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Mating weight and condition score are both good predictors of lambing potential for young Merino and Border Leicester Merino ewes across different environments and years in Australia

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ABSTRACT

Context. Increasing mating weight or condition score increases the lambing potential of ewes (fetuses scanned per 100 ewes joined). **Aim.** We hypothesised that in some years, condition score would contribute an additional effect to mating weight on lambing potential. **Methods.** Border Leicester Merino and Merino ewes were mated naturally to Merino or Terminal rams between 2008 and 2013 at eight linked sites across Australia. Border Leicester Merino ewes were mated in their first year while Merino ewes were not mated until their second year. All ewes were mated for a second time as 2 year olds (Border Leicester Merinos) or 3 year olds (Merino). A total of 4270 Border Leicester Merino and 5788 Merino ewes were weighed and condition scored at mating and scanned for pregnancy. **Key results.** Lambing potential increased by 3.1% per 1 kg increase in mating weight, compared to 1.3% for 1 and 2 year old Border Leicester Merinos respectively, and by 2.1% compared to 1.4% for 2 and 3 year old Merinos respectively ($P < 0.05$). Lambing potential increased by 27% compared to 13% per increase in condition score for 1 and 2 year old Border Leicester Merinos respectively, and by 29% compared to 25% for for 2 and 3 year old Merinos respectively ($P < 0.05$). All relationships were linear. When both mating weight and condition score were fitted together, mating condition score explained additional variation to weight in one instance of all the 160 possible breed ($n = 2$) × age ($n = 2$) × site ($n = 8$) × mating year ($n = 5$) combinations. **Conclusions.** Mating weight and condition score increased the lambing potential of ewes linearly with differences due to ewe age, year and possibly ewe breed. Mating condition score rarely explained additional variation in lambing potential to weight in young Merino or Border Leicester Merino ewes. **Implications.** If ewes are weighed at mating then condition scoring is of minimal extra benefit to predict lambing potential. Achieving the heaviest possible mating weights or highest condition score maximises the lambing potential of ewes in their first two mating years.

Keywords: condition score, liveweight, management, mating, Merino, reproduction, reproductive rate, sheep breeding programs.

Introduction

Increasing liveweight or condition score at mating has positive effects on the subsequent reproductive performance of ewes and this is well recognised in Australia (Killeen 1967; Cumming *et al.* 1975; Kelly *et al.* 1983; Kleeman and Walker 2005; Ferguson *et al.* 2011) and internationally (Coop 1962; Adalsteinsson 1979; Gonzalez *et al.* 1997; Esmailizadeh *et al.* 2009; Kenyon *et al.* 2014; Corner-Thomas *et al.* 2015). Condition score is a subjective assessment made by physical palpation of the muscle and fat on and around the backbone of the sheep (Russel *et al.* 1969). Liveweight, alternatively, is an objective measure of both skeletal size and condition (muscle and fat tissue). Both measurements are indicative of muscle and fat reserves and, not surprisingly, are correlated (reviewed by Kenyon et al. 2014). The objective nature of liveweight and its positive correlation with muscle and fat make it a reliable indicator of the reproductive performance of ewes, however liveweight can be limited for comparing different sized sheep breeds where significant differences exist in the total weight of muscle, fat and bone (McClelland et al. 1976). Condition score offers additional information about fat and muscle reserves that are independent of body size, but that are relevant to stage of growth and maturity (Black 1974; Butterfield 1988) as well as potentially indicating genetic differences in fat and muscle deposition. Therefore condition score could explain additional variation to liveweight observed in the lambing potential of ewes.

Ewes in better condition have been reported to be more responsive to environmental breeding cues; they start cycling earlier (Gunn and Doney 1975), and finish cycling later (Newton et al. 1980), thus expressing greater opportunity for a successful breeding event. In addition, the ovulation rate of ewes in better condition is less responsive to changes in immediate nutrition (Viñoles et al. 2010), which may help explain why some studies have reported a threshold effect of increasing condition score on observed reproductive responses (Gunn et al. 1991; Smith 1991; Vatankhah et al. 2012; Corner-Thomas et al. 2015). In Australian farming systems the ewe breeding season occurs typically when paddock feed is most limited (autumn) and a majority of systems rely on supplementary feeding during this period. The response of ewes to supplementary feeding will depend on its quality and quantity, mostly dictated by cost but also dependent on their growth path leading into summer (Blumer et al. 2018), determined mostly by seasonal year. This is supported by Ferguson et al. (2010) who reported that genetic fat influenced reproduction only in some years and by Brown and Swan (2015) who report significant benefits of genetic fat on reproduction. It may therefore be expected that condition score may have a larger effect on lambing potentials in some years rather than others.

Reported relationships between condition score and liveweight differ depending on the experience of the assessor, timing, ewe age, breed and mature size. In Merino ewes, 5–11 kg of liveweight per condition score have been reported compared to 3–16 kg for non-Merinos depending on the timing of the assessment (reviewed Kenyon et al. 2014). This variation perhaps indicates that condition score is more important at different ages and between different sheep breeds. However, there is little information on whether condition score explains additional variation in lambing potential to liveweight, or how the relationship between condition score and lambing potential might change between different ewe ages and breeds in the same environment or between the same ewe ages and breeds in different environments. In this study, we hypothesised that both liveweight and condition score would have positive effects on the lambing potential of ewes, but these relationships would differ depending on ewe age, breed and mating year. We also hypothesised that in some mating years, increasing condition score would have an additional benefit to liveweight on lambing potential.

Materials and methods

All procedures reported in this paper were conducted according to the guidelines of the Australian Code of Practice for the Use of Animals for Scientific purposes and received approval from the respective state department Animal Ethics Committees.

Experimental sites and design

The results presented in this paper are based on the reproductive performance of female progeny from the Information Nucleus Flocks (Fogarty et al. 2007; van der Werf et al. 2010; Geenty et al. 2014), which consisted of linked flocks at research sites in eight differing environments around Australia (Armidale NSW, Trangie NSW, Cowra NSW, Rutherglen Vic., Hamilton Vic., Struan SA, Turretfield SA and Katanning WA). At each research site, the female progeny were from Merino sires mated to Merino ewes (Merinos) and from Border Leicester sires mated to Merino ewes (Border Leicester Merinos).

Ewes across all sites were mated naturally to Merino and Terminal type sires (a minimum of 1–2 sires per 100 ewes) for 21–53 days (Table 1). Mating took place throughout summer and autumn (Table 1) in environments that ranged from subtropical highland to subtropical Mediterranean (Geenty et al. 2014). Annual rainfall for the eight sites over the mating years studied is overlayed on mating weights in Fig. 1.

The first age group of female progeny were born in 2007 and mated naturally to lamb as 1 and 2 year olds in 2008 and 2009 (Border Leicester Merinos) or 2 and 3 year olds in 2009 and 2010 (Merinos). This was repeated for progeny born from 2008 to 2011. Border Leicester Merinos were joined with a minimum of 5% teasers. The teasers were wethers (castrated rams) given three consecutive 2 mL doses of liquid testosterone (Ropel® 200 mL). The teasers remained with the Border Leicester Merinos until they were replaced with fertile rams at 7–9 months old. Border Leicester Merino and Merino ewes of both ages were weighed and condition scored (Russel et al. 1969) monthly prior to mating by experienced research technicians. Research technicians were mostly consistent (but not always) across years and condition score models developed by the Lifetime Ewe Project were used as a calibration tool across sites (Curnow et al. 2011). Feeding rates were adjusted at each site to achieve minimum liveweight gains of approximately 50 g/hd/day coupled with minimum condition score

Table 1. The mating date and length of mating (days) for Border Leicester Merino and Merino ewes over 5 years at eight different Information Nucleus sites across Australia ('nv' indicates records that could not be verified from the database).

		IN01 (Armidale, NSW)	IN02 (Trangie, NSW)	IN03 (Cowra, NSW)	IN04 (Rutherglen, Vic.)	IN05 (Hamilton, Vic.)	IN06 (Struan, SA)	IN07 (Turretfield, (SA)	IN08 (Katanning, WA)
Border Leicester Merinos									
Mating date	2008	18 April	nv	4 February	26 February	2 June	26 March	7 March	26 February
Days mated		21	nv	38	45	50	36	42	36
Mating date	2009	14 April	17 February	5 February	16 March	24 April	5 February	2 March	24 February
Days mated		34	36	43	39	35	53	43	35
Mating date	2010	15 April	17 February	10 February	3 March	23 April	4 March	22 February	4 March
Days mated		33	33	35	34	34	56	49	
Mating date	2011	19 May	28 March	2 March	25 February	28 April	15 March	18 February	4 March
Days mated		35	35	42	49	32	31	41	41
Mating date	2012	10 April	1 March	1 March	9 March	nv	23 March	23 February	1 March
Days mated		35	20	42	49	nv	42	47	41
Merinos									
Mating date	2009	14 April	nv	5 February	4 March	24 April	5 February	24 February	24 February
Days mated		35	nv	36	50	35	52	49	nv
Mating date	2010	15 April	17 February	10 February	3 March	23 April	4 March	23 February	4 March
Days mated		32	33	35	34	35	56	48	nv
Mating date	2011	19 May	21 February	2 March	25 February	28 April	15 March	18 February	4 March
Days mated		35	35	42	48	32	31	41	40
Mating date	2012	10 April	1 March	1 March	9 March	3 April	12 January	21 February	1 March
Days mated		35	42	42	49	42	39	48	41
Mating date	2013	18 April	31 January	31 January	28 February	nv	8 March	12 February	8 January
Days mated		nv	35	35	46	nv	41	42	45

targets of 2.5 at mating with at least 60% of ewes being condition score 3 or more.

All ewes were ultrasound scanned trans-abdominally for number of fetuses (Taverne *et al.* 1985) at approximately 50–80 days of pregnancy each year by a commercial ultrasound scanner contracted at each site. Dry, single and multiple lambs were identified and used to indicate the lambing potential of ewes. Mating weight and condition score plus a pregnancy scanning result was considered a complete mating record. A total of 4270 Border Leicester Merino and 5788 Merino records collected between 2008 and 2013.

Statistical analyses

All statistical analyses were performed using GENSTAT (GENSTAT Committee 2008). Lambing potentials (number of fetuses scanned per 100 ewes mated – including dry ewes) were analysed using a generalised linear model with a multinomial distribution and logit link function. Each breed × ewe age was analysed independently *via* three models. In the first model, mating year, mating weight and their interactions were fitted as fixed effects. The quadratic of mating weight was then added to the model to test for curvilinearity. In the second model mating year, condition score at mating and their interactions were fitted as fixed effects. The quadratic function of condition score was then added to test for curvilinearity. The third model included both mating weight and condition score to determine any additional benefits of higher condition score. Coefficient estimates and standard errors presented in Table 3 are for the transformed data.

The relationships between mating weight and condition score for each site × ewe age were analysed using a linear regression model. Within this procedure mating year and condition score were fitted as fixed effects. A combined linear regression model using both ewe ages at each site and adding ewe age as a fixed effect was used to report an overall phenotypic correlation between liveweight and condition score for each site.

Results

Younger ewes were lighter than older ewes for both breeds across mating years (Fig. 1). Two year old Border Leicester Merinos were heavier than 2 year old Merinos, even though

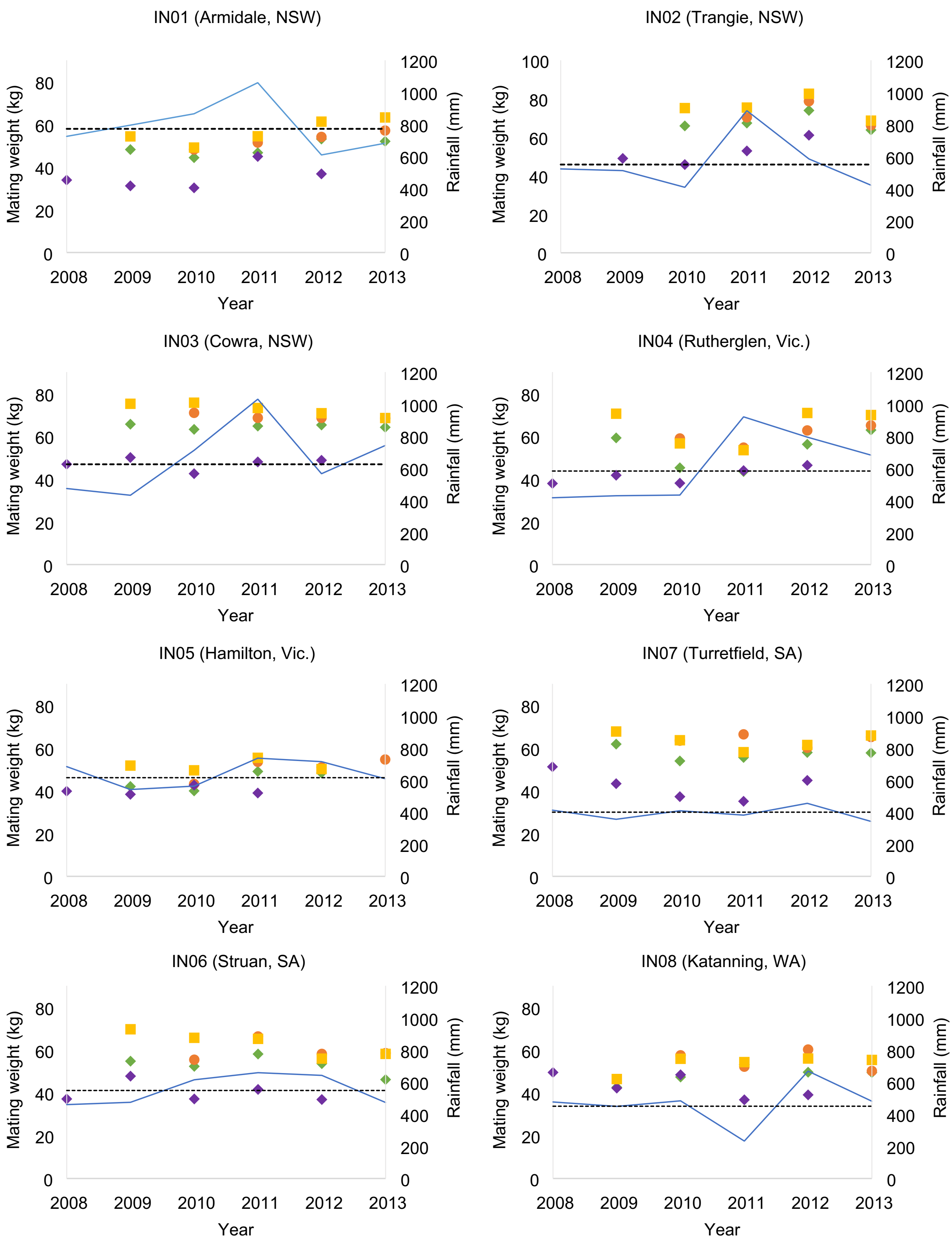

Fig. 1. The mean mating weight (kg) of Merino ewes mated as 2 (green) and 3 (orange) year olds and Border Leicester Merino ewes mated as one (purple) and two (yellow) year olds between 2008 and 2013 at eight Information Nucleus sites across Australia. Annual rainfall (blue line) and the Long-Term-Average rainfall (black dashed line) are overlayed for each site.

Border Leicester Merinos were mated as 1 year olds. Younger ewes were in lower condition than older ewes for both breeds across mating years (Table 2).

Lambing potential increased significantly with mating weight at all eight sites for 2 year old Merinos and at seven sites for 1 year old Border Leicester Merinos ($P < 0.05$; Table 3). For 3 year old Merinos the relationship between mating weight and lambing potential was significant at six sites, and at three sites for 2 year old Border Leicester Merinos ($P < 0.05$; Table 3). The magnitude of the responses in lambing potential to mating weight varied by nearly three times between sites, ewe ages and ewe breeds (Table 3). Across all sites, the back-transformed estimates from Table 3 represent an average increase in lambing potential of 2.1% per 1 kg increase in mating weight for 2 year old maiden Merinos compared to 1.4% for 3 year old ewes. For 1 year old maiden Border Leicester Merinos, lambing potential increased by 3.1% per 1 kg increase in mating weight compared to 1.3% for 2 year old ewes ($P < 0.05$). The quadratic function of mating weight was not significant for any breed × site × ewe age combination.

Lambing potential also increased significantly with mating condition score at seven sites for 2 year old Merinos and at three sites for 1 year old Border Leicester Merinos ($P < 0.05$; Table 3). For 3 year old Merinos the relationship between mating condition score and lambing potential was significant at four sites for both 3 year old Merinos and 2 year old Border Leicester Merinos ($P < 0.05$; Table 3). The magnitude of the responses in lambing potential to mating weight varied by nearly four times between sites, ewe ages and ewe breeds (Table 3). Across all sites, the back-transformed estimates from Table 3 represent an overall increase in lambing potential of 29% per one unit increase in condition score for 2 year old maiden Merinos compared to 25% for 3 year old ewes. For 1 year old maiden Border Leicester Merinos, lambing potential increased by 27% per one unit increase in condition score compared to 13% for 2 year old ewes. The quadratic function of condition score was not significant for any breed × site × ewe age combinations.

Table 2. The mean condition score at mating of Border Leicester Merino ewes mated as 1 and 2 year olds and Merino ewes mated as 2 and 3 year olds between 2008 and 2013 at eight Information Nucleus sites across Australia.

	IN01 (Armidale, NSW)	IN02 (Trangie, NSW)	IN03 (Cowra, NSW)	IN04 (Rutherglen, Vic.)	IN05 (Hamilton, Vic.)	IN06 (Struan, SA)	IN07 (Turretfield, (SA)	IN08 (Katanning, WA)
Border Leicester Merino 1 year olds								
2008								3.4
2009	2.3	3.3	3.1	2.6	3.6	2.6	3.0	2.9
2010	3.0	2.8	3.2	3.2	3.6		2.8	
2011	3.5	3.1	3.6	2.3	3.4	3.9	2.6	
2012	3.4	3.2	3.4	3.2		3.1	4.3	2.5
Border Leicester Merino 2 year olds								
2009	3.4				3.5	3.0	3.0	2.6
2010	3.5	3.7	4.1	3.5	3.4	2.8	2.8	3.1
2011	4.0	3.2	3.5	2.6	2.4	3.7	2.8	2.8
2012	4.2	3.4	3.5	3.8	3.3	3.1	3.6	2.7
2013	4.3	3.2	3.4	3.4		3.2	3.3	2.8
Merino 2 year olds								
2009	2.9					2.4	2.8	2.5
2010	3.4	3.0	3.5	3.0	3.0	2.6	2.5	2.5
2011	3.7	3.1	3.2	2.1	2.4	3.3	2.9	2.6
2012	3.7	3.2	3.3	3.1	3.1	3.0	3.4	2.6
2013	4.0	3.3	3.3	3.2		2.8	2.9	2.6
Merino 3 year olds								
2010	3.1		3.5		2.9	2.7	2.5	2.8
2011	3.9	3.0	3.2	2.4	2.2	3.3	2.9	2.6
2012	3.6		3.2	3.3	3.0	2.7	2.9	2.9
2013	4.1	3.2	3.1	3.0	3.0	3.0	3.0	2.6

Table 3. The slope (Pearson estimate for transformed data) predicting lambing potential from mating weight for Merino ewes joined as 2 year olds (first mating) and 3 year olds, and for Border Leicester Merino ewes joined as 1 year olds (first mating) and 2 year olds at eight different Information Nucleus sites across Australia over 5 years (2009–2013).

Site	Mating weight			Condition score		
	Estimate	Error	Sig.	Estimate	Error	Sig.
Merino 2 year olds						
IN01 (Armidale, NSW)	0.06	0.003	***	1.00	0.290	***
IN02 (Trangie, NSW)	0.05	0.016	**	1.33	0.418	**
IN03 (Cowra, NSW)	0.05	0.022	*			n.s.
IN04[A] (Rutherglen, Vic.)	0.14	0.062	**	0.56	0.277	*
IN05 (Hamilton, Vic.)	0.09	0.026	***	1.03	0.456	*
IN06 (Struan, SA)	0.05	0.018	**	0.63	0.315	*
IN07 (Turretfield (SA)	0.08	0.015	***	0.62	0.258	**
IN08 (Katanning WA)	0.10	0.015	***	0.07	0.015	***
Merino 3 year olds						
IN01 (Armidale, NSW)	0.07	0.020	**			n.s.
IN02 (Trangie, NSW)			n.s.			n.s.
IN03 (Cowra, NSW)			n.s.	1.33	0.377	***
IN04 (Rutherglen, Vic.)	0.07	0.020	**			n.s.
IN05 (Hamilton, Vic.)	0.06	0.021	**	0.98	0.443	*
IN06 (Struan, SA)	0.04	0.019	*	0.70	0.338	*
IN07 (Turretfield (SA)	0.07	0.016	*			n.s.
IN08 (Katanning WA)	0.07	0.015	***	1.23	0.298	***
Border Leicester Merino 1 year olds						
IN01 (Armidale, NSW)	0.13	0.028	***	1.12	0.293	***
IN02 (Trangie, NSW)	0.07	0.027	*			n.s.
IN03 (Cowra, NSW)	0.07	0.024	**	1.21	0.453	n.s.
IN04 (Rutherglen, Vic.)			n.s.			n.s.
IN05 (Hamilton, Vic.)	0.09	0.034	*			n.s.
IN06 (Struan, SA)	0.13	0.031	***			n.s.
IN07 (Turretfield (SA)	0.12	0.021	***	1.63	0.342	***
IN08 (Katanning WA)	0.08	0.022	***			***
Border Leicester Merino 2 year olds						
IN01 (Armidale, NSW)	0.05	0.018	***	0.55	0.235	***
IN02 (Trangie, NSW)			n.s.			n.s.
IN03 (Cowra, NSW)			n.s.			n.s.
IN04 (Rutherglen, Vic.)			n.s.			n.s.
IN05 (Hamilton, Vic.)	0.11	0.023	***	1.08	0.403	**
IN06 (Struan, SA)			***	0.97	0.286	***
IN07 (Turretfield (SA)			n.s.			n.s.
IN08 (Katanning WA)	0.10	0.019	***	2.04	0.600	***

[A]Mating weight coefficient only significant for mating years 2010 and 2011.
*Significant at $P < 0.05$; **significant at $P < 0.01$; ***significant at $P < 0.001$.

When both mating weight and condition score were fitted together, condition score only explained additional variation to mating weight in one instance of the 160 age × breed × site × mating year combinations ($P < 0.05$). This significant additional effect of condition score was evident for 2 yearold Merinos from site IN04 in mating years 2011 and 2012. In these years the mating weights of the ewes were lighter than in other years (Fig. 1).

Mating year increased lambing potential significantly for both Merino and Border Leicester Merinos. This was evident when either mating weight or condition score were used as the explanatory variate for lambing potential (Table 3). The effect of mating year differed depending on ewe age. At some sites, such as Katanning (IN08), mating year had no significant effect on lambing potential for 2 year old Merinos, however 3 year old Merinos from Katanning had higher lambing potential in 2012 than in other years ($P < 0.001$; Fig. 2).

A significant interaction between mating weight and mating year was only detected in one instance of the 160 age × breed × site × mating year combinations. For 2 year old Merinos, the effect of mating weight on lambing potential was greater in 2010 and 2011 than for other years (5.2% versus 1.3% per kg mating weight, $P < 0.05$). This interaction was not evident when condition score was used instead of mating weight. The condition score × mating year interaction was not evident at any site; nor amongst older Merinos; nor amongst Border Leicester Merinos of any age (Fig. 2).

The relationship between mating weight and condition score was variable between sites and years ranging from 0.7 to 16.1 kg and from 4.2 to 14.9 kg for 1 and 2 year old Border Leicester Merinos respectively, and from 0.7 to 18 kg and 3.2 to 13.7 kg for 2 and 3 year old Merinos respectively (Table 4). Both extremes in the variation observed for 2 year old Merinos (0.7–18 kg) were observed at the same site (IN08; Table 4). This same site had steeper relationships between mating weight and condition score for 1 year old Border Leicester Merinos as well (13.8 kg; Table 4). Phenotypic correlations between mating weight and condition score ranged from 0 to 0.41 between sites (Table 4). The quadratic term was not significant for either breed of ewes, at any individual site or year studied.

Discussion

The lambing potential of ewes increased linearly with increasing mating weight or condition score and the magnitude of the relationship varied depending on ewe age, year and possibly ewe breed. These results supported our initial hypothesis. However, when fitted together condition score rarely explained extra variation in lambing potential to that explained by mating weight alone which was surprising and in contrast to our second hypothesis. Liveweight includes muscle and fat however, as indicated by

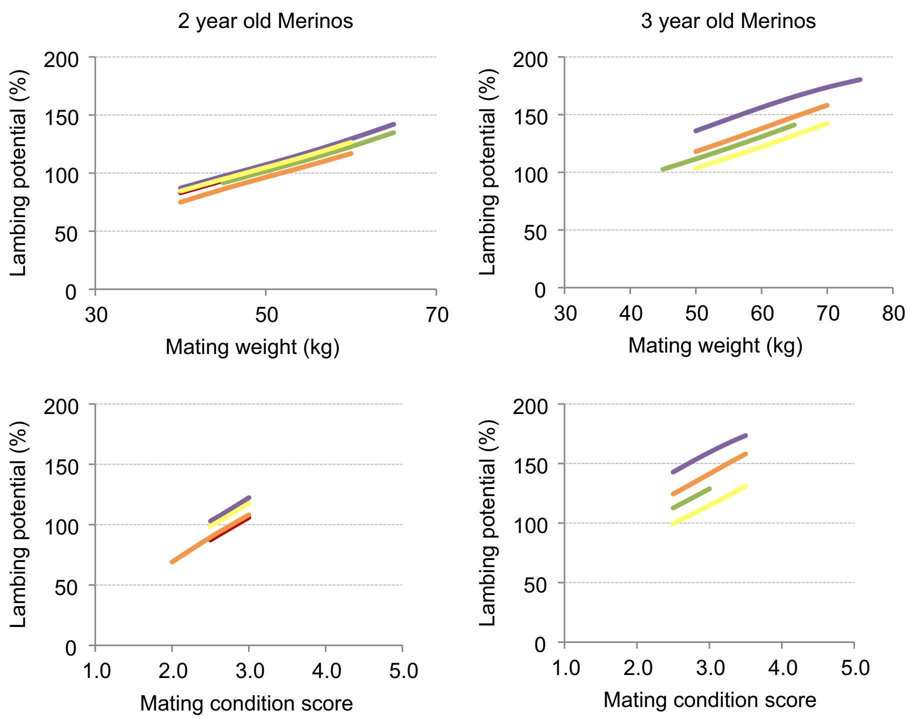

Fig. 2. The effect of mating weight and condition score on lambing potential (fetuses scanned per 100 ewes joined) of 2 (left) and 3 (right) year old Merinos in 2009 (red), 2010 (orange), 2011 (green), 2012 (purple) and 2013 (yellow) at Katanning, WA. Predictions are only made for condition score intervals where there were >10 ewes and the average 95% confidence interval across all years was 13.16% (top left), 17.44% (bottom left), 19.07% (top right) and 8.45% (bottom right).

Table 4. The relationship between mating weight and condition score at mating for Merino 2 and 3 year old ewes and Border Leicester Merino 1 and 2 year old ewes at eight sites across Australia from 2009 to 2013 (r^2 = phenotypic correlation at each site).

Site	Year	Merinos		Border Leicester Merinos		Site	Year	Merinos		Border Leicester Merinos	
		2 years	3 years	1 year	2 years			2 years	3 years	1 year	2 years
Armidale, NSW						Hamilton, Vic.					
IN01	2009	4.0		6.2	7.5	IN05	2009				
r^2 = 0.41	2010	3.0	3.2	6.5	6.6	r^2 = 0.00	2010	5.8	10.7	9.9	14.2
	2011	3.0	3.8	4.7	4.3		2011	4.1	5.7	5.3	9.1
	2012	3.6	3.8	5.6	7.0		2012	4.9	10.5		9.3
	2013	4.8	6.1		9.2		2013		7.9		
	Mean	3.7	4.2	5.7	6.9		Mean	4.9	8.7	7.6	10.8
Trangie, NSW						Struan, SA					
IN02	2009					IN06	2009	4.4		1.3	7.9
r^2 = 0.18	2010	4.9		2.9	10.2	r^2 = 0.04	2010	3.1	7.9		10.5
	2011	17.8	11.4	7.7	14.6		2011	3.6	6.4	4.5	9.5
	2012	6.4		0.7	9.2		2012	6.5	10.0	2.2	8.9
	2013	8.7	8.5		12.0		2013	11.0	4.3		9.9
	Mean	9.4	9.9	3.8	11.5		Mean	5.7	7.1	2.7	9.3
Cowra, NSW						Turretfield, SA					
IN03	2009					IN07	2009	4.2		7.9	10.7
r^2 = 0.08	2010	3.4	10.2	6.3	6.3	r^2 = 0.04	2010	3.4	4.3	6.9	8.6
	2011	6.2	4.6	5.4	4.9		2011	7.9	6.2	6.7	7.9
	2012	4.9	6.6	6.4	7.6		2012	5.9	7.1	7.5	10.4
	2013	6.6	7.4		10.5		2013	6.2	6.5		6.3
	Mean	5.3	7.2	6.0	7.3		Mean	5.5	6.0	7.2	8.8
Rutherglen, Vic.						Katanning, WA					
IN04	2009					IN08	2009	17.2		16.1	14.9
r^2 = 0.22	2010	1.8		4.7	7.9	r^2 = 0.17	2010	8.6	8.5		9.7
	2011	2.4	3.7	1.5	4.2		2011	0.7	6.3		3.8
	2012	4.9	5.4	1.3	5.7		2012	7.6	4.8	11.5	10.4
	2013	3.3	9.4		4.7		2013	18.0	13.7		13.1
	Mean	3.1	6.1	2.5	5.6		Mean	10.4	8.3	13.8	10.4

Rosales Nieto *et al.* (2013), liveweight *per se* is simply mass and so encompasses no physiological or mechanistic process that affects the reproductive system. Muscle and fat tissues however are metabolically, physiologically and hormonally active and can become involved in processes at the brain, pituitary and ovarian levels that influence lambing potential (Rosales Nieto *et al.* 2018). It is known there is a moderate correlation between condition score and total weight of fat (Ferguson 2012) and the phenotypic correlations between mating weight and condition score in our study were generally lower than 0.5. Nevertheless, it is still likely that mating weight was correlated highly with the total weight of tissues directly controlling reproduction. This suggests that if ewes are weighed to inform management decisions relating to nutrition prior to mating to optimise lambing potential, then the additional benefits from condition scoring as well will be minimal.

The positive effect of mating weight on lambing potential was approximately twice as important for younger ewes being mated for the first time. The effect of condition score at mating on lambing potential was also greater in younger ewes, especially 1 year old Border Leicester Merino ewe lambs compared to two-tooth ewes. Comparisons between studies suggest that the responses in lambing potential to improved mating weight (Lindsay *et al.* 1975; Ferguson *et al.* 2011; Thompson *et al.* 2019, 2021, 2022) are much greater for ewe lambs than adult ewes regardless of breed, but few studies have compared the responsiveness of ewe lambs versus two-tooth ewes from the same flock or of two-tooth maidens versus older ewes. The reproductive performance of Border Leicester Merino ewe lambs was most often poor and variable, with lambing potentials being less than 70% in three quarters of all their mating events. The lambing potential was much lower than those achieved by commercial flocks of similar ewe breeds reported by other studies which varied between 97 and 117% (Thompson *et al.* 2021, 2022; Clune *et al.* 2022), and consistent with their low and variable mating weights. Our data implies that the lambing potential and hence potential marking rate of younger ewes is more sensitive to management prior to mating than is the case for adult ewes. It is not clear from our data why the responses in lambing potential to mating weight or condition score varied so much between years. Above average rainfall at sites in NSW and Vic. in 2011 did not appear to improve the mating weights or condition scores in 2012, but rainfall does not necessarily indicate the feed available to ewes at each site in each year. While genetics across the Information Nucleus flocks were controlled they were still highly variable, with maternal genetics varying from small superfine Merinos through to larger-framed medium wool types (Geenty *et al.* 2014). This significant genetic variation would contribute to some of the differences observed. Another contributor is likely to be the liveweight profile of these ewes prior to mating. Blumer *et al.* (2018) found that one kg of liveweight gain prior to mating increased lambing potential by 1.2% in adult non-Merino ewes in addition to the 1.3% reported per kg of mating weight. It would not be surprising if these effects were even more significant in younger, inexperienced ewes. While outside the scope of this study, a further analysis including liveweight profiles of these ewes from weaning to mating would help us improve the management of ewes to achieve more predictable outcomes.

Direct comparisons between Merinos and Border Leicester Merinos were difficult to make with this dataset, due to a confounding effect of age; as Merinos were not mated for their first time until 2 years old, in contrast to Border Leicester Merinos that were mated as 1 year olds. Nevertheless, some differences are worthy of comment. For both breeds, the effect of mating weight on the lambing potential of ewes mated for their second time was similar (1.3 and 1.4% per kg) for 2 year old Border Leicester Merino and 3 year old Merinos respectively. Lambing potential of ewes mated for the first time differed by about 1% (2.1% for Merinos and 3.1% for Border Leicester Merinos) per kg of mating weight. This difference was similar to the 3.9% for Merinos and 4.7% for maternal-type ewe lambs reported by Thompson *et al.* (2022). These data combined with the insignificance of any threshold (the quadratic effect of mating weight or condition score) indicate that achieving the heaviest possible mating weights appears to be the ideal management option for ewes when bred young (up to 2 years old for Border Leicester Merinos or up to 3 years for Merinos), providing feed is cost-effective to achieve this.

In all instances relationships between mating weight, condition score and lambing potential were linear and the phenotypic correlations between condition score and mating weight were all lower (except at Armidale; IN01) than the 0.55 correlation reported from an analysis of 19 sites across New Zealand (Shackell *et al.* 2011). While one might muse that our trans-tasman colleagues are more adept at the subjective assessment of condition score, there are alternative explanations. In the current study, less than 5% of all ewes were less than condition score 2.5 despite a third of all ewes (33%) weighing less than 40 kg at mating, which is the minimum recommended mating weight for maximum expression of puberty and consequent reproductive performance for 7–10 month old ewe lambs (Rosales Nieto *et al.* 2013; Paganoni *et al.* 2014). Corner-Thomas *et al.* (2015) reported a maximum threshold in lambing potential at a condition score 2.5 for young Romney ewes, with ample representation of ewes in poorer condition than 2.5 to draw their conclusion. Less than 5% of all ewes in the current study were less than condition score 2.5 at mating. This would reduce the slope and significance of the relationships and this is perhaps most evident in the older ewes of each breed where the relationships between condition score and lambing potential are less significant across sites.

To overcome some of the inconsistencies in the relationships between condition score and liveweight, it is suggested that multipliers are needed for different ewe breeds and ages (Kenyon *et al.* 2014). We observed multipliers between liveweight and condition score for 2 and 3 year old Merinos of 2–18 kg and 1–16 kg for 1 and 2 year old Border Leicester Merinos, which is greater than previously reported ranges for Merinos (6–11 kg, van Burgel *et al.* 2011) and non-Merinos (3–16 kg, Kenyon *et al.* 2014). Variation due to reproductive status should be minimal in the current study as only measurements at mating were analysed. Therefore the extra variation observed must come from different experienced assessors between years in addition to breed and age effects. Variation from assessors can be amended for by calibration equations (van Burgel *et al.* 2011) using standardised models such as those developed by the Lifetime Wool Project (Curnow *et al.* 2011). At some sites, the multipliers were very consistent across mating years, indicative of experienced consistent scoring. As for breed and age effects: generally, the multiplier for Border Leicester Merinos across most sites and ewe ages was greater than for Merinos, which seems logical given Border Leicester Merino breeds are likely to be heavier at maturity than Merinos and therefore also likely to differ in muscle and fat mass at any level of maturity, as observed in other breeds of equally variable mature weights (McClelland *et al.* 1976). It also seems logical that we observed the multiplier for older ewes was greater than for younger ewes of both breeds, which can also be attributed to them being heavier. There was also evidently variation in the multipliers for the same breed at different sites, indicating variation in the mature size of different genotypes within each breed. The most obvious example of this is the difference between Armidale (site IN01) and Katanning (site IN08). At Armidale, these multipliers suggest an increase of 3.7 kg is required to raise the condition score of a 2 year old Merino by one unit. This is low compared to a 2 year old Merino ewe from Katanning, who needs to gain closer to 10.4 kg to raise her condition score by one unit. Differences like these would have significant implications for the costs of common condition score targets across genetically varied flocks. They also question the validity of optimal condition score targets developed for Lifetime Wool guidelines (Young *et al.* 2011) using just the multiplier reported by van Burgel *et al.* (2011). There is sufficient published information available now for these guidelines to be revised using more tailored multipliers for different breeds of sheep.

Conclusions

The lambing potential of ewes increased significantly and linearly with mating weight and condition score and the magnitude varied depending on ewe age, year and possibly ewe breed. If ewes are weighed at mating to inform management decisions relating to nutrition to optimise lambing potential, then the additional benefits from condition scoring as well will be minimal. Achieving the heaviest possible mating weights appears to be the ideal management option for ewes when bred young (up to 2 years old for Border Leicester Merinos or up to 3 years for Merinos), providing of course, that feed is cost-effective to achieve this.

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Data availability. All the data used in this manuscript is available on request to the corresponding author including mating weight and condition score figures for each breed × age × site × year.

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