Contributed paper

DEFINING LONGEVITY AND ESTIMATING GENETIC PARAMETERS IN AUSTRALIAN MERINO EWES

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SUMMARY

Currently, there are no measures of ewe longevity recorded by Australian sheep breeders for utilisation as part of their breeding objective. In the absence of disposal codes, this study explored the potential to use production records to define ewe longevity in Merino sheep and estimate genetic parameters for the resulting trait. The longevity trait was defined as the ewe's total life (TL) in the flock from birth to their last available production record. To identify suitable non-censored data, cohorts were selected based on the amount of pedigree and consistent annual production recording. Under these assumptions, the MERINOSELECT database provided 267,517 longevity records from 143 flocks. The heritability of TL was 0.22 ± 01. Adjusting TL for the ewe's lifetime reproductive performance, accounted for 94% of the variation in TL, reduced the heritability to 0.11 ± 01. The results herein indicate that it is possible to describe longevity in the Merino ewes using production records from the MERINOLSELECT database. TL was found to be heritable but further exploration is required before incorporation in industry breeding objectives.

INTRODUCTION

Longevity can be defined as the duration of a ewe's productive life in the flock. In Australian Merino, ewes are usually first mated at 1.5 years old with most ewe's final mating at 4.5 to 6.5 years of age, after which they are culled as cast for age ewes (Kleemann *et al.* 2016). Age based culling is extensively used in Australian commercial sheep flocks (Hatcher *et al.* 2009), most commonly at 6 years of age. Longevity is a composite trait describing aspects of production, health, and reproduction and it is considered a trait of high economic importance for sheep production systems (McLaren *et al.* 2020). Greater longevity in sheep production leads to an increased overall mean age of the flock, more lambs available for sale, and higher reproductive performance (Conington *et al.* 2004). Conington *et al.* (2001) defined longevity as the period from birth to culling or death (days). According to previous research, the heritability estimates of longevity commonly ranges between 0.05 to 0.08 with a range from 0 to 0.33 depending on the species, production system and trait definition (Conington *et al.* 2001; El-Saied *et al.* 2005). In the MERINOSELECT database (Brown *et al.* 2007), culling date and reason are sparsely recorded. Therefore, building on the proposition by McLaren *et al.* (2020), we explored the potential of using the ewe's last production record as a proxy for culling age. The objective of this study was to define ewe longevity using production records and estimate genetic parameters for the resulting trait.

MATERIALS AND METHODS

Describing Longevity. At the time of the analysis, there was no standard recording practice for capturing ewe longevity and limited recording of disposal date in the MERINOSELECT database. The MERINOSELECT database, described by Brown *et al.* (2007), currently includes pedigree and phenotypic records for 3,078,163 animals from 1,759 flocks submitted by Australian and New Zealand Merino breeders. A longevity trait was built based on the birth date of an individual and the

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date of their last submitted production record, which was suggested by McLaren *et al.* (2020) as an alternative to a specified culling date. Total life of the ewes was referred to as the time between these two dates in years and aligns with the longevity traits presented by Conington *et al.* (2001); El-Saied *et al.* (2005). For TL to reflect the lifetime of the ewe it was assumed that the ewe's cohort (site of birth, flock and year of birth) is routinely recorded and so the absence of the ewe record reflects her departure from the flock and not that the cohort was not recorded. Cohorts considered to have suitable data were characterized as; 1) born since 2000, 2) had a minimum of 3 years of production records, 3) had an annual record for wool and reproduction recorded up to 6 years of age, and 4) contained at least 30 ewes and a minimum of 70% of the animals were assigned a sire. Approximately 20% of ewes in the database were from a cohort with sufficient recording (Table 1).

Table 1. Number of flocks, cohorts and animals represented in the cleaned data set after implementing each of the data assumptions to ensure the eventual phenotype will reflect the animal's longevity in the flock are instated

Assumptions	Flocks	Cohorts	Animals
Ewes	1,086	7,923	1,574,855
Born since 2000	771	5358	1,371,799
Minimum lifespan of cohort 3+ years	676	4,410	1,187,133
Cohort recorded annually up to 6 years of age	447	3,249	1,147,498
Cohorts contain at least 30 ewes and > 70% of animals assigned sire	285	1,451	473,698
Cohorts had annual reproduction and wool production records	143	746	267,517

Statistical Analysis. Genetic parameters for TL were estimated from a series of univariate analyses using an animal model in ASReml version 4.1 (Gilmour *et al.* 2015). A pedigree spanning 2 generations back from the phenotyped animals, due to computational restraints, was extracted from the MERINOSELECT database (Brown *et al.* 2007) and incorporated 335,704 animals.. The phenotyped individuals descended from 6,030 sires and 103,730 dams. The base animal model (Model 1) used in the analysis can be described by the following equation:

$$Y = Xb + Z_1a + e$$

Where Y is the vector of TL records, b is the vector of fixed effects that include the birth type (1, 2, 3, 4+), rear type (1, 2, 3+), age of dam (linear) and cohort. Where cohort was defined by the animals' site of birth, flock and year of birth. a is the vector of animal genetic effects with X and Z the incidence matrices that relate the respective effects to Y and e is the vector of the random residual effect. The phenotypic variance was calculated as the sum of the additive and residual variance.

TL reflects the lifetime of the ewe in the flock, which describes both the ewe's fitness and survivability but also the ewe's production performance and merit relative to the flock's breeding objective. To create a trait that more closely reflects the ewe's fitness and survivability and understand the underlying factors that may impact the ewe's time in the flock, TL was adjusted by fitting a series of co-variates, nested within cohort.

The covariates included; 1) the ewe's Merino Production Plus (MPP) index value (Swan *et al.* 2017), 2) the ewe's annual wool production across their lifetime (AWP, total lifetime greasy fleece weight (kg) / TL), 3) proportion of successful lambing opportunities (SLO, number of successful lambing opportunities / TL), and 4) proportion of lambs born (ALP, sum of lambs given birth to / TL). Animals culled from the flock prior to producing a lamb or fleece were assigned covariate values of zero. In Model 2, the covariates were fitted as fixed effect terms where they were nested within cohort. To better understand the proportion of variation in TL described by each of the covariates and which of these is having the greatest impact on the phenotypic and additive variance, the terms were fitted as random effects (Model 3).

RESULTS AND DISCUSSION

The result of the final assumption filters left 267,517 ewes with TL records from 143 flocks across 746 cohorts (Table 1). Only 76% of ewes born stayed in the flock to the yearling stage (42% to 2 years of age). This includes 203,350 ewes with at least one record describing lambing outcomes or fleece production (missing covariates were given a value of 0). The average TL for the Merinos was 2.37 (SD = 1.89) years with a maximum of 13.06 years. The results are much lower than 4.5 to 6.5 years reported by Kleemann *et al.* (2016) in Merino breeding flocks. In another study in Merino commercial flocks, Hatcher *et al.* (2009) stated that animals are usually culled at 6 years of age. This is in part likely due to the greater selection pressure placed on the ewe flock to achieve desired genetic gains within the seed stock sector. The mean SLO and ALP were 0.30 (SD = 0.30) and 0.41 (0.45), respectively.

The phenotypic variance and heritability of TL using Model 1 were 3.34 ± 0.02 and 0.22 ± 0.01, respectively (Table 2). After adjusting for the overall genetic merit, wool production, and reproductive performance (Model 2) the phenotypic variance and heritability were reduced to 1.22 ± 0.01 and 0.11 ± 0.01. The heritabilities herein for TL align with the low heritability estimates reported in the literature of 0.08 ± 0.01 in Scottish Blackface ewes by Conington *et al.* (2001) and 0.02 ± 0.01 to 0.06 ± 0.02 in Spanish Churra ewes by El-Saied *et al.* (2005). In an Australian Merino research flock, Hatcher *et al.* (2009) reported the heritability of ewe survival at 2nd, 3rd, 4th and 5th year in a range from 0 to 0.12. Brash *et al.* (1994) also described a heritability in an Australian Dorset sheep population of 0.06. As mentioned earlier, the breeders submitting data to the database tend to apply selection pressure and maintain heavily selected ewe flocks, which leads to censored data, which in part might explain the higher heritability of Model 1.

Table 2: Variance components estimates (± se.) for total life with Model 1 (base), Model 2 (base + covariates nested within cohort) and Model 3 (base + covariates nested within cohort and fitted as random effects). The percent column represents the proportion of total variation accounted for by each random effect fitted in Model 3

	Model 1	Model 2	Model 3	Percent
Heritability (h^2)	**0.22 ± 0.01**	**0.11 ± 0.01**	**0.11 ± 0.01**	
Phenotypic (σ^2_p)	**3.34 ± 0.02**	**1.22 ± 0.01**	**1.22 ± 0.01**	
Residual (σ^2_e)	2.61 ± 0.01	1.08 ± 0.01	1.08 ± 0.01	4 %
Direct additive (σ^2_a)	0.73 ± 0.02	0.14 ± 0.01	0.14 ± 0.01	1 %
Cohort			0.16 ± 0.01	1 %
Success rate of lambing opportunities (SLO)*			14.94 ± 0.83	63 %
Annual lamb production (ALP)*			7.25 ± 0.42	31 %
Annual wool production (AWP)*			0.03 ± 0.01	0 %
Merino production plus index (MPP)*			0.00 ± 0.01	0 %

*Covariates were fitted as nested terms within cohort

The majority of the variation in ewe longevity was described by the ewe's reproductive performance (94%) with the more fertile (SLO = 63%) and larger litter producing (ALP = 31%) ewes retained in the flocks longer (Table 2). This suggests that the underlying factor determining the length of time ewes are retained in the flock is associated with breeders' selection decisions around reproduction and not necessarily because of the ewe's inherent fitness to survive. Reproduction is one of the most important traits in the profitability of sheep farming enterprises, and ewes with high reproductive performance are most likely to perform better in the longer term (Zishiri *et al.* 2013). In the current study, AWP explained only a small proportion of the variation in ewe longevity, and it is hypothesised that variation in wool produced across her lifetime seems to have had little impact on the breeders' selection decisions to keep the ewe in the flock.. However, genetic merit for wool production is likely to have a significant influence on the ewe's value to the flock and this could be explored further by estimating the genetic association between longevity and wool production and quality traits. The MPP index explained no variation in the TL of the ewe. This may be in part because the index values used in this study was based on the information available at time of analysis not when the animal was being dispersed from the flock.As the flock's breeding objectives are likely to differ, the MPP index whilst moderately correlated with most flock's breeding objectives may not entirely reflect all the selection decisions placed on the ewe flock at the individual breeder level.

CONCLUSIONS

The results of this study indicated that it is possible to capture and define longevity in Australian Merino ewes by utilizing performance records available within the MERINOSELECT database. Reproductive performance is the largest factor behind ewe longevity and should be accounted for if the desired trait is to more closely reflect the ewe's fitness to survive and not just her ability to produce a lamb. Correlations between longevity and key production traits as well as the estimation of its economic value require exploration before determining the value of TL within industry breeding objectives.

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