated with paddock subdivision and retaining or purchasing extra stock. The capital cost was converted to an equivalent annual value (annuity $/year) using a discount rate of 5%. The change in profit has been presented per ewe that was allocated to an altered paddock. The breakeven mob size was calculated as the mob size which results from subdividing a paddock such that the increase in annual income is equal to the sum of the annual maintenance costs and the annuity of the capital costs. This implies that the breakeven mob size is providing a return-on-investment (ROI) equivalent to the discount rate used to calculate the annuity. This approach allows optimum mob size and ROI to be derived.

By necessity, the optimum mob size is a range rather than a specific mob size. The shape of the paddock will limit options for subdivision. Nevertheless, there will be multiple possible paddock sizes and therefore the optimum must be a range. Subdivision is not profitable if the current paddock size is within this optimum range. However, subdividing the paddock would increase profit if the paddock size is larger than the upper end of the optimum range. To simplify the presentation of the results, the values presented for the optimum mob size represent the lower value of the optimum range. Thus, subdivision is not profitable if it generates a mob size less than the analysis result.

2.4.2. Adjusting the mob size of single- and twin-bearing ewes within current paddocks

This analysis was carried out as a single-year analysis because there are no capital costs associated with paddock subdivision. The change in survival of single- and twin-born lambs was calculated based on reducing mob size for twin-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 equal-sized paddocks that are used for lambing ewes. The number of paddocks was set to achieve an average mob size of 150 ewes per paddock and the proportion of the paddocks used for single- and twin-bearing ewes was varied, which altered the mob size. This was carried out for flocks with varying scanning percentages and hence a varying proportion of single- and twin-bearing ewes.

3. Results

Subdividing a paddock and having a smaller mob size at lambing increases income. The increase in income is linear with increasing final mob size for scenarios that only consider the value of improved lamb survival (Fig. 1a and c). A larger final mob size implies that subdivision leads to a greater reduction in mob size and a larger increase in lamb survival per ewe managed. The response is curvilinear if the impact of reducing paddock size on potential stocking rate is also included because of the logarithmic function underpinning the relationship between potential stocking rate and paddock size (Fig. 1b and d). The slope of the line is greater for the non-Merino flock because the value of an extra lamb surviving is greater (Fig. 1a cf. Fig. 1c). Subdividing a large paddock is more expensive but the cost of the fencing material and pipe only increases with the square root of the paddock area. Therefore, the cost of the subdivision per ewe managed at a given stocking rate reduces for large mobs. The cost of subdivision per ewe is lower when stocking rate is increased because for a given mob size a higher stocking rate implies a smaller paddock and therefore less fencing and piping is required (Figs. 1 and 2).

The cost of subdivision will be greater than the benefit gained and hence the ROI will be less than 5% if subdividing a paddock results in mobs smaller than the breakeven mob size. However, if the resulting mobs are larger than the breakeven mob size then the cost of subdivision will be less than the benefit achieved and the ROI will be greater than 5%. Optimum mob size was lower for non-Merinos compared with Merinos because of the increased income per ewe achieved from subdivision (Fig. 1a cf. Fig. 1c). Optimum mob size was also reduced by including the impact of paddock size on potential stocking rate (Fig. 1a cf. Fig. 1b), reducing the cost of subdivision by managing ewes at a higher stocking rate (Fig. 1a) or using temporary fencing (Fig. 1a/c cf.

Table 6
Optimum mob sizes for non-Merino ewes for scenarios where mobs are subdivided using permanent or temporary fencing, with lamb price at $6/kg and a return on investment of 5%. Optimum mob sizes reflect the breakeven mob size, where the increase in annual income is equal to the sum of the maintenance costs and the annuity of the capital costs. The mob sizes represent the lower value for the optimum range in mob size.

Stocking rate (DSE/ha)	Subdivision type	Pasture utilisation benefits excluded					Pasture utilisation benefits included				
		Single	Twin	Scanned Wet/dry (150%)	Not scanned (150%)	Not scanned (180%)	Single	Twin	Scanned Wet/dry (150%)	Not scanned (150%)	Not scanned (180%)
1.8	Permanent	255	93	119	120	104	44	31	37	36	32
3.6	Permanent	216	81	105	106	90	39	28	31	30	29
7.2	Permanent	185	72	93	94	80	42	31	37	36	33
7.2	Temporary, with water	122	48	60	61	52	–	–	–	–	–
7.2	Temporary, without water	69	25	31	32	27	–	–	–	–	–
14.4	Permanent	168	66	84	85	74	55	39	46	45	41
14.4	Temporary, with water	109	44	55	55	48	–	–	–	–	–
14.4	Temporary, without water	55	19	25	26	22	–	–	–	–	–
21.6	Permanent	160	63	81	81	71	64	42	50	49	45
21.6	Temporary, with water	103	42	52	53	46	–	–	–	–	–
21.6	Temporary, without water	48	17	22	23	19	–	–	–	–	–

Fig. 2a/b).

3.1. Factors influencing optimum mob size

Optimum mob sizes were most sensitive to the type of fencing used and thus the cost of subdivision, whether ewes were single- or twin-bearing, whether the impacts of pasture utilisation were included and the target return on investment. Optimum mob sizes were also influenced by, but were less sensitive to, breed, lamb price, scanning percentage and stocking rate. The impact of halving mob size on income and costs for scenarios where paddocks were subdivided with permanent or temporary fencing are shown in Figs. 1 and 2. The optimum mob sizes for Merino and non-Merino scenarios are presented in Tables 5 and 6.

3.1.1. Breed and pregnancy status

The optimum mob size for single-bearing ewes was similar for Merino and non-Merino ewes that are run at the same stocking rate (Tables 5 and 6). In contrast, the optimum mob size for twin-bearing non-Merino ewes was approximately 15% smaller than that for twin-bearing Merino ewes when run at the same stocking rate (Tables 5 and 6). This is because the value of a twin-born Merino lamb is lower than the value of twin-born non-Merino lamb (Table 2). The optimum mob size for twin-bearing ewes was smaller than for single-bearing ewes based on the greater sensitivity of twin lamb survival to mob size at lambing. The reduction was approximately 55% for Merino ewes and 62% for non-Merino ewes. The optimum mob size for ewes that are not pregnancy scanned or that are only scanned as pregnant was calculated as approximated by the optimum mob size for single- and twin-bearing ewes weighted by the proportion of lambs born as singles or twins, rather than weighted by the number of single- and twin-bearing ewes (Tables 5 and 6). This is because lamb survival is the source of the benefits and this determines the optimum mob size. The optimum mob size for unscanned Merino ewes that would have achieved a scanning percentage of 150% was on average 17.5% smaller than that for unscanned ewes that would scan 118% (Table 5). Similarly, the optimum mob size was on average 14% smaller for unscanned non-Merino ewes that would have achieved a scanning percentage of 180% compared with those that would have scanned 150% (Table 6).

3.1.2. Lamb price

Higher lamb prices also reduce the optimum mob size. Increasing lamb price by $1/kg within a range of $5–7/kg decreased the optimum mob size by approximately 11–14% for paddocks that are permanently or temporarily subdivided without the effects of pasture utilisation included or by about 16% when the impacts of pasture utilisation are included. These effects were consistent for single- and twin-bearing ewes and are entirely related to the extra income associated with improved lamb survival.

3.1.3. Fencing and water

Optimum mob sizes were smaller when paddocks were subdivided with temporary fencing compared with permanent fencing because of the reduced cost of subdivision. Reducing the cost of fencing from $3000/km to $600/km reduced the optimum mob size by approximately 35%. Removing the cost of providing water reduced the mob size by about a further 45% to 55% (Tables 5 and 6).

3.1.4. Pasture utilisation and potential stocking rate

Optimum mob sizes were approximately 60% smaller where the impacts of pasture utilisation were included compared with when they were excluded and the effect was greater at lower stocking rates compared with higher stocking rates (Tables 5 and 6) because the increase in potential stocking rate is greater if the initial paddock size is larger and low stocking rate means initial paddock size is larger. Where the impacts of pasture utilisation were included there was a slight increase

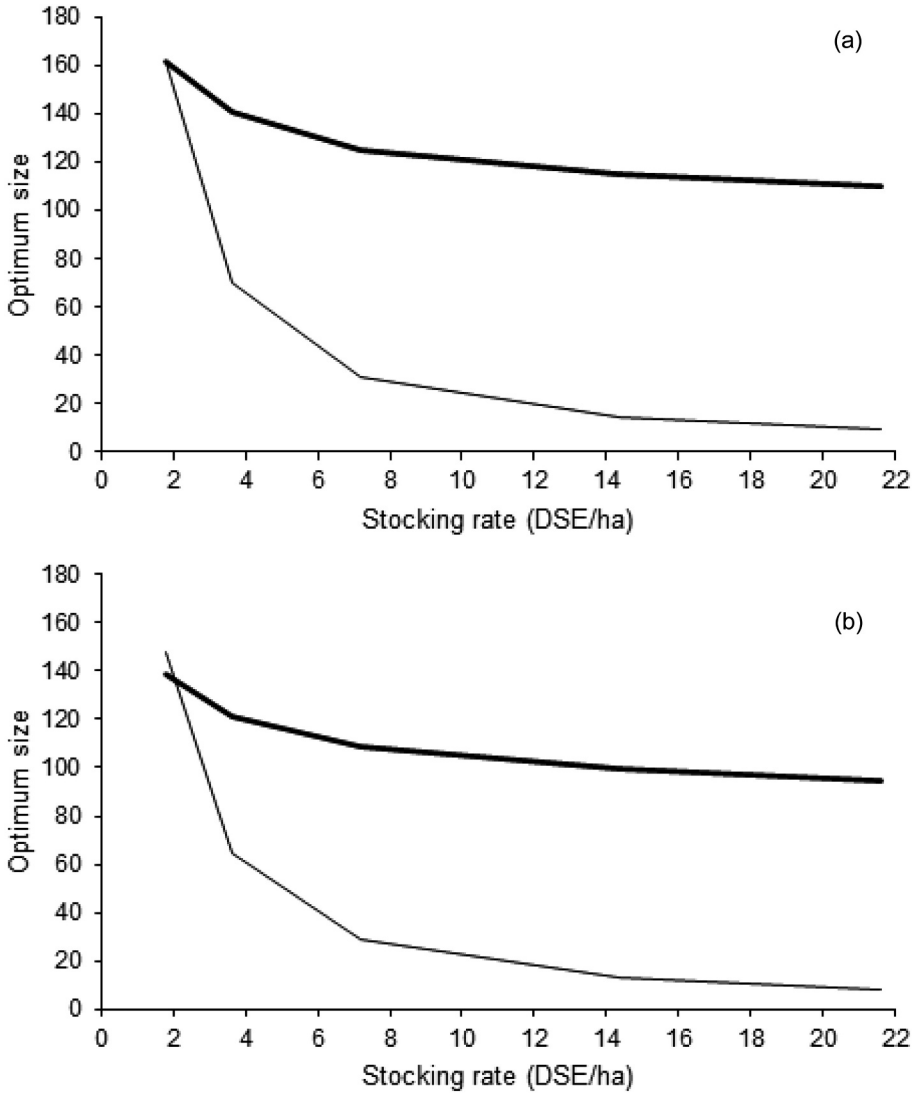

Fig. 3. Optimum mob size (bold line) and paddock size (ha; thin line) for twin-bearing (a) Merino and (b) non-Merino ewes where paddocks are subdivided using permanent fencing. The scenario is with the benefits of pasture utilisation excluded, lamb meat at $6/kg and a target return on investment of 5%.

in optimum mob size when stocking rate was increased, however, there was still a reduction in optimum paddock size.

3.1.5. Optimum paddock size

Optimum paddock size equals optimum mob size (in DSE) divided by the stocking rate and therefore reduced more with increasing stocking rate than the optimum mob size (Fig. 3). The optimum paddock size for twin-bearing ewes varied from 108 ha at 1.8 DSE/ha down to 6 ha at 21.6 DSE/ha for Merino ewes and 98 ha down to 5.5 ha for non-Merino ewes.

3.1.6. Target return on investment

The optimum mob size was derived such that a 5% return on investment will be achieved from subdividing a paddock to reduce the mob size from double the optimum to the optimum. Optimum mob sizes were larger when targeting a higher ROI because a greater increase in income is required; and subdividing a larger mob is associated with a greater reduction in lamb mortality (see Fig. 4). A scalar for mob size was calculated (Table 7) that approximates the optimum mob size at a range of ROI up to 50% compared to the optimum mob size calculated with a ROI of 5% (from Tables 5 and 6). This scalar can be used to calculate the target breakeven mob size to generate a specified ROI by multiplying the breakeven mob size at a 5% ROI with the scalar for the target return. A scalar can also be generated to estimate the actual ROI by dividing the final mob size achieved from subdivision by the breakeven mob size from Tables 5 or 6. If the current mob size is 20% greater than double the optimum then the return on investment from subdividing would be 10%. If current mob size is 60% greater then the return would be 20% and if the current mob size is 2.5 times double the optimum then the return on investment would be 50%.

3.2. Allocation of single- and twin-bearing ewes within existing paddocks

The optimum relative mob size for twin-bearing ewes was approximately 50% and 43% that of single-bearing ewes for Merinos and non-Merinos. This is similar to the relative mob size if paddocks are subdivided. The value of adjusting the relative mob size of single- and twin-bearing ewes depends on the scanning percentage of the flock. The value was greatest if the scanning percentage is approximately 150%, which equates to half of the ewes bearing singles and half bearing twins (Fig. 5). At this scanning percentage, the annual return from adjusting relative mob size to improve lamb survival was $0.27/Merino ewe and $0.44/non-Merino ewe.

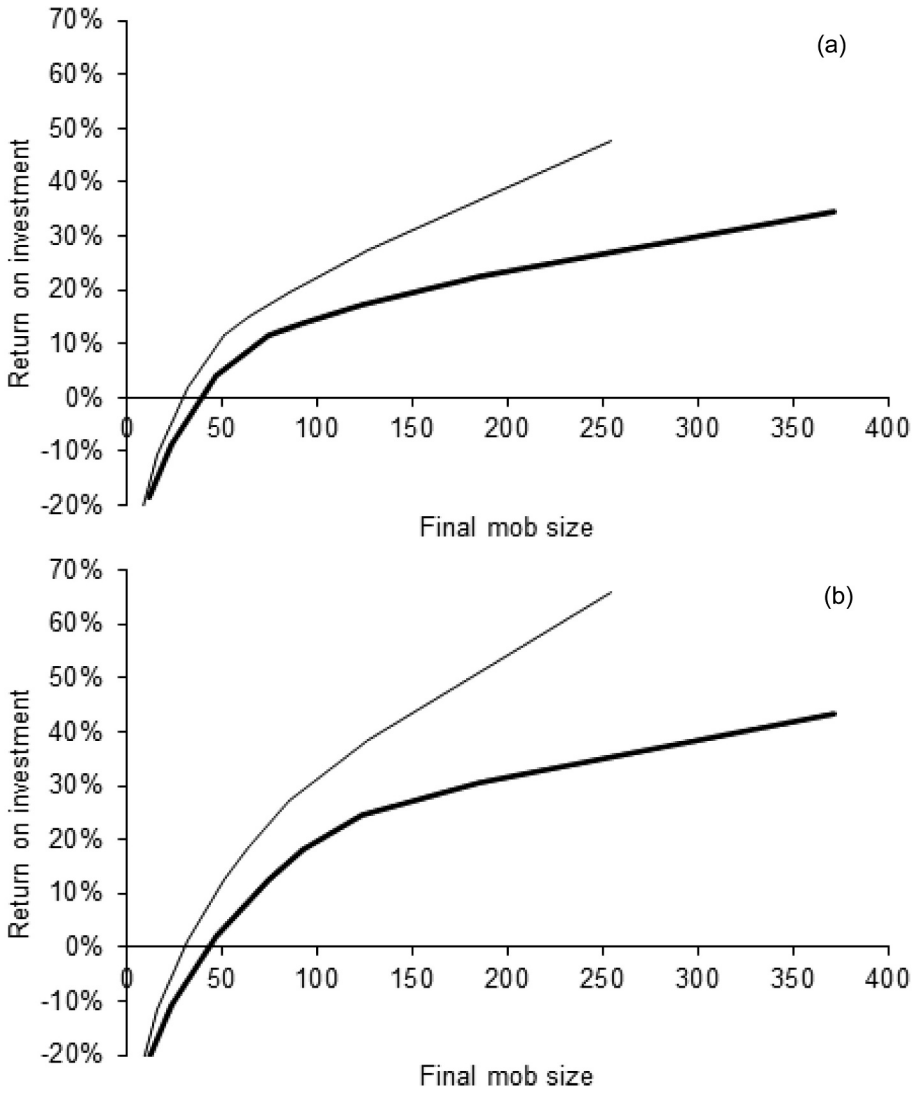

Fig. 4. Expected return on investment from halving mob size to the 'final mob size' when subdividing a paddock using permanent fencing and capturing the benefits of increased pasture utilisation for single-bearing ewes (thick line) and twin-bearing ewes (thin line) of (a) Merino and (b) non-Merino breed. The scenario is for Merino ewes stocked at 7.2 DSE/ha, non-Merino ewes stocked at 14.4 DSE/ha and lamb meat at $6/kg.

Table 7
Scalars for the optimum mob size for ewes at lambing when targeting return on investment of between 5% and 50%.

Target return on investment	Scalar
5%	1.0
10%	1.2
20%	1.6
50%	2.5

4. Discussion

The analysis showed that both income and costs were increased by subdividing paddocks. Our hypothesis was supported because the income response per ewe from further subdivision reduced whereas the cost increased and therefore there is an optimum mob size at lambing that maximises profit. Furthermore, the optimum mob size for twin-bearing ewes was approximately half that of single-bearing ewes, regardless of whether paddocks were subdivided or ewes were reallocated within existing paddocks. Hence, there was an optimum ratio for mob size when allocating single- and twin-bearing ewes to existing paddocks. When subdividing paddocks, the optimum mob sizes were very sensitive to the type of fencing used and thus the cost of subdivision, whether ewes were single- or twin-bearing, whether the effect of paddock size on potential stocking rate was included and the target return on investment. Breed, the stocking rate of ewes, scanning percentage and lamb price also impacted optimum mob size but they had a smaller effect. It is difficult to provide generic recommendations to producers for the optimum mob size of ewes at lambing because these factors are enterprise-specific. A decision support tool that accounts for enterprise-specific data would therefore facilitate implementation of these findings by producers.

Producers in southern Australia who pregnancy scan for multiples typically lamb Merinos in mobs of 270–300 single-bearing ewes and 120–200 twin-bearing ewes (Hancock et al., 2019; Lockwood et al., 2019a). Non-Merino ewes are often lambed in slightly smaller mobs, averaging 200–230 single-bearing ewes and 130–165 twin-bearing ewes across southern Australia (Hancock et al., 2019; Lockwood et al., 2019a). Comparing these typical mob sizes with the expected ROI for a Merino and non-Merino flock at 7.2 and 14.4 DSE/ha indicates that subdividing the average twin-bearing mob into two mobs for the typical producer will generate a ROI of 25% to 40% if using permanent fencing and capturing the gain in potential stocking rate, and between 4% and 8% if not capturing the gains in potential stocking rate. Utilising

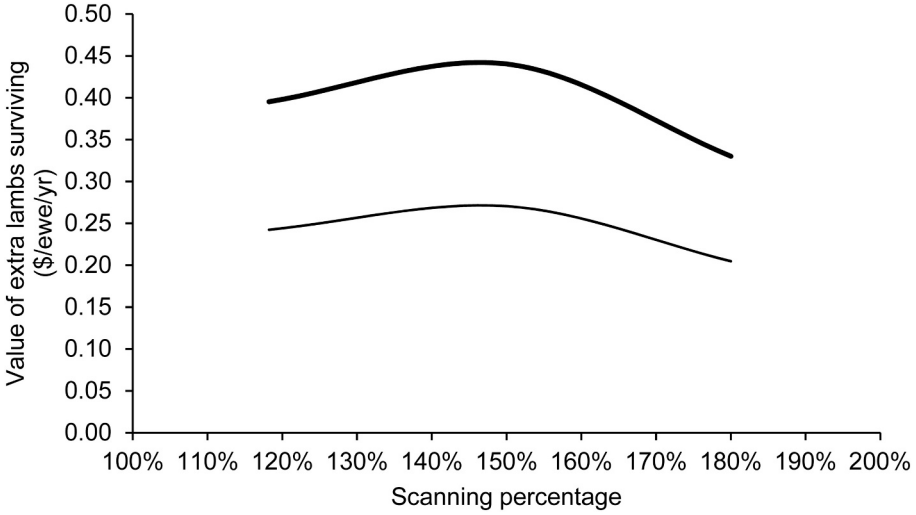

Fig. 5. The effect of scanning percentage on the value of extra lambs surviving when the relative mob size for twin-bearing ewes of Merino (thin line) and non-Merino breed (bold line) is reduced from 100% to 50% that of single-bearing ewes. The scenario is for a lamb price of $6/kg.

temporary fencing has an ROI of 17% to 22% if water is required. A much higher ROI is achieved if water is not required and the typical producer would generate a ROI of 60% to 90%. Furthermore, at least 25% of producers lamb ewes at mob sizes above these average values (Hancock et al., 2019; Lockwood et al., 2019a) and would achieve a higher ROI. Hence, producers should prioritise splitting up larger mobs to increase the ROI of subdividing paddocks.

Producers can profitably subdivide paddocks providing that splitting up their current mobs would not result in mobs smaller than the breakeven mob size for their relevant scenario. The return on investment from subdividing is greater for those producers currently lambing ewes in larger mobs. The results showed that optimum mob sizes were small for some scenarios, particularly where paddocks were temporarily subdivided and ewes were grazed at high stocking rates or with paddocks that were permanently subdivided and the benefits of improved pasture utilisation were included. However, producers need to consider the practicality of managing the extra mobs before embarking on paddock subdivision.

Some producers may consider paddock subdivision and lambing ewes in smaller mobs a practical challenge. Reasons may include limited labour availability, limited capital resources, small paddocks being impractical for other uses on-farm or the features of existing paddocks make them challenging to subdivide. Temporary fencing of paddocks offers flexibility by presenting the opportunity to maintain larger paddocks for cropping or grazing larger mobs during the remainder of the year and therefore may be a more desirable option for some producers to achieve smaller mob sizes at lambing. Paddock subdivision will require producers to consider features of the paddock which impact management and lamb survival when deciding which paddocks to subdivide and where the subdividing fence will be located. This includes the resulting paddock shape, access to water, availability of shelter, pasture quality, and topography or aspect and thus the risk of exposure to adverse weather. Paddocks that will be temporarily subdivided without supplying water must also have adequate available green feed to supply ewes with water via grazing and/or access to natural water sources. Paddock layouts which enable shorter subdividing fences will reduce the cost of subdivision and increase profitability. Costs will also be reduced if the paddocks are able to share a watering point or the distance between watering points is reduced. The analysis reported in this paper was based on subdividing square paddocks by splitting them in half. This is a high cost subdivision and therefore will return a lower ROI than most other paddock shapes. Alternative paddock shapes may be best subdivided with multiple fences to optimise the reduction in mob size and ROI. These factors highlight the complex decisions producers are faced with when deciding on which paddocks are best for lambing and subdivision.

Smaller mobs and paddocks should be prioritised for twin-bearing ewes as the survival of twin-born lambs is more sensitive to mob size than single-born lambs. Adjusting the relative mob size of single- and twin-bearing ewes within existing paddocks to improve lamb survival is only an option where ewes have been pregnancy scanned for multiples. Hence, this option currently applies to about a third of Australian producers (Kubeil, 2017; Howard and Beattie, 2018). Reallocating ewes within existing paddocks by increasing mob size for single-bearing ewes and decreasing mob size for twin-bearing ewes requires no capital investment and is therefore a strategy that can be implemented immediately. The economic gains from reallocating ewes within existing paddocks are generally much lower when compared with those achieved from paddock subdivision. Producers achieving pregnancy scanning results of less than or more than 150% will receive diminished returns from reallocating ewes within existing paddocks because there is reduced capacity to adjust the relative mob size.

The values calculated in this analysis are based on the expected increase in lamb survival over a number of years. However, reducing mob size may not always be associated with improvements in lamb survival as found by Lockwood et al. (2019b) when pasture availability at lambing was high. Therefore, the profitability of reallocation of ewes within existing paddocks could vary between years depending on the improvement in lamb survival achieved. The variable nature of the response between years is less important for the decision to subdivide paddocks because the investment decision is long-term.

5. Conclusion

This analysis has demonstrated that there is an optimum mob size for ewes at lambing. Survey results indicate that most producers could profitably subdivide paddocks to lamb ewes in smaller mobs and improve lamb survival. Pregnancy scanning ewes for multiples means that producers can prioritise smaller mobs and paddocks for twin-bearing ewes to maximise improvements in lamb survival and profitability. A large proportion of Australian sheep producers do not differentiate single- and twin-bearing ewes, so there may be scope to further increase profitability in these enterprises. Selection and subdivision of lambing paddocks by producers requires consideration of several factors which influence lamb survival. Furthermore, producers must consider factors influencing the profitability of paddock subdivision. Incorporation of these factors into a management tool could aid decisions by producers to optimise paddock subdivision and lamb survival for a whole-farm

scenario. The impact of paddock size on pasture utilisation and potential stocking rate is an important driver for these results and requires more research.

Declaration of Competing Interest

None.

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