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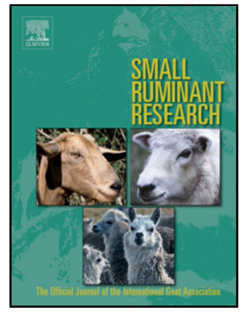

Title: Reducing mob size increases the survival of twin-born Merino lambs when feed-on-offer from pasture is limited and ewes are supplementary fed during lambing

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Reducing mob size increases the survival of twin-born Merino lambs when feed-on-offer from pasture is limited and ewes are supplementary fed during lambing

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Highlights

- Survival of twin-born lambs is greater at a lower mob size
- Effect of mob size on lamb survival may be greater when pasture availability is low
- Interaction with foreign ewes or lambs at birth was not greater at the higher mob size

Abstract

Improving the survival of twin-born lambs is a high priority for the Australian sheep industry. Higher mob sizes at lambing have been suggested to decrease the survival of twin-born lambs. However, our recent work indicated that this effect may not occur when feed-on-offer (FOO) exceeds 2400 kg DM/ha during the lambing period. Increasing mob size at lambing when FOO is limited may exacerbate the risk of mismothering due to the need for ewes to seek feed and thus result in poorer lamb survival. Therefore, this study tested the hypothesis that (i) a higher mob size at lambing will decrease lamb survival when FOO from pasture is limited and ewes are supplementary fed and (ii) that this is related to a greater rate of interaction with foreign ewes and lambs during the periparturient period. Twin-bearing Merino ewes (*n* = 795) were allocated into one of two treatments on day 140 of pregnancy; high (*n* = 210) or low (*n* = 55) mob size, with three replicates of each treatment. Feed-on-offer from live pasture at lambing was below 390 kg DM/ha and ewes were supplementary fed until lamb marking. Behaviour during the periparturient period was observed and dead lambs were collected for autopsy for 14 days during the peak of lambing. The survival of lambs to marking was recorded for each mob. Lamb survival was 6.2% higher at the low compared to the high mob size ($P<0.05$). The proportion of ewes which interacted with a foreign ewe or foreign lamb at lambing did not differ significantly between mob sizes. Whilst the relationship between mob size, ewe-lamb behaviour and lamb survival remains unclear, this study has shown that the survival of twin-born Merino lambs is improved by lambing ewes in smaller mobs when FOO from live pasture is limited and ewes are supplementary fed.

Keywords: density, pasture, behaviour, interaction, ewes

1. Introduction

Improving the survival of twin-born lambs is the highest priority for increasing reproductive performance within the Australian sheep industry (Young et al., 2014). Several management and environmental factors such as ewe condition score, feed-on-offer and access to shelter are known to influence lamb survival (Hinch and Brien, 2014). However, the relationship between mob size and lamb survival remains unclear. Kleemann et al. (2006) suggested that the survival of single and twin lambs born to adult ewes was optimised at mob sizes of approximately 400 ewes. In contrast, Allworth et al. (2017) reported that the survival of twin lambs born on commercial farms tended to be lower at mob sizes greater than 200 ewes compared to less than 200 ewes. Higher mob sizes at lambing could therefore decrease lamb survival.

Increasing the density of lambed ewes has been linked with an increased risk of permanent ewe-lamb separations (Cloete, 1992). Furthermore, Robertson et al. (2012) found that 24% more lambs died between birth and marking at a stocking rate of 30 ewes/ha compared to 16 ewes/ha. These deaths were partly associated with starvation and mismothering which the authors suggest may have been the result of interference from other ewes during the periparturient period. In support, Alexander et al. (1983a) observed 22% of twin-bearing Merino ewes which became permanently separated from their lambs had experienced interference from foreign ewes or lambs. Subsequently most separated lambs died (79%) with the remainder being cross-fostered by other lambing ewes. However, Winfield (1970) observed fewer lambs die after being cross-fostered or becoming separated from their dam due to interference from a foreign ewe. Nevertheless, at higher mob sizes, where a greater number of ewes lamb per day, the risk of interference to lambing ewes and their newborn progeny may be greater thereby compromising lamb survival. Yet, mob size was not observed to influence interaction with foreign ewes or lambs at lambing or lamb survival when FOO at lambing exceeded 2400 kg DM/ha (Lockwood et al., 2018). It could be expected that the effect of mob size on lamb survival may be more evident when

FOO at lambing is lower due to poorer ewe-lamb behaviour.

Poor maternal nutrition during late pregnancy and lactation can compromise ewe-lamb behaviour and lamb survival. Ewes fed a restricted diet throughout pregnancy have been observed to spend less time grooming their progeny after birth and more time eating (Dwyer et al., 2003; Freitas-de-Melo et al., 2015). Lambs born to ewes which lose more body condition during pregnancy also take longer to stand and suck following birth and are less active in the first 3 days of life (Dwyer, 2003). Lamb survival may be compromised when FOO at lambing is below 800 kg DM/ha due to lower birthweight (Oldham et al., 2011). Modelling by Oldham et al. (2011) indicated that lamb survival is optimised when FOO is 2000 kg DM/ha at lambing. However, other studies have suggested that grazing multiple-bearing ewes on herbage masses greater than 1100 to 1400 kg DM/ha during late pregnancy and lactation may not improve lamb survival (Kenyon et al., 2013; Corner-Thomas et al., 2015).

Low FOO at lambing may also affect lamb survival independent of maternal nutrition and lamb birthweight. For example, very low FOO at lambing could decrease the time spent at the birth site as ewes move away to graze and seek water. Cloete (1992) found that permanent separations of ewes from one or more of her lambs was 20% to 30% higher when the ewe spent two or less hours at the birth site compared to ewes which spent at least two hours at the birth site. This is supported by the findings of Alexander et al. (1983a). Therefore, a higher mob size at lambing coupled with low FOO could exacerbate the risk of mortality of twin-born lambs. This study tested the hypothesis that (i) a higher mob size at lambing will decrease lamb survival when FOO from live pasture is limited and ewes are supplementary fed and (ii) that this is related to a greater rate of interaction with foreign ewes and lambs during the periparturient period.

2. Materials and Methods

All procedures described were performed according to the guidelines of the Australian Code of Practice for the Use of Animals for Scientific Purposes 2013 and received approval from the University of Western Australia and Murdoch University Animal Ethics Committees (RA/3/100/1523 and NS2973/17).

2.1. Research site, animals and experimental design

The research was performed at the University of Western Australia Future Farm near Pingelly in Western Australia (coordinates: 32°30'23"S, 116°59'31"E). Merino ewes aged 2 to 5 years and from two different flocks were joined to Merino sires for 35 days in late January or early February 2017. Ewes were pregnancy scanned via transabdominal ultrasonography in early April to identify pregnancy status (single or twin) and foetal age. Foetal age was categorised as early or late at pregnancy scanning where early were foetuses aged over 74 days and late were foetuses aged 54 to 74 days. Twin-bearing ewes (n = 795) were randomly allocated into one of three replicates of two treatments on day 140 from the start of joining; high (n = 210) or low (n = 55) mob size, according to age (maiden or adult), date of joining (flock), foetal age and condition score at pregnancy scanning.

The experimental site consisted of six adjacent paddocks with similar shelter, pasture composition and access to water. Each treatment was allocated to a lambing paddock using a restricted randomisation to account for slight variation in paddock characteristics. The stocking rate was set at 8.5 ewes/ha across all treatments such that ewes in the high and low mob size treatments lambed in paddocks of 24.7 ha and 6.5 ha respectively. Lambs were born between late June and early August. Lamb survival was recorded until lamb marking which occurred in mid-August. The average chill index between lambing and marking was 1009 kJ m^2.h (Donnelly, 1984).

2.2. Animal management and measurements

Ewes were body condition scored at pregnancy scanning, day 140 of pregnancy and lamb marking as described by Jefferies (1961). Ewes were managed under the same conditions and grazed paddocks with similar FOO from pregnancy scanning until day 140 of pregnancy, when they were assigned a unique paint-brand for identification, allocated to treatments and moved to their lambing paddocks. Ewes were supplementary fed twice weekly between lambing and marking via trail feeding the equivalent of 830g of oat grain/head/day. Bales of oaten hay were also placed at four locations within each paddock for the high mob size treatments and two locations per paddock for the low mob size treatments. Fresh bales of hay were placed at the designated locations in each paddock weekly such that the hay was available *ad libitum*.

All ewes were intensively monitored for 14 days during the peak of lambing. Between 07:00 and 08:00 each day, newborn lambs were captured, ear tagged and their dam brand recorded. A total of 968 lambs were tagged during the 14-day period, which represents approximately 61% of all foetuses identified at pregnancy scanning. Dead lambs (*n* = 227) were collected for autopsy using the procedure as described by Holst (2004), with dystocia categories (a), (b) and (c) defined as dystocia, stillbirth and birth injury, respectively. The number of lambs autopsied is shown in Table 2. Between approximately 08:00 and 16:00 each day ewes were monitored and details of lambing, ewe-lamb behaviours and interactions with foreign ewes and lambs were recorded as described in Table 1. A total of 102 ewes were observed at lambing with the number of measurements for each behavioural trait shown in Table 2. Ewes and lambs remained in their paddocks until lamb marking, when the number of lambs in each mob was counted. Lamb survival reflected losses between pregnancy scanning and marking and hence was calculated according to the number of foetuses allocated and the number of lambs marked per mob.

2.3. Pasture assessment

A visual assessment of live FOO (kg DM/ha) was made at 20 to 25 sites in each paddock at peak lambing, approximately 165 days from joining with rams, and lamb marking using a similar technique to that described by

Thompson et al. (1994). The visual assessments of FOO were calibrated against ten 0.1m^2 quadrat cuts taken from across the 6 paddocks. 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.

2.4. Statistical analysis

All statistical analyses were performed using GENSTAT (VSN International, 2017). For all models, mob size was fitted as a fixed effect and lambing paddock was fitted as a random term. Covariates were only included if they were significant statistically (P<0.05).

Survival of lambs to marking, mean condition score of ewes in the mob and FOO at lambing and marking, time between birth of the first and second lambs, and time taken for the first- and second-born lambs to stand were analysed using ANOVA. Data for one ewe was removed from the analysis of time between birth of the first and second lambs, and two lambs were removed from the analysis of time taken for the second-born lamb to stand due to leverage effects. For the analysis of lamb survival, ewe condition score and FOO at lambing and marking were fitted separately as covariates.

Foreign ewe or lamb interactions were classified as having a total interaction time of at least one minute. For the analysis of foreign lamb interactions, one paddock was removed due to insufficient data. Hence analysis of foreign lamb interactions includes data for five paddocks. For all ewes observed during lambing, the effect of mob size on the rate of interaction with a foreign ewe or lamb was assessed by fitting Generalized Linear Mixed Models. The approach used a logit-transformation and binomial distribution. The effect of mob size on the total time of foreign ewe or lamb interactions was analysed using ANOVA. Data was log-transformed for this analysis and is presented in the back-transformed state.

The effect of mob size on each cause of death was assessed by fitting Generalized Linear Mixed Models. The approach used a logit-transformation and binomial distribution. Data included all lambs autopsied during the 14-day observation period.

3. Results

3.1. Mob size and lamb survival

Lamb survival was 6.2% higher at a mob size of 55 ewes compared to 210 ewes (Table 3). The condition score of ewes and FOO at lambing and marking did not differ between treatments (Table 3). However, on average ewes lost 0.5 condition score between lambing and marking despite an increase in FOO during this period. There was no effect of mean ewe condition score or FOO at lambing or marking on lamb survival.

The proportion of lambs which died from each cause of death did not differ between mob sizes (Table 4). The primary causes of death of lambs were stillbirth, birth injury and exposure. No lambs were categorised as dying due to infection or misadventure.

3.2. Ewe-lamb behaviour and interactions at lambing

The time between birth of the first-born and second-born lambs did not differ between the high and low mob sizes (19.3 vs 26.0 minutes; r.s.d. 0.65; $P = 0.15$). There were also no differences between the high and low mob sizes in the time to stand for first-born lambs (16.3 vs 14.7 minutes; r.s.d. 0.61; $P = 0.54$) or second born lambs (12.7 vs 14.5 minutes; r.s.d. 0.63; $P = 0.43$).

The proportion of ewes and their newborn progeny which were observed to experience interaction with a foreign ewe during the periparturient period did not differ between the high and low mob sizes (27.7% vs 16.4%; $P = 0.32$). There was also no difference in rate of interaction with a foreign lamb at the high and low mob sizes (40.2% vs 14.5%; $P = 0.13$). The total time of interaction with a foreign ewe did not differ between the high and low mob sizes (6.6 vs 4.1 minutes; r.s.d, 0.94; $P = 0.30$). There was also no difference in the total time of interaction with a foreign lamb at the high and low mobs sizes (4.8 vs 4.4 minutes; r.s.d. 1.0; $P = 0.87$).

4. Discussion

The survival of twin-born Merino lambs to marking was 6.2% higher at a mob size of 55 ewes compared to 210 ewes. There were no significant differences between mob sizes in the proportion of ewes which interacted with a foreign ewe or foreign lamb at the time of lambing or in the total time of these interactions. Behaviour at lambing was observed for less than 20% of ewes. Hence, caution is required when drawing conclusions regarding behaviour as the results are limited by the number of interactions observed at lambing.

The greater survival of twin-born lambs at a lower mob size contrasts the findings of Kleemann et al. (2006). In their study, Kleemann et al. (2006) observed a quadratic relationship between mob size and lamb survival when mob size ranged from 200 to 500 adult ewes. However, our results tend to support those of Allworth et al. (2017). The difference in lamb survival observed between mob sizes in this study represents a decrease of 4% per extra 100 twin-bearing ewes in the mob. About 75% of ewes lambed during a consecutive 20-day period in the current study. Approximately 5 and 15 lambs per day were born at the low and high mob sizes during this peak lambing period, respectively. The synchronisation of ewes for joining in the study of Lockwood et al. (2018) resulted in a shorter peak lambing period and therefore, on average, a higher number of lambs were born per day compared to the current study. Despite this, the survival of single and twin lambs born at mob sizes of 50 and 130 ewes was not observed to differ when FOO from live pasture exceeded 2400 kg DM/ha between lambing and marking (Lockwood et al., 2018). Hence, even though the estimated lambing density was lower in the current study, a significant effect of mob size on lamb survival was observed when FOO was less than 390 kg DM/ha at lambing and ewes were supplementary fed during lambing.

Whilst poorer maternal nutrition is known to increase lamb mortality (Oldham et al., 2011; Paganoni et al., 2014), the differences in survival between mob sizes in the current study were not the result of differences in nutritional status. Anecdotal evidence suggests that trail feeding ewes at lambing may cause them to abandon their lambs and increase the risk of mismothering (Morcombe et al., 1988). Furthermore, ewes could spend less time at the birth site, which is known to increase the risk of mismothering and ewe-lamb separation (Alexander et al., 1983b; Cloete, 1992; Nowak, 1996). In this study, the feeding and location of hay within each paddock was managed to avoid differences in hay availability per ewe, the travelling distance to hay or the density of ewes around the hay between the high and low mob sizes. Trail feeding was also consistent between mob sizes. However, the impact of supplementary on ewe-lamb behaviour and lamb survival was not quantified and requires further research.

Greater lamb survival at the lower mob size could not be explained by differences in ewe-lamb behaviour from the limited data collected at lambing. Although, it is possible that the timing of observations was restrictive or important behaviours were not recorded. For example, interaction with foreign ewes or lambs may have been greater as the ewe and her progeny left the birth site, which is typically within 3 hours of lambing for Merino ewes (Stevens et al., 1982; Bickell et al., 2010). Furthermore, ewe-lamb separations were not recorded in this study but could be associated with increased interaction with foreign ewes or lambs as the ewes and her progeny become more active in the hours following lambing. Hence, further research perhaps using remote technology, such as sensors, is required to quantify the relationships between mob size, ewe-lamb and mob behaviour and lamb survival throughout lambing.

Interference during labour can inhibit uterine contractions and may increase the risk of dystocia or prolonged births leading to poorer lamb survival (Naaktgeboren, 1979). However, the observed difference in lamb survival could not be explained by differences in the duration of labour between twin lambs or time taken for the lambs to stand. A longer duration between birth of twin-born lambs has been associated with reduced grooming of the lambs by the ewe (Dwyer and Lawrence, 1998). Standing soon after birth is important for the stimulation of the lamb, establishment of the ewe-lamb bond and suckling (Nowak et al., 2007; Nowak et al., 2011). Furthermore, lambs which experience a prolonged or difficult birth are recognised to take longer to stand and are less likely to suck within 2 hours of birth (Dwyer, 2003; Darwish and Ashmawy, 2011). The time taken for lambs to stand in the current study was similar to those reported previously for Merino lambs (Bickell et al., 2010). Therefore, the limited results from this study indicate that increasing mob size did not influence the length of labour or ewe-lamb behaviour at birth.

The proportion of lambs which died from dystocia or starvation-mismothering also did not differ at the high and low mob sizes. Dystocia was identified as the major cause of death of lambs which is consistent with the findings of previous studies (Hinch et al., 1986; Holst et al., 2002; Refshauge et al., 2016). It is possible that dystocia and starvation-mismothering will remain the predominant causes of death regardless of mob size given their direct links to birthweight, birth type and ewe-lamb behaviour which are key determinants of lamb survival (Darwish and Ashmawy, 2011; Dutra and Banchero, 2011; Refshauge et al., 2016). Nevertheless, more intensive research is required to link individual ewe-lamb behaviour and subsequent cause of death in lambs at different commercial mob sizes.

5. Conclusion

Lambing twin-bearing ewes in smaller mobs improved lamb survival when FOO from live pasture was limited and ewes were supplementary fed during lambing. This highlights scope to improve lamb survival by reducing the mob size of twin-bearing ewes at lambing. It remains unclear why higher mob sizes result in poorer lamb survival. Further research is required to quantify the relationships between mob size and ewe-lamb behaviour during the first 3 days after birth when lamb mortality is known to be greatest. The relationship between mob size, FOO at lambing, supplementary feeding and lamb survival also requires investigation given reducing mob size may not improve lamb survival under all seasonal conditions.

Declaration of interest

The authors declare no conflicts of interest.

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Table 1. Description of behavioural traits measured during the periparturient period

Trait	Description
Time between birth of lamb 1 and 2	The time between complete delivery of the first- and second-born lambs
Time to stand	The time between birth and the lamb standing on all four feet for at least 5 seconds as per Dwyer and Lawrence (1999)
Foreign ewe interactions	An interaction was defined as the foreign ewe being within two ewe body lengths of the ewe and her progeny whilst displaying interest for at least one minute. Interest was defined as being actively interested and/or in physical contact with the ewe, her progeny and/or the amniotic fluids or foetal membranes, including grooming, nudging or allowing the ewes progeny to seek her udder. Recording of the time of each interaction ceased when the foreign ewe became greater than two ewe body lengths from the ewe and her progeny.
Foreign lamb interactions	An interaction was defined as the foreign lamb being within two ewe body lengths of the ewe and her progeny whilst displaying interest for at least one minute. Interest was defined as being actively interested and/or in physical contact with the ewe, her progeny and/or the amniotic fluids or foetal membranes, including grooming, nudging or

	seeking the udder. Recording of the time of each interaction ceased when the foreign lamb became greater than two ewe body lengths from the ewe and her progeny.

Table 2. Total number of observations during the periparturient period for the time between birth of twin lambs, time taken for the lambs to stand and lambing events which involved interaction with a foreign ewe or foreign lamb for the low (*n* = 55 ewes) and high (*n* = 210 ewes) mob sizes across the 14-day observation period

	Low	High
Ewes observed at lambing	36	66
Time between birth of lamb 1 and 2[A]	26	42
Time to stand for lamb 1[B]	26	44
Time to stand for lamb 2[B]	26	46
Foreign ewe interactions[C]	10	11
Foreign lamb interactions[D]	7	27

[A] Measured as the time between complete expulsion of the first- and second-born lambs

[B] Measured as the time between birth and the lamb standing on all four feet for at least 5 seconds as per Dwyer and Lawrence (1999)

[C] An interaction was defined as the foreign ewe being within two ewe body lengths of the ewe and her progeny whilst displaying interest for at least one minute

[D] An interaction was defined as the foreign lamb being within two ewe body lengths of the ewe and her progeny whilst displaying interest for at least one minute

Table 3. Predicted mean condition score of ewes and feed-on-offer (FOO) from live pasture at lambing and marking and survival of lambs to marking for the low (*n* = 55 ewes) and high (*n* = 210 ewes) mob sizes

	Low	High	*l.s.d.*	*r.s.d.*	*P*-value
Condition score at lambing	3.2	3.2	0.11	0.05	0.95
Condition score at marking	2.7	2.7	0.15	0.07	0.97
FOO at lambing (kg DM/ha)	383	293	142.5	62.85	0.15
FOO at marking (kg DM/ha)	565	459	176.7	77.95	0.17
Lamb survival (%)	79.9	73.7	3.7	1.62	<0.05

Table 4. The total number of lambs autopsied and percentage (%) which died from each cause of death category at the low (*n* = 55 ewes) and high (*n* = 210 ewes) mob sizes during the 14-day observation period. Data are presented in the back-transformed state.

	Low	High	P-value
n	39	188	-
Dystocia	5.1	6.9	0.68
Stillborn	20.6	16.7	0.68
Birth injury	25.6	22.8	0.73
Starvation-mismothering	15.4	17.0	0.80
Predation	0.0	3.5	0.44
Death in utero/premature	7.7	2.7	0.14
Exposure	17.9	22.3	0.55
Physical abnormalities	4.2	0.5	0.26
Undiagnosed	2.6	5.9	0.42