COW HERD POPULATION DYNAMICS IN A MODEL FOR ECONOMIC COMPARISON OF BEEF BREEDS AND CROSSING SYSTEMS

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INTRODUCTION

The choice of replacement female breeding policy is a topic of considerable interest to UK beef suckler cow farmers. Contributing factors include the decline in the availability and the beef merit of beef x dairy heifers due to the contraction in size of the UK dairy herd, and the increased use of Holsteins. There are also concerns about the disease risks associated with purchasing replacements from the dairy herd.

Predicting the consequences of alternative replacement female breeding strategies is very complex. This is partly because of the large number of breeds and crossing systems available to choose from, and also the large number of traits which differ among breeds, and which have considerable impact on the profitability of alternative system. Furthermore, breeding cow herds are found over a wide range of geographical environments with many alternative management systems including herds with calving split across more than one season. Because of this complexity, a major project has been initiated in the UK to assist farmers in choosing replacement female breeding strategies. One part of this project has been to develop a computer software model of suckler cow herd breeding and farm performance. The model is described in more detail by Roughsedge *et al*. (2002).

Prediction of the population dynamics within a beef suckler cow herd with alternative replacement female breeding systems is also complex. Pang *et al*. (1999) described a model that directly simulates groups of cows by age group. However, this model is primarily focused towards comparison of management systems for a given biological type, and does not appear to predict the dynamic consequences of alternative crossbreeding strategies. Jenkins *et al*. (1998) describe a beef decision support model which tracks and simulates daily events for individual animals, with options to specify rotational crossing systems, and additional sire breed mating groups. However, such an approach may be computationally demanding if complex iterative models of biology and management have to be computed for each individual.

The objective of this paper was to describe a deterministic approach to the prediction of numbers of animals of different classes present in, and generated from, a breeding cow herd. Specific focus is on the transition of breed cross types (subsequently referred to as generations) over time as new sire breeds are introduced as part of the new breeding system.

MATERIALS AND METHODS

Let us assume that an existing herd for which alternative replacement breeding systems are to be modelled contains cows of a uniform breed or breed cross. For herds with mixed types of cows, a single representative breed or breed cross must be defined. These existing cows are defined as generation 0, and are grouped into age group, calving season and calving interval combination subclasses based on inputted probabilities for survival from one age group to the next and for age at first calving.

We define a matrix M containing the probability that one replacement heifer of a specific generation (breed type) at two years of age has a calf at each of all possible later ages (rows specified in half yearly intervals from 2 years of age until the end of the planning horizon for the model) for successive calves (blocks of 3 columns corresponding to each successive calving up to a maximum number of calvings per cow), and following a calving interval of either 12, 18 or 24 months (successive columns within each calving block). Matrix M is computed as follows :

$$M_{i,i} = h_i \text{ for } i = 1 \text{ to } 3$$

$$M_{i,j} = \sum_{k=1}^{3} M_{i-j+2,k} \cdot PS_{i-j+2,j-3} \text{ for } i = 3 \text{ to } 7,\ j = 4 \text{ to } 6, \text{ if } (i+2 > j) \text{ and } (i-2 < j)$$

$$M_{i,j} = \sum_{k=1}^{3} M_{i-j-1+x,k-3+x} \cdot PL_{k,j-x} \text{ for } i = 5 \text{ to ntp},\ j = 7 \text{ to nc, where } x = 3 \cdot \text{floor}(j/3)$$

where h is a vector of probabilities of the heifer first calving at 2, 2.5 and 3 years of age, PS is a 3 by 3 matrix of probabilities of a second calving cow which first calved at 2, 2.5 or 3 years (rows) having a first calving interval of 1, 1.5 or 2 years (columns), PL is a 3 by 3 matrix of probabilities of a third or later calving cow which had a previous calving interval of 1, 1.5 or 2 years (rows) having a calving interval of 1, 1.5 or 2 years (columns), ntp is the number of 6 monthly time periods within the planning horizon of the model and nc is the maximum number of calvings per cow. Elements of h should sum to 1, while rows of PS and PL should sum to the total probability of calving again (< 1), given the first calving age, or previous calving interval defined by the row. A number of M matrices were computed, with each one based on parameters in h, PS, and PL which correspond to the expected performance of the k'th generation.

The model then steps through successive time intervals spaced at 6 months to account for the two calving seasons per year. The maximum possible number of replacement females at two years of age for a specific generation and time period can be computed from the number of cows of the previous generation calving two years previously, the sex ratio, and a survival probability that a female calf reaches two years of age. Matrices M are then used to compute the numbers of each generation of cows, initially assuming all surviving female calves are kept as replacement heifers. The total number of cows is then summed. If the total number of cows is less than expected for the time period, additional replacement females can be purchased. If there is a surplus of cows, then either the number of replacement females at two years of age is adjusted downwards, or voluntary culling prioritised towards the oldest cows of the earliest generations. Combinations of these two options for controlling herd size are also possible.

The numbers of voluntary culls, homebred replacements, surplus replacements and surplus female calves not required as replacements are all stored by the model along with the number of cows by parity, first calving age (if second calving), previous calving interval (if third or later calving) by generation and time period (year and calving season). From these, all necessary animal class numbers for the herd, including potential numbers of terminal sire matings and terminally sired calves (based on surplus heifer numbers), involuntary culls, and the surplus progeny produced for future sale are derived.

For the purpose of illustration, the model was used to predict the time profile of a replacement policy using homebred replacements to grade up to a new breed. A single calving season was assumed with a maximum of 70 % of female calves born being suitable for use as replacement females. Of first calving heifers, 70 % and 30 % were assumed to be 2 and 3 years of age at first calving respectively. Of those first calving at 2 years of age, 70 % and 15 % were assumed to have a subsequent calving interval of 1 and 2 years respectively. The remainder were assumed not to rebreed successfully or die, and therefore defined as involuntary culls. Of heifers first calving at 3 years of age, 85 % and 5 % were assumed to have a subsequent calving interval of 1 and 2 years respectively. From second calving onwards, 95 % of cows were assumed to survive to calve again. Proportions with a 2 year calving interval were 10 % if the previous calving interval was 1 year and 5 % if the previous calving interval was 2 years.

RESULTS AND DISCUSSION

Figure 1 shows the time taken for animals of the third generation or higher (genetic makeup is less than or equal to 25 % of the original breed type) to become predominant within the herd. Maximising the introduction of female replacements accelerated herd turnover, though this option is unlikely to be economically competitive unless cull cow prices are high relative to the costs (including opportunity costs of not selling) replacement heifers.

The population dynamics prediction model described here is computationally very fast, and provides quite detailed information of numbers of different animal classes. For example, the number of male calves born to a terminal sire, out of a mother of generation 3 at her 4th calving in year 5 in the autumn calving season can be derived from the output.

Similar predictions could be achieved using stochastic simulation of individual animals, although replication would be required to avoid random sampling errors occurring in the results unless herd sizes were very large. If the biological and economic prediction equations are computationally demanding, then some sort of aggregation of animals into sub-categories might still be necessary to restrict the time required for the model to run.

Because cow sub-classes are differentiated by generation, it is straight-forward to adapt the model as described to all breeding strategies exclusively involving homebred replacements (e.g. rotational systems and upgrading to a purebred or composite). Different choices of breeds, and different numbers of breeds included in a rotation affect the parameters used, but not the method. The method can also be modified to handle breeding systems where a proportion of the replacements are purchased, and mated to generate remaining replacements.

The population dynamics model described here has been implemented in a computer model (Roughsedge *et al.*, 2002) for predicting animal performance and economic results on UK suckler cow farms with alternative breed and breeding system choices. It allows the short-, medium- and long-term effects of transition from the current breed into a new breeding system to be observed and taken into account without creating the computational burden associated with simulating individual animals.

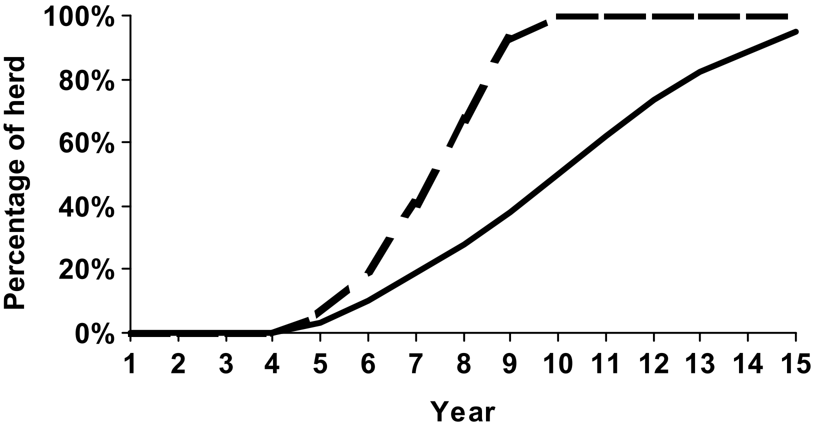

Figure 1. The percentage of cows in a suckler herd made up of less than or equal to 25 % of the original breed over time with a new replacement breeding policy. The broken line indicates the situation with maximum rate of herd turnover while the solid line indicates a situation with maximum possible use of a terminal sire

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REFERENCES

Jenkins, T.G. and Williams, C.B. (1998) *Proc 6th WCGALP* **27** : 461-462.

Pang, H., Makarechian, M., Basarab, J.A. and Berg, R.T. (1999) *Can J. Anim. Sci.* **79** : 409-417.

Roughsedge, T., Amer, P.R. and Simm, G. (2002) *Proc 7th WCGALP* (This conference).