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THE INHERITANCE OF FLIGHT DISTANCE AS A MATERNAL BEHAVIOUR SCORE OF THE DAM AND ITS IMPACT ON LAMB SURVIVAL

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SUMMARY

This study was carried out to test two hypotheses: 1) whether flight distance of the dam (scored at tagging of her lamb within 24 hours of birth) is an indicator of her maternal behaviour and is a dam trait correlated with the survival rate of her lambs; and 2) whether the genetic and permanent maternal environmental effects of survival rate differ between single and multiple born lambs. The results showed that flight distance was genetically correlated only with survival rate at marking. The direct genetic effects for survival rate at birth, marking or weaning did not differ significantly between single- and multiple-born lambs, but the permanent maternal environmental effects were more important in multiple- than in single-born lambs. These observations support the notion that ewes that rear multiple-born lambs should be retained as replacement ewes in breeding programs.

INTRODUCTION

Lamb survival is key determinant of a profitable lamb production system, yet it is estimated that lamb losses in Australia amount to $540 million annually (Lane *et al*. 2015). Lamb survival is affected by a variety of genetic and environmental factors (Brien *et al*. 2014). Several lines of evidence demonstrate the importance of the genetics of maternal behaviour: 1) Ewe temperament is a heritable trait and survival rate is higher for lambs from calm ewes than for lambs from nervous ewes (Murphy 1999); 2) Maternal rearing ability to weaning is also heritable and can be improved by selection (Cloete *et al.* 2009); 3) Maternal behaviour score is heritable (Brown *et al.* 2016) suggesting that it could be improved by selection.

On the other hand, Bunter *et al.* (2018) reported that litter size at lambing influences genetic evaluation of maternal rearing ability and suggested that rearing ability traits should be defined separately by litter-size class to improve the accuracy of genetic evaluation for rearing ability. This paper therefore investigates the inheritance of flight distance as a maternal behaviour trait and survival rate of the lambs, both as traits of the dam, and this aims to elucidate the effect of litter size on the genetic parameters of lamb survival and flight distance.

MATERIALS AND METHODS

Resources. The data were collected on the Breech Strike Resource flocks of the Department of Primary Industries and Regional Development (previously the Department of Agriculture and Food) in Western Australia. This flock consisted of approximately 1,000 ewes that were annually mated to 22 sires. The total dataset consisted of 16,788 repeated records that were collected over the lifetime of 4,767 dams that had been mated annually, from 2005 to 2018, to one of 243 sires.

Management and measurements. Ewes were mated in February/March and lambs were born in July/August. Body weights and body condition score (1 to 5) were recorded on all ewes pre- and post-mating. Two weeks prior to lambing, each sire's lambing ewe group was drafted off, weighed, condition scored and placed on a lambing plot to obtain accurate pedigrees of the lambs at lambing. This resulted in lambing plot and sire of the lambs being confounded within year. However, link sires across years were rotated between mating groups to ensure that repeat mating groups don't lamb in the same paddock again. Between 4 and 18 linked sires were used between years.

The lambs were tagged and weighed within 24 hours after birth. Date of birth, dam identification, gender of lamb, birth status (single, twin or triplet) and lambing difficulties were recorded at birth. During the process of tagging and recording birth information, flight distance, as an indicator of mothering ability, was scored from 1 (dam stays close to lamb) to 6 (>50 meters away from scorer) based on the average distance between the dam and the lamb. At marking, approximately 4 to 5 weeks after lambing, the lambs were tail docked, weighed and identification checked. They were weaned and weighed at an average age of 110 days. All deaths from birth to weaning were recorded.

Statistical analyses. Three survival rate categories were created as traits of the dam: survival at birth (within 24 hours after birth), survival from birth to marking, and survival from marking to weaning. The data were analysed with ASREML (Gilmour *et al.* 2015). A sire model for dam of the lamb, with repeat measurements of the dam (of the lamb) as an additional random factor, was fitted to estimate additive genetic variance and permanent maternal environmental effects for flight distance, survival at birth, survival from birth to marking, and survival from marking to weaning, as traits of the dam. The flight distance data were treated as normally distributed. By contrast, the survival data were binary (alive = 1; dead = 0) so were subjected to a binomial analysis with a logit link function. Year of birth, lamb gender, litter size, dam age, lambing paddock, and dam body weight and condition score (pre-mating, post-mating, pre-lambing) were fitted as covariates. All interactions between fixed effects were initially fitted. Statistically non-significant ($P < 0.05$) factors were dropped from the model until the final model only contained statistically significant factors.

The same analyses were carried out where the dataset was split into sets containing only singletons or only multiples. The phenotypic variance (Vp) was calculated as the sum of the sire variance, permanent maternal environmental variance and error variance. As this analysis was on a logistic scale, a variance of 3.289 was used for the error. The heritability of survival rate was calculated as 4 times the sire variance as a proportion of the phenotypic variation. The importance of the permanent maternal environmental effect was calculated as the proportion of the permanent maternal environmental variation relative to the phenotypic variation. A series of bivariate analyses were then carried out between the survival traits and flight distance, using the significant fixed factors from the univariate analyses of the different traits in the model to estimate the genetic covariance between flight distance and survival traits. The genetic correlation (r_g) was estimated as the covariance between flight distance and the survival traits divided by the square root of the product between the variance of flight distance and that of the survival traits.

RESULTS AND DISCUSSION

Table 1 shows the number of records, means and variances for the three survival traits and genetic parameters for the combined dataset, separately for single- and multiple-born lambs. Survival rates were 0.95 at birth, 0.87 from birth to marking, and 0.98 from marking to weaning, resulting in 81 lambs surviving per 100 lambs born. Year of birth affected all traits ($P < 0.01$). Larger litters had lower survival rates at birth, marking and weaning ($P < 0.01$). Survival rates at marking and at weaning were lower ($P < 0.01$) for older ewes. However, older ewes stayed closer to their lambs at tagging than younger ewes ($P < 0.001$). For flight distance, interactions ($P < 0.001$) were observed between year of birth and litter size, and between year of birth and age of dam.

Heritability estimates (h^2_D). Where the dataset was split into single- and multiple-born lambs (Table 1), multiple lambs had higher phenotypic variances at birth, marking and weaning. Heritability estimates of survival rate in the total dataset were moderate (0.24 ± 0.09) at birth, low (0.09 ± 0.04) at marking, and not significantly different from zero at weaning. The heritability estimates of survival rate of multiple-born lambs at birth, marking and weaning were higher than those of single-born lambs, but all these estimates had large standard errors so were not significantly (2 x SE) different from zero.

The heritability of flight distance was low (0.07 ± 0.02). However, for single- and multiple-born lambs, the heritability estimates were considerably higher than those of the combined dataset. The heritability of flight distance of multiple-born lambs was higher ($P < 0.001$) than that of single-born lambs (0.33 ± 0.06 vs 0.17 ± 0.04), suggesting that survival rate as a dam trait may not be genetically the same trait for single and multiple born lambs.

Permanent environmental effects (m^2_{pe}). A moderate permanent maternal environmental effect of 0.25 (± 0.03) was found for survival rate at birth, which decreased to 0.10 (± 0.02) at marking. It had no effect on survival rate at weaning, showing the importance of maternal behaviour early in life. For flight distance a moderate permanent maternal environmental effect of 0.26 (± 0.01) was found in the combined dataset. The effect was more than five times that for multiple born lambs (0.47 ± 0.02) compared to single born lambs (0.09 ± 0.02).

Table 1. Number of records, means ± standard deviation (sd), variances and genetic parameters of survival rate as a trait of the dam at birth, marking and at weaning, for the combined dataset and for single- and multiple-born lambs

Parameter	Survival rate			Flight
	Birth	Marking	Weaning	distance
Total dataset				
No. of records	15,224	14,445	12,819	14,682
Mean ± sd	0.95 ± 0.22	0.87 ± 0.33	0.98 ± 0.12	3.69 ± 1.50
Vp	4.74	3.76	3.56	0.82
h^2_D ± SE	0.24 ± 0.09	0.09 ± 0.04	0.19 ± 0.16	0.07 ± 0.02
m^2_{pe} **± SE**	0.25 ± 0.03	0.10 ± 0.02	0.03 ± 0.07	0.26 ± 0.01
Single births				
No. of records	6,763	6,503	5,918	6,555
Mean ± sd	0.96 ± 0.19	0.91 ± 0.29	0.99 ± 0.09	3.70 ± 1.40
Vp	3.54	3.61	3.74	0.80
h^2_D ± SE	0.02 ± 0.18	0.05 ± 0.08	0.33 ± 0.21	0.17 ± 0.04
m^2_{pe} **± SE**	0.07 ± 0.09	0.07 ± 0.04	0.04 ± 0.07	0.09 ± 0.02
Multiple births				
No. of records	8,461	7,942	6,901	8,127
Mean ± sd	0.94 ± 0.24	0.84 ± 0.37	0.98 ± 0.15	3.69 ± 1.59
Vp	5.57	3.93	3.61	0.99
h^2_D ± SE	0.17 ± 0.12	0.09 ± 0.05	0.12 ± 0.19	0.33 ± 0.06
m^2_{pe} ± SE	0.37 ± 0.04	0.14 ± 0.02	0.06 ± 0.08	0.47 ± 0.02

Correlations. Table 2 shows the phenotypic, genetic and environmental correlations between flight distance and survival rate as a trait of the dam at birth, marking and at weaning. Correlations between flight distance and survival rate traits at birth and weaning were very low or not significantly different from zero, as were the genetic correlations at birth and weaning. The only significant genetic correlation was between flight distance and survival rate at marking (0.64 ± 0.20).

Table 2. Phenotypic (r_p), genetic (r_g) and environmental (r_e) correlations and standard errors (SE) between flight distance at tagging and survival rate at birth, marking and weaning as traits of the dam

Trait	Flight distance		
	r_p ± SE	r_g ± SE	r_e ± SE
Survival rate at birth	-0.03 ± 0.01	-0.12 ± 0.24	-0.03 ± 0.00
Survival rate at marking	-0.01 ± 0.01	-0.64 ± 0.20	0.01 ± 0.00
Survival rate at weaning	0.05 ± 0.02	-0.30 ± 0.45	0.06 ± 0.01

CONCLUSIONS

Survival rate as a trait of the dam at birth, was a heritable trait. This study did not show major differences in direct heritability estimates for survival rate at birth, marking and weaning, in the separate estimates for single- and multiple-born lambs. However, the permanent environmental effect was more important for survival rate in multiple-born than in single-born lambs at both birth and marking.

The direct heritability estimate, and the permanent environmental effect of flight distance were also significantly greater in multiple-born than in single-born lambs, suggesting that maternal behaviour as scored by flight distance is an important factor in the survival of multiple-born lambs. These observations support the conclusion of Hatcher *et al.* (2014) that ewes that consistently rear twins should be retained rather than ewes that consistently rear a single lamb. We conclude that, in breeding programs, permanent environmental effects should be accounted for more accurately to identify ewes that consistently rear multiple born lambs. More research on the inheritance and importance of permanent environmental factors is required on this issue as well as the underlying physiological causes of this phenomenon.

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