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A METHOD FOR MAXIMISING AVERAGE FLOCK REPRODUCTION BY OPTIMISING CULLING POLICIES ACROSS AGE GROUPS

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SUMMARY

Increasing the average reproduction of a sheep flock is beneficial for most commercial sheep producers, and especially those focussing on meat production. Not only does it increase selection intensity for further selection if required, but it also increases the quantity of meat sales, and therefore the value of the flock. Currently some producers cull ewes if they are dry once (or sometimes dry twice). The aim of this study was to optimise culling strategies based on expected lifetime reproductive performance across age groups to achieve a desired higher average flock reproduction. If commercial sheep producers were able to use information readily available to them to improve their average flock production and reproduction it would provide a simple way to increase the value of their flock.

INTRODUCTION

There are many benefits of increasing the average reproduction of a flock of sheep. Benefits such as increased selection intensity (with more lambs to select replacements from), more excess lambs (kg of meat) for sale and the need to support fewer ewes for the same number of lambs produced. These and other benefits can result in both immediate financial advantage as well as continued genetic improvement.

Reproduction is lowly heritable and low-moderately repeatable. This suggests that selection on lifetime performance may be a useful way to increase flock reproduction levels. Lee and Atkins (1996) found that ewes that produced lambs in the first two joinings subsequently reared twice as many as those that didn’t rear any lambs in their first two joinings. In an attempt to increase reproduction in flocks some commercial sheep producers cull ewes that are dry once or sometimes dry twice.

There is potentially a better approach that could increase the average reproduction of the flock by recording all the previous lambings of each ewe and using this information to predict later lifetime performance for making management decisions. Optimal culling policies could be based on the historical lambing information for each ewe. This information is easily recorded by lambing rounds where lambs are manually identified and recorded with their dam or by using more recent technology such as Pedigree MatchMaker (Richards and Atkins 2007) which identifies which lambs belong to which ewe and subsequently how many lambs each ewe raised each lambing.

It would be impractical waiting several years to examine various culling policies in trials on farm. Instead, simulation can be used to examine various scenarios to determine the best culling policy. We used a model previously developed for optimising culling strategies across age groups for continuous traits and this model was adapted for non-continuous traits, in this case fertility.

METHOD

Method and code was previously developed for simulating flock changes over age classes for a single continuous trait, such as fibre diameter. This also had the option of optimising culling strategies for increased profitability (or a similar objective) (Richards, unpublished). This was adapted to handle reproduction, with the additional challenge of handling discrete data rather than continuous data. This original model used a normal distribution with a mean and SD to simulate the base flock group of sheep for a continuous trait. Later years were simulated using a measure of growth as well as correlations between trait expressions in different years. This method would not by itself work for a discrete trait, such as fertility.

To adapt this model to be used for discrete traits, a liability distribution was created for predicting realised reproduction thereby allowing it to be based on the continuous model approach. Thresholds were used to determine the number of lambs for ewes within the flock given their liability values. Figure 1 shows a normal distribution of liability scores and thresholds for singles and twins. When culling a proportion of the flock with continuous data a truncation point along the x-axis can be used to split the animals into keep and cull groups. With liability scores for predicting discrete traits it is more complicated. When knowing the proportion of animals required the best animals can be determined according to liability scores. However, within a lambing subclass, we cannot observe liability as all have the same discrete phenotypic value. For example, in Fig. 1 everything from ‘a’ to ‘b’ is only observed to be single. The proportion of singles needed will then be taken equally from all liability values within the subclass; shown by the shaded (selected) section of singles. All of the twins are selected in this case. This approach of using a liability score allows discrete traits to be modelled via an underlying continuous trait.

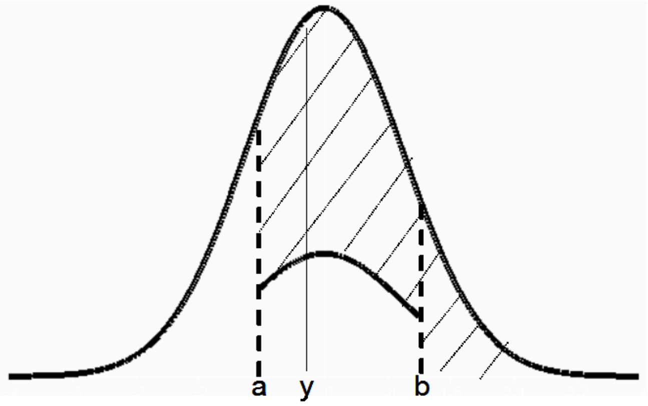

Figure 1: Liability distribution showing thresholds for realised dry (<a), single (a-b) and twin (>b) ewes. A cutoff at point y liability score would result in shaded animals selected based on observed reproductive phenotype

The distributions of subsequent years are then simulated based on the selection in the previous year. The age class means are adjusted by age adjustment factors (Table 1) and correlations between performance in subsequent years are presented in Table 2. The distribution is divided into 100 segments, with the animals in each segment having a similar liability score. The mean value of a given segment in the next (i^{th}) year will be predicted from the regression of the current mean on the mean of the next year as follows:

$$y_i = x_i + \frac{(y_{i-1} - x_{i-1}).SD_i.r_{i,i-1}}{SD_{i-1}}$$

where *y* is the liability as in Figure 1, *x* is the average flock liability, *r* is the phenotypic correlation between the current year and next year's performance as in Table 2, and *SD* is the standard deviation of y_i for if there was no selection. Values for SD are derived from the mean of each age group using a coefficient of variation of 7%.

The variation around the segment is generated as follows:

$$RSD_i = \sqrt{(1-r^2)}.CV_{i.}.y_i$$

where *RSD* is the residual *SD* and *CV* is coefficient of variation. The full distribution of liability for a given year is found by summing these distributions across segments. These liability scores are then used for selection as described above for the first year (Figure 1). For fixed thresholds, this process is equivalent for "across age groups within year" and "for the same cohort across years", but the latter has been used for description here.

Optimisation seeks to set the best set of truncation points (y in Fig 1.) for each year, with the objective of maximising predicted overall flock reproductive performance.

The age adjustments and the correlations used in the model are shown in Tables 1 and 2.

Table 1: Age adjustments for reproduction (fertility) of animals (age 1 to 6 yrs) used in simulation model Source: (Turner and Dolling, 1965)

	Age 2	Age 3	Age 4	Age 5	Age 6
Reproduction adjustment	0.838	0.940	0.990	1.072	1.108

Table 2: Phenotypic correlations for litter size between subsequent ages used in simulation model Source: (Atkins, 1990)

	Age 2	Age 3	Age 4	Age 5	Age 6
Correlation to previous age		0.14	0.15	0.12	0.17

Adjustment of the thresholds (points a and b in Figure 1) can be made to reflect conditions (eg. genetics, nutrition, stocking rate) that affect reproduction, and change the proportion of each class expected within a flock or age class in a particular year.

In order to optimise the culling policies an objective needs to be set. We assumed that profit was determined by a fixed price per lamb produced. In further development it would be useful to also account for a lamb trait such as weaning weight or carcass value, and maximise overall profit, accommodating the correlation between fertility and the lamb trait.

When optimising culling strategies for increased value across multiple age groups additional considerations need to be made, such as the benefit of younger animals having higher genetic merit due to genetic trend, a survival rate per age group that decreases for the older animals and a different accuracy between younger and older ewes to predict lifetime performance because young animals have less information available whereas the older ewes have proven reproduction rates. By setting the objective to achieve the highest dollar value the optimal culling policy will be determined (as this would be highest number of lambs).

A software package was developed based on the model described, including an evolutionary algorithm to optimise culling decisions for the prevailing parameters. It enables scenarios such as using one, two, and three years of fertility records for selection to be compared by recording the total dollar value as well as average lifetime reproduction of the flock. This can be used to compare the value of optimising across age groups against the more traditional methods (by setting the selection cutoff manually to the same as the single threshold), so all animals that were dry in one, then one and two, and lastly one to three age groups were culled.

DISCUSSION

The model does not only allow a comparison of various culling strategies but it also can be used to identify whether it would be worth the extra labour and time to record fertility records of ewes for at least 1, 2 or 3 joinings and using this information to better select the animals to retain. The resulting increase in flock reproduction would have added benefits to the flock than just the extra meat value, so the benefits would actually be greater than the dollar value shown from the output. If there is a large increase in value from using this approach then it suggests this process would be a suitable alternative for increasing average flock reproduction with little extra labour and time (if using a low labour intensive method for collecting these records such as Pedigree MatchMaker or DNA tests for pedigree) or alternative manually recording information on daily lambing rounds. If it is a similar value to the traditional approach then it may not be worth the extra effort required to achieve it.

The addition of other traits to the model would be desirable as it would make the results more realistic. Once additional traits are added for examining the results of selecting on one trait, it would be very beneficial to then be able to combine one or more traits into the selection process and in calculating overall flock profit. This may be examined in future studies. The ability to combine continuous traits with discrete traits will be very useful and should be possible with more work on the model also.

CONCLUSION

The results of this study show that data on fertility performance of ewes can be used to establish better culling policies for increasing average flock reproduction in commercial sheep flocks. We described a model that can compare different culling policies and determine the value of optimising culling strategies as well as the value of recording performance data in commercial flocks. Liability scores are a useful way of simulating and examining discrete traits and this model could easily be adjusted for other traits, including traits in other species as long as the age effects, correlations to previous year and potentially other traits have been determined.

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