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A simulation model to partition ewe efficiency into component traits for genetic analysis

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ABSTRACT

Ewe efficiency is extremely topical in the New Zealand sheep industry. This paper describes a stochastic simulation model which facilitates partitioning of a defined ewe efficiency equation into its component genetic traits. It accounts for, and simplifies, the complex and sometimes unfavorable interactions among components of ewe efficiency. The model tracks simulated genetic effects, inherited from the ewe's sires, in breeding ewes and their lambs for key performance recorded traits. The traits simulated are weaning weight, mature weight, number of lambs born, lamb survival, and longevity. Ewe efficiency is defined as the difference between value of lambs weaned and ewe and lamb costs, rather than as a ratio. Output value in NZ$ for the efficiency equation is computed on a ewe by ewe basis, as a function of number of lambs born, lamb survival and weight of lamb weaned, with each of these components partly influenced by one or more genetic effects inherited from simulated sires of the breeding ewes. Preliminary results from the model have identified litter size, ewe longevity, maternal lamb survival, and maternal weaning weight as being important drivers of ewe efficiency. The relative balance of their importance is influenced by farm production levels and environment.

Keywords: sheep; efficiency; genetics; economics; breeding.

INTRODUCTION

The productive output of breeding ewes at weaning and as culls, relative to the cost of ewe feed and raising flock replacements is a useful definition of ewe efficiency. Ewe efficiency has become topical in New Zealand as sheep farmers seek to maintain the momentum of productivity gains achieved over the last 20 years through higher litter sizes and heavier carcass weights (Cocks & Brown, 2005). A ewe's performance reflects the expression of many separate component genetic traits, some of which may have been improved by historic quantitative genetic selection. For example, weaning weight is readily recorded and direct genetic effects are highly heritable (Safari *et.al.,* 2005). Other traits such as litter size are easily recorded but associated with delays and are unknown at the time of selection. Still others such as direct and maternal lamb survival, maternal weaning weight, twinning rate at a constant average litter size, and ewe longevity, can be recorded, but there is minimal evidence of favourable genetic progress having occurred in any of them in New Zealand (Amer, 2009). These traits may have very low heritability or be recorded too late in life to influence the selection of the recorded animal or its sire.

Potential antagonisms between traits can mean that selecting for one may have a negative effect on another. For example, ewe longevity may deteriorate with increased litter size, resulting in lower than anticipated expected aggregate benefits of genetic improvement from an improvement in selection on any single component trait. While modelling using selection index theory can unravel some of these antagonisms, the theory also implies linear relationships between traits and profit that may not necessarily occur. The process and results of selection index theory are also relatively unintuitive to many.

The objective of this study was to create a framework upon which ewe efficiency could be studied under a variety of price structures and farm conditions. The model framework used simultaneously accounted for the degree of genetic variation expected to exist in sires, the transmission of genetic merit for relevant traits from sires to their daughters and further descendents, as well as the complex interactions amongst traits within the farm production environment. Traits identified as being important potential drivers for genetic improvement in ewe efficiency will be targeted for further research using novel breeding strategies that incorporate large numbers of genetic markers.

MATERIALS AND METHODS

Overview

We describe a simulation model, developed using Mathcad 14.0 (2008) software, which inputs price structures for different farm types to provide an indication of which component traits are important in determining ewe efficiency under varying conditions.

The model simulates known interactions between eight component traits either measureable or inferred, to generate breeding values for sires and their daughters within a sire breeding scheme, and then measures the efficiency of those daughters. This in turn provides an assessment of the efficiency

TABLE 1: Simulated trait breeding values and efficiency component affected.

Simulated component trait	Abbreviation	Efficiency component affected
Weaning weight	WWT	Weight of lamb weaned
Maternal weaning weight	WWTmat	Weight of lamb weaned
Ewe mature weight	EweWT	Weight of lamb weaned
Lamb survival	SUR	Weight of lamb weaned
Maternal survival	SURmat	Weight of lamb weaned
Number of lambs born	NLB	Weight of lamb weaned, and ewe feed value
Triplet proportion	TRIP	Weight of lamb weaned, and ewe feed value
Longevity	LONG	Ewe replacement value

TABLE 2: Heritability, phenotypic variance, and unit of measurement of simulated traits. Explanation of abbreviations for component traits given in Table 1.

Simulated component trait	h^2	Phenotypic variance	Units
WWT	0.20	12.2	kg
WWTmat	0.10	12.2	kg
EweWT	0.45	49	kg
SUR	0.01	0.16	lambs
SURmat	0.02	0.16	lambs
NLB	0.10	0.32	lambs
TRIP	0.04	0.06	lambs
LONG	0.05	1.2	years

of the sire. Phenotypic variation of ewe efficiency is simulated as a function of genetic and environmental variation in the component traits. Since statistical evaluation of ratios can be problematic when the variance in the numerator relative to the denominator is inconsistent (Gunsett, 1984), a difference equation as opposed to a ratio of outputs over inputs has been used.

Working definition of ewe efficiency

Ewe efficiency was measured as a function of the individual components. The formula used for calculating efficiency (EE) for an individual ewe (*i*) was

$$\mathrm{EE}_i = \mathrm{TWWTV}_i + \mathrm{EV}_i - \mathrm{FC}_i - \mathrm{RC}_i$$

where TWWTV is the value of the total weight of lamb weaned, EV is cull ewe value, FC is feed costs including the cost of annual maintenance and the additional costs associated with pregnancy, lactation and post-weaning growth prior to mating, and RC is the expected annual cost of replacement based on the expected survival of the ewe. All lambs not required as replacements are assumed to be sold at weaning.

Each of these components of ewe efficiency is influenced by genetic merit for a subset of the total number of traits simulated. The breeding values simulated along with the component traits affected are shown in Table 1.

Simulation of genotypes, phenotypes and estimated breeding values

The simulation model generated true breeding values for the eight component traits. A total of 500 sires were generated, and each mated to 100 randomly generated ewes, with breeding values and phenotypes simulated for 50,000 daughter offspring in total.

The estimated breeding value for each component trait (t) in the daughters was calculated as

$$\mathrm{BV}_{\mathrm{t,daughter}} = 0.5(\mathrm{BV}_{\mathrm{t,sire}} + \mathrm{BV}_{\mathrm{t,dam}}) + \mathrm{Mendelian}$$

where Mendelian variation was allowed for by addition of a random normal deviate sampled from a distribution with a mean of 0 and a standard deviation derived using the heritability and phenotypic variance of the trait.

Phenotypes were calculated as

$$\mathrm{Pheno}_{\mathrm{t,daughter}} = \mathrm{mean}_{\mathrm{t}} + \mathrm{BV}_{\mathrm{t}} + \mathrm{Env}$$

where the breeding value was added to the trait mean, and environmental variation was allowed for by the addition of a random normal deviate with variance equal to the environmental variance for the trait.

The heritability, phenotypic variance and mean trait values are shown in Table 2, along with the trait measurement units. Genetic and phenotypic correlations among traits were simulated by taking a Cholesky decomposition of the variance covariance matrix, where genetic correlations between traits included: WWT:EweWT (0.6), WWT:NLB(0.15), EweWT:NLB (0.15), LONG:NLB (-0.1) LONG:TRIP (-0.2). All other trait combination interactions were assumed to be zero. Environmental correlations were assumed to be identical to genetic correlations.

Deriving efficiency components from simulated traits

The daughters generated were assessed for efficiency. A single mating was assumed for each ewe, with the age of the ewe at mating, the number of lambs born and raised, and weight of lamb weaned determined according to the ewe's genetic merit. The cost of feeding each ewe was determined by her individual live weight phenotype, and the additional feed costs associated with pregnancy, lactation and post-weaning recovery. The cost of flock replacements was determined by the longevity breeding value of the ewe's sire.

***Farm type**:* Three types of farms were defined. Easy Country (mean number of lambs born = 1.5) and High Performance (mean number of lambs born = 2.1) farm types had low death rates, but higher average feed costs due to the potential to convert a proportion of spring feed into silage for sale to dairy farms. The third farm was modelled as Hard Country, (mean number of lambs born = 1.5) with lower lamb weaning weights and decreased survival rates for both ewes and lambs. Overall feed costs were also lower, with no opportunity to convert spring feed into silage.

Ewe age: Age of the ewe at mating was sampled from a distribution derived from the average survival of a ewe at different ages, according to farm type, and the longevity breeding value of the sires used to breed the ewes. Longevity breeding values reflect the time, in years, that can be added or subtracted to a ewe's expected lifespan. Ewes were assumed to be first mated at the age of two years with no allowance made for joining as a hogget.

On Easy Country, the annual ewe survival rates for 2 to 8 year-old ewes were assumed to be 0.90, 0.95, 0.80, 0.60, 0.40, 0.20 and 0.10 respectively. Using a sire with a longevity breeding value of 0, the proportion of daughters aged 2 to 8 years was; 0.25, 0.22, 0.21, 0.17, 0.10, 0.04, 0.01. On Hard Country, annual ewe survival rates were dropped to 0.85, 0.90, 0.75, 0.55, 0.35, 0.10 and 0.05 respectively for 2 to 8 year-old ewes. The lower annual ewe survival rates increased the proportion of two year-old ewes entering the flock (0.28), with more flock replacements required per ewe. If the sire breeding value for longevity increased to 0.5, then the proportion of two year-olds would drop to 0.23 resulting in the average ewe age increasing by 0.24 years.

Ewe number of lambs born: The number of lambs assigned to a ewe, was determined by a litter size distribution derived from the ewes number of lambs born (NLB) breeding value. The distribution was adjusted for ewe age, with ewes aged two year-old, or older than five year-old, having 0.2 less lambs than a ewe aged three to five years of agewith the same NLB breeding value. The proportion of singles, twins and triplets for a ewe was adjusted according to the ewe's triplet breeding value. When numbers of triplets in the flock were low, the reduction in triplets was constrained to the number of triplets that would otherwise have been present. Conception rate was set at 98%.

Ewe number of lambs weaned: The number of lambs weaned by the ewe was determined by randomly assigning lambs as being alive or dead, so that on average the survival rates of singles, twins and triplets equaled probabilities of survival defined by the mean survival rate and the ewe's direct and maternal breeding values for lamb survival. The probability of a lamb surviving was calculated as

$$\mathrm{pLS} = (0.5\mathrm{SUR} + \mathrm{SURmat})_{\mathrm{eweBV}} + \mathrm{mean}$$

where the mean survival was dependent on ewe litter size and type of farm. The lamb survival probabilities for singles, twins and triplets were 91%, 89% and 60% respectively for the Easy Country and High Performance farms and 90%, 80% and 50% for the Hard Country farms.

Weight of lamb weaned: The total weight of lamb weaned was calculated as the sum of surviving lamb weaning weights, with the value per kg of live weight weaned set to $2.70.

Lamb weaning weight was calculated as

$$\mathrm{WWT} = (0.5\mathrm{WWT} + \mathrm{WWTmat})_{\mathrm{eweBV}} + \mathrm{mean} + \mathrm{M} + \mathrm{E}$$

where Mendelian and environmental variation was allowed for by the addition of random normal deviates sampled from a distribution with a mean of 0 and a standard deviation derived using the heritability and phenotypic variance of weaning weight. The mean weaning weights assumed for single, twin and triplet lambs on Easy Country are 30 kg, 25 kg and 22.5 kg and 28 kg, 23 kg and 20 kg on Hard Country respectively.

Ewe survival post mating: Survival of ewes mated through to lambing, and from lambing to weaning was randomly sampled from a distribution according to the ewe's NLB. The probability of the ewe surviving between mating and lambing was set to 98%, 98% and 95%; and surviving from lambing, including birthing, to weaning, 98%, 96% and 91% for ewes lambing single, twin and triplet litters respectively. No lambs were assigned to ewes which died between lambing and weaning.

Maintenance: The cost of maintenance was calculated as the cost of feeding the ewe for a year, with three seasonal feed prices. If a ewe died the cost of maintenance ceased at the time of death. The feed costs were derived according to the base cost of feeding a ewe and farm type. A provisional figure of $40.15 has been published by Ministry of Agriculture and Fisheries, (2008) as the total farm expenditure per stock unit over all farm classes in 2007-08. The original stock unit classification of a 55 kg ewe weaning a single lamb and consuming 550 kg/DM per year was adjusted to reflect the cost of maintaining a 62 kg ewe, excluding pregnancy and lactation. This resulted in a base feed value of $0.064 per kg/ dry matter (DM). In spring, Easy Country feed can be converted to silage and sold to dairy farmers. With the current value of silage at

$0.25 per kg/DM, if 20% of pasture can be converted to silage, this increases the spring feed value from $0.064 to $0.105. In winter, additional silage is required for additional feed on both Easy and Hard Country properties. In Easy Country we assumed 30% of the feed was silage valued at $0.28 kg/DM and in Hard Country, 40% of the feed was silage valued at $0.36 kg/DM where this included the additional labour and transport costs associated with silage production and feeding on more extensive terrain.

***Pregnancy and lactation*:** These costs were calculated according to winter and spring feed costs for pregnancy and lactation of 1, 2 or 3 lambs. No lactation costs were incurred if the ewe died during pregnancy.

***Post-weaning recovery*:** The cost of replacing weight lost during pregnancy and lactation was calculated according to the autumn food cost for ewes weaning 1, 2, or 3 lambs. If the ewe died between weaning and mating, it was assumed she consumed half of the food required for post-weaning weight replacement.

***Cost of replacement*:** The number of replacements required per ewe was determined by the proportion of two tooths in the flock as derived from the sires longevity age distribution, and adjusted for survival between selection and mating at two years of age. The cost of replacement was calculated using the number of replacements multiplied by the cost of feed to grow a replacement to the same mature weight, plus the cost of labour associated with the ewe between selection around the age of eight months and two years of age when she matured and was able to produce lambs. The cost of labour was estimated assuming one labour unit earning a $50,000 salary can maintain 5,000 stock units, with the cost of labour for one stock unit being $0.027 per day.

***Cull ewe value*:** The cull value was determined by the number of flock ewe replacements required per ewe adjusted for a mature weight of 62 kg. The average value of a cull ewe was set at $60. Where a ewe died during pregnancy, lactation or post-weaning, the cull value was set to zero.

RESULTS

A mean efficiency was calculated for each sire based on his daughters. On easy country, the mean efficiency of the 500 sires ranged from $8 to $42, with a mean of $23. When mean NLB increased from 1.5 to 2.1, representing a High Performance flock, efficiency increased to $35 with a range of $12 to $50. On Hard Country with lower ewe and lamb survival rates, the average efficiency dropped to $6 with a range of -$9 to $17.

On Easy Country the number of ewe replacements per sire group ranged from 0.19 to 0.36 with an average of 0.26. The cost of replacement over all ewes ranged from $18 to $37, with an average replacement value of $26. On Hard Country, where ewe survival rates were lower, the average number of ewe replacements per sire group increased to 0.29 with a range of 0.21 to 0.40, with an average cost of $32.

Major drivers affecting ewe efficiency included the cost of feed and the value of lamb. The value of winter and spring silage was included in feed costs. When the opportunity cost of spring silage was removed, the efficiency of a standard flock on Easy Country increased from $23 to $32. However, that would be offset by the lost value of silage sold to other users, which indirectly affected the overall efficiency of the farm. Assuming the feed costs included the allowance for silage, the value of lamb weaning weight was a key driver. An increase from $2.70/kg to $3.50/kg, increased the average efficiency to $50. If lamb price dropped to $2.00/kg then average efficiency was less than $1.

Pearson correlation statistics were used to test the relationship between estimated sire efficiency

TABLE 3: Correlations between estimated sire efficiency and the component traits for easy country, high performance and hard country. Explanation of abbreviations for component traits given in Table 1.

Simulated component trait	Farm type and proportion of estimated variation in sire efficiency explained by component traits								
	Easy country (59%)			High performance (49%)			Hard country (58%)		
	Correlation coefficient	P value	Explained variation (%)	Correlation coefficient	P value	Explained variation (%)	Correlation coefficient	P value	Explained variation (%)
WWT	0.21	<0.001	6.8	0.17	<0.001	9.9	0.13	<0.001	6.4
WWTmat	0.29	<0.001	15.8	0.34	<0.001	25.0	0.29	<0.001	16.1
EweWT	-0.01	<0.001	6.8	-0.03	<0.001	5.2	-0.11	<0.001	10.6
SUR	0.18	<0.001	2.3	0.27	<0.001	10.4	0.21	<0.001	3.9
SURmat	0.39	<0.001	25.7	0.43	<0.001	41.0	0.43	<0.001	31.4
NLB	0.49	<0.001	36.2	0.05	0.403	0.1	0.31	<0.001	15.9
TRIP	-0.06	0.854	0.0	-0.17	0.005	1.7	-0.12	0.629	0.0
LONG	0.19	<0.001	6.4	0.22	<0.001	6.7	0.32	<0.001	15.7

and sire breeding values for each of the component traits. Table 3 shows the correlations observed for an Easy Country flock, a High Performance flock run on easy country and a Hard Country flock using the feed costs described with the value of lamb set at $2.70/kg. Estimated efficiency and breeding values for WWT, WWTmat, SUR, SURmat and LONG showed strong positive correlations. Longevity reduces replacement cost, and high direct and maternal breeding values for WWT and SUR result in heavier lambs that are more likely to survive. NLB was very important at low litter sizes. However, in a High Performance flock NLB breeding values had little effect as mean NLB was very high and likely close to its economic optimum. EweWT and Triplet breeding values were negatively correlated. Ewes with a high mature weight cost more to feed, whilst the negative interaction between triplet and longevity breeding values, as triplet bearing ewes tend to ‘burn out’ faster, results in triplet bearing ewes having higher replacement costs.

SAS PROC GLM was used to estimate the relative importance of each of the component traits in the model based on percent sums of squares in a regression of ewe efficiency on sire breeding values for traits of interest. Relative importance was computed by taking each component trait’s sum of squares from the analysis of variance, and expressing this as a proportion of the total sum of squares. In Easy Country, the eight component traits explained 59% of the variation observed in estimated sire efficiency. Significant effects were observed for all traits except TRIP, with the majority of the variation explained by NLB, and maternal traits for WWT and SUR (Table 3). In a High Performance flock, little variation was explained by NLB breeding value, with the component traits explaining 49% of the total variation observed within the sires. Maternal survival breeding values had a large impact with the ability of the ewe to care for her young accounting for 41% of the variation explained by the traits. Whilst the component traits explained a similar amount of variation in estimated sire efficiency in both Easy and Hard country at 59% and 58% respectively, lower rates of ewe and lamb survival on Hard country, result in ewe weight and longevity becoming more important with larger ewes costing more to feed and replace.

DISCUSSION

This report confirms the importance of NLB in selecting for overall ewe efficiency, with NLB accounting for 36% of the variation in efficiency on Easy Country. Maternal traits for WWT and SUR together accounted for 66% of the variation observed in a High Performance flock and are also very important. Longevity explained 6 to 7% of variation in flocks on Easy Country and was of greater importance in Hard Country explaining 16% of variation when ewe survival was reduced and the cost of replacement was high. The negative correlation between ewe efficiency and triplet breeding values, due to the additional feed costs associated with triplet pregnancy and lactation, and lower lamb survival in triplets, had very low impact and explained little variation in the index. However, ewe mature weight was important with the cost of maintaining and replacing large ewes reducing the additional cull value that may be obtained at slaughter. It is likely that the overall influence of ewe mature weight was being moderated by its association with direct (lamb as opposed to ewe) genes for weaning weight.

Where unfavorable interactions occur among the component traits, the net benefits of ewe efficiency are compromised. By identifying key traits which affect efficiency, new emphasis can be placed on recording or genetic testing for these traits. Identifying DNA markers associated with component traits such as longevity, or maternal traits for weaning weight or survival could assist in selection decisions made in young stock with limited performance information. Industry consultation is now required to both refine the assumptions used and develop a working efficiency index which can be used to aid selection decisions.

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REFERENCES

Amer, P.R.; Sise, J.A.; Jopson, N.B.; Bray, A. 2009: Background effects on ewe lambing and weaning performance in well recorded breeding flocks. *Proceedings of the New Zealand Society of Animal Production* **59**: 115-117.

Cocks, J.; Brown, C. 2005: Long term analysis of price, productivity, and profitability trends in New Zealand agriculture. *Proceedings of the New Zealand Grasslands Association* **67**: 9-18.

Gunsett, F.C. 1984: Linear index selection to improve traits defined as ratios. *Journal of Animal Science* **59**: 1185-1193.

Ministry of Agriculture and Fisheries, 2008: National sheep and beef statistics 2008: http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/farm-monitoring/2008/sheep-and-beef/national

Mathcad, 2008: 14.0 software: http://www.hearne.co.nz/products/mathcad/edition/mathcad14

Safari, E.; Fogarty, N.M.**;** Gilmour, A.R. 2005: A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. *Livestock production science* **92(3)**: 271-289.