INBREEDING AND ITS IMPLICATIONS FOR AUSTRALIAN MEATSHEEP BREEDS

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SUMMARY

Australian meatsheep breeds have a hierarchical breed structure which means that genetic improvement in the lamb industry is dependent on progress being achieved in the top flocks. This structure results in a high degree of relationship and a high rate of increase in inbreeding within flocks and breeds. The level of inbreeding was examined in a top level Poll Domet stud. Pedigrees of 1855 ewes selected into the flock over 19 years, which were the progeny of 27 homebred and 20 introduced sires, were traced to foundation stock. Inbreeding increased from zero to 0.15, at a rate of 0.008/year or 0.031/generation. It was increasing at 0.015/year or 0.056/generation over the later years. The implications for genetic improvement in meatsheep breeds of such a high degree of relatedness and inbreeding are discussed.

INTRODUCTION

Genetic improvement in the Australian prime lamb industry is dependent on the effectiveness of breeding programmes in the various meatsheep breeds. These breeds are characterised by a hierarchical breed structure. This has been documented for the Dorset Horn breed (Fogarty 1978a) and the other breeds are known to have a similar structure. A small number of important flocks at the top of the hierarchy supply most of the stud rams used in the breed. These top flocks are generally larger than the average for the breed and use a high proportion of homebred rams, although most use some rams from other top flocks.

This structure ensures genetic improvement made in the top flocks is passed on to other levels within the breed and to the commercial industry. The rate of genetic improvement in the breed and industry is therefore dependent on that achieved in the top flocks. The structure may result in a high degree of relationship between animals within flocks and also between flocks. These genetic links between flocks can be exploited to assist breeders increase their rate of genetic improvement. For example, animals can be evaluated across flocks using between-flock links and animal evaluation programmes, such as sire referencing, could be enhanced by extending the results to relatives. This structure, with its high degree of relationship also leads to a high rate of increase in inbreeding (Fogarty 1978b). High levels of inbreeding depress performance, in particular reproduction and fitness (Lamberson and Thomas 1984). This reduces genetic variation and the number of animals available for selection which subsequently reduces selection differentials and the genetic response ultimately achieved.

Data from a large Poll Dorset stud are being used to estimate genetic parameters for reproduction and maternal traits to enhance LAMBPLAN. Construction of the numerator relationship matrix for the mixed model analyses permitted calculation of inbreeding levels which are presented in this paper. The flock is...
regarded as representative of important ram breeding flocks in the Poll Dorset and other meatsheep breeds. Implications for genetic improvement programmes in the industry are discussed.

MATERIALS AND METHODS

Pedigree records from 1855 ewes born over 19 years in a Poll Dorset stud were used to calculate coefficients of inbreeding and relationship. The ewes were the progeny of 27 homebred and 20 introduced sires. The stud was established when introduced Poll Dorset sires were mated to ewes from the owner's Dorset Horn stud. The Poll Dorset stud replaced the Dorset Horn stud over twelve years, and was later dispersed in year 20. The stud was regarded as a top level flock within the breed. Sheep were successfully exhibited at shows across Australia, many stud rams were sold to other breeders, and sires from only a few leading studs were used to establish and improve the flock. It was a large stud with over 600 ewes joined annually in the late 1970s and early 1980s. Homebred rams were used extensively from the fourth year, and they sired 63% of all the ewes selected into the breeding flock.

Complete pedigrees were available for home-bred animals, and were traced back through Dorset Horn ewes as far as 1963. For introduced rams, sire and maternal grandsire were available from the Flock Register for Poll Dorset Sheep in Australia, published by the Australian Poll Dorset Association. These lines of pedigree were each traced until either a foundation Poll Dorset sire or a Dorset Horn sire was encountered. Inbreeding coefficients ($F$) and coefficients of relationship ($r$) (Wright 1923) for all ewes selected into the breeding flock were compiled in a numerator relationship matrix. Average coefficients of inbreeding and relationship were calculated for each cohort of ewes. The average $r$ is the sum of the individual coefficients of relationship between pairs of ewes in the cohort divided by the number of such pairs (ie. $n(n-1)/2$).

RESULTS

The number of Poll Dorset ewes selected into the breeding flock each year is shown in Figure 1. There was a gradual increase in the number of Poll Dorset ewes over the first ten years. This was followed by a rapid increase in flock size for two years, when most of the remaining Dorset Horn ewes were mated to Poll Dorset rams. Thereafter, the number of ewes selected each year ranged from 117 to 195, with a total flock size of about 600 ewes.

The average coefficient of relationship was high from the start (Figure 1) because of the small number of ewes in the flock and as a result the relatively high proportion of half and full sisters. The fluctuations between 0.19 and 0.29 over the first five years reflects varying numbers of introduced sires used each year. Relatedness increased from year 5 to year 10, following the increasing use of homebred sires. The mating of more Dorset Horn ewes to Poll Dorset rams in years 11 and 12 decreased the average relatedness. Subsequently the average coefficient of relationship increased to 0.46 in year 18.

Average inbreeding among ewes entering the flock steadily increased to year 10 (Figure 1). There was a small decrease in inbreeding from year 10 to year 13 corresponding to the introduction of more Dorset Horn ewes outlined above, and the expansion of the flock with more sires being used. Inbreeding steadily increased from year 13 to an average coefficient of 0.15 in year 18. This is greater than the level of 0.125, achieved by mating half sibs. The decrease in inbreeding and relatedness in the last year was largely due to the introduction of a sire that was only remotely related to the flock. The average generation interval in the flock was 3.7 years. The slope of the regression for increase in inbreeding over the 19 years was $0.008$/year or $0.031$/generation. In the period from year 13 to year 18 when flock structure was relatively stable the increase in inbreeding was $0.015$/year or $0.056$/generation. From this $ΔF$ value the effective population size ($N_e$) during this period was estimated to be 9 from the formula $N_e=1/2ΔF$ (Falconer 1981).
Inbreeding results from the mating of related animals and leads to an increasing frequency of homozygous loci. All Australian meatsheep breeds and their constituent straight-bred flocks will have some level of inbreeding. 'Linebreeding,' a mild form of inbreeding is widely practised in the industry to produce uniform lines of sheep that breed true to type. While inbreeding depresses performance, natural selection and selective breeding programmes will tend to counter this depression. If inbreeding is increasing rapidly the selection forces will not have sufficient time to counter the detrimental effects of inbreeding. Improvement in flock management may mask the effects of inbreeding.

The major effects of inbreeding are depressed performance in the reproduction and fitness traits. In their review of many sheep experiments Lamberson and Thomas (1984) estimated that a 10% increase in inbreeding would on average lead to reductions in weaning weight of 1.1kg, ewe fertility of 14% and lamb survival of 28%. Other effects include lowered ram fertility and libido and increased mortality at all ages.

The rate of increase in inbreeding in the flock reported in this paper is high, particularly over years 13 to 18, and is cause for concern. A selection program concentrating on reproduction and survival traits would be unlikely to counter the increasing effects of inbreeding depression. Preliminary estimates of heritability for ewe lifetime reproductive traits in this flock are moderate (number of lambs born 0.20, ewe fertility 0.07, ewe rearing ability 0.06). Efficient selection for reproduction alone would only increase lambing rate by 1 to 2% per year whereas the increase in inbreeding would be expected to decrease lambing rate on average by 3 to 4% per year. Growth and leanness have higher heritabilities (0.3 for both traits, Atkins et al. 1991) and are less affected by inbreeding so that response to selection could be achieved.
Australian meatsheep breeds are generally used in a tiered crossbreeding structure to produce slaughter lambs. Consequently there is no inbreeding depression amongst crossbred lambs or their crossbred dams. However high levels of inbreeding in the straight-bred flocks have a considerable impact on the lamb industry as well as individual stud flocks. Lower lamb turnoff rates in stud flocks reduces the breeder's income from sale sheep. Lower survival of sheep increases costs to the lamb producer and also stud breeder. Fewer sheep are available for selection which reduces the selection intensity, particularly among ewes, and hence reduces the rate of genetic improvement that can be achieved. It may also mean that a greater level of culling is required which further dilutes selection intensity. Inbreeding reduces genetic variation and limits the selection differentials that can be achieved, which further restricts genetic improvement. Genetic drift which has highly variable effects that are magnified by inbreeding will have a major impact in some flocks by fixing undesirable genes and/or superior genes being lost.

The results presented in this paper are from a flock with a structure and breeding programme regarded as typical of the top level studs in the Poll Dorset breed. The flock was large (over 600 ewes), there was no deliberate policy of close inbreeding and rams were regularly introduced. However, some of these rams were closely related to the flock, and because of the small foundation population of the breed other introduced sires were still distantly related. Some rams were used widely in the flock; 47 rams were used, but over half the ewes selected into the breeding flock were the progeny of only 11 rams. The levels of inbreeding in other Poll Dorset flocks would be expected to be as high and possibly higher for smaller flocks and those using a higher proportion of homebred rams and/or mating closely related animals.

Inbreeding was estimated to be 0.125 in the Dorset Horn breed in 1974 and increasing at the rate of 0.015/generation (Fogarty 1978b). Individual flocks within the Dorset Horn breed would have been increasing at a much higher rate. It would be expected that the rate of increase of inbreeding in flocks from other meatsheep breeds would be at least as high as that found in this Poll Dorset flock. The rate would be expected to be higher in those breeds with a small total population and/or narrow genetic base of foundation animals, and in those flocks that are small and mate close relatives.

Breeders should be aware that inbreeding levels can increase rapidly and become a problem in their flocks. Monitoring inbreeding may be of benefit. The following can be used to reduce the increase in inbreeding:
* purchase of sires (or ewes) that are not related or only remotely related to the flock
* not mating close relatives such as half sibs or sire and daughter
* reduce generation interval by replacing all sires after two or three years use and replacing older ewes (if you are making genetic progress, the best progeny should be better than their parents)
* reduce variation in family size by mating each ram to a similar number of ewes, and selecting one ram progeny from each sire used.

Artificial insemination and other developments in reproductive technology need to be used cautiously in meatsheep flocks. This technology can lead to rapid increases in inbreeding through a dramatic reduction in effective population size, within individual flocks and also within a whole breed.

REFERENCES