GENETICS AND STATISTICS IN IMPROVING FUR BEARING ANIMALS

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SUMMARY

The use of computerized breeding programmes including statistical methods for breeding value estimation is increasing among fur breeders. As the capacity of personal computers has increased, it has become possible to use calculation methods, which utilize most of the available information and thus result in more accurate breeding values. At present, single trait models are used and in most cases the weighting of traits in the final selection and ranking of animals is done on farm basis.

The accuracy of animal grading greatly depends on the skill of the breeder and affects the possible gain. However, in traits with more objective information, such as litter size and body weight, the computer systems have proved superior to mass selection.

In the future it is important to get more accurate knowledge about the heritability of different traits and to develop models, which can efficiently treat categoric, not normally distributed data. Furthermore, simulation models should be developed and used to estimate the effect of different strategies.

INTRODUCTION

Compared with other livestock, fur animal production is a young business. The first real farms were established early in this century. During the first 3 decades research was very much concentrated on feeding, disease problems and on qualitative genetics as new colour types emerged and caused a great deal of sensation on fur markets.

However, live animal shows soon became popular and convinced the breeders of the importance of quantitative traits like size, darkness or clarity of colour and fur quality. On farms the selection of breeding animals was thus based on the criteria used at animal shows. For quite a long time the only selection method was mass selection. Individuals were graded and the decision was based on the animal's own phenotype. However, great progress was made even with this simple method of selection.

After new breeding programmes for quantitative traits had become a reality in livestock breeding in the late 50's, the question of applying the theories of quantitative inheritance to fur animal breeding was occasionally discussed. Quite a lot of genetic research was done especially regarding reproduction, the pioneers in this field being Arthur Hanson, Ivar Johansson and later on Ole Venge. It has, however, taken about 30 years from this first beginning until it has become possible for the fur breeders to take advantage of the statistical methods of quantitative genetics in a way comparable with e.g. cattle production.

There are many reasons why the development has been slower in fur animal breeding. First of all the entire existence of fur production has for some periods been questionable and pelt prices and thus the profitability much more dependent on the world economic situation than on the quality of the products. Secondly, in the early times of fur farming the low reproduction greatly limited possibilities to select for other traits. The practical problems in grading and record keeping seemed hard to solve, and the profit of breeding work modest compared to the achievements with better feeding and health control. From the beginning of the 1970's, however, efforts have been made to develop modern breeding programmes for fur animals.

In this paper we try to give a review of the special problems in breeding work with fur animals, to describe the present status of breeding systems and breeding programmes especially in North European countries and to view the present status and future perspectives of applying modern statistical methods in improving fur bearing animals.

THE BREEDING STRUCTURE IN FUR ANIMAL PRODUCTION

One of the special features of fur animal production is that no hierarcical breeding structure exists. Each production unit normally selects the breeding stock from own population except for the occasional purchase of some breeders. Even though the reproduction has been greatly improved, the average number of offspring is still fairly low, in mink about 4 to 5 kits per mated female and in silver fox only 3 to 4 pups. The only more prolific species is the blue fox with an average reproduction of about 6 to 7 pups per mated female. Normally about 50% of females need to be replaced per year, which means that depending on the species 20 to 50% of female offspring must be selected.

In mink production even the average number of offspring per sire is limited because so far only natural mating can be used. In fox production, however, artificial insemination has become widely used during the last decade thus making two important things possible: a larger number of dams per sire and the use of the same sire on several farms. The freezing technique for preserving fox sperm has further extended the use of best sires. These facts bring the fox breeding system closer to other livestock breeding and open up new possibilities for utilizing progeny testing and hierarcical breeding structure.

BREEDING GOAL

An overall goal for any production unit is profitability. In fur animal production this means a large number of pelts per breeding female, high average price of pelts and low production costs. The marketing price depends on several characteristics of the pelt and thus makes the definition of the breeding goal more complicated. Knowledge about the economic value of the different characteristics is therefore important. Since 1980, analyses of pelt prices in regard to the effect of different traits have yearly been carried out based on the prices achieved in the Nordic fur auctions (Lohi et al., 1989). On the basis of these analyses the pelt traits can be divided into long-term and short-term traits. A well defined goal and long-term breeding strategy is necessary for the first group, whereas in the short-term traits the breeding goal must be rejudged, probably even altered more often. Good size and good fur quality are typical long-term goals regardless of species. On the other hand, what is desired in regard to the intensity and the clarity of colour, is not constant over species or colour types, nor even within colour types over longer periods. The continuous follow-up of market prices is therefore necessary for optimal balancing of traits in multiple trait selection.

Norway is obviously the only country, where a national breeding strategy including goals for different traits has been set up by the fur breeders' central organization (Einarsson et al., 1983). In other countries no national strategy is written down, but the central advisery service supplies uniform information to all breeders. However, opinion differences between local advisers can influence the definition of breeding goal on individual farms. Good reproduction and vitality are generally considered to be important goals but in regard to the priority of pelt characteristics different opinions can be met.

PRESENT STATUS OF BREEDING PROGRAMMES IN THE NORDIC COUNTRIES

The development of scientific breeding programmes for fur animals started in the 1970's, and at the moment computerized breeding programmes for fur animals are available in most countries. At first they only served to keep animal records, but in the 1980's breeding value estimations were included in most programmes. Breeding value for litter size was the first improvement, and possibility for calculating breeding values for 1 to 5 pelt traits was added later.

It is natural that breeders do not without any doubt accept these new systems, because changes in their earlier breeding traditions have been necessary. For example standard system for identification numbers, necessity to abandon multiple sire matings. An efficient education programme, including not only the practical use of systems but also the genetic principles and advantages of modern breeding value estimation compared to traditional mass selection, must therefore be run parallelly to launching the new systems into practice. However, the number of users is steadily increasing in all fur producing countries. For example in Denmark at the moment about 40% of the mink breeders (including 60-65% of breeding animals) are now using a computerized breeding program.

THE EVALUATION OF DIFFERENT TRAITS

One of the great problems of fur animal breeding is how to get objective information about the traits included in selection programme. No objective methods for measuring traits like general fur quality or darkness or clarity of colour on live animals are yet found. The accuracy of the subjective evaluation depends on the skill of the person grading the animals and is not comparable between judges. The scale of graduation is often limited, and normal distribution is not always achieved. Developing statistical methods for efficiently treating this type of information in the estimation of breeding values is therefore an important task for future research.

In Scandinavian breeding programmes, the reproduction index is based on the number of live offspring at the age of about 3 weeks. However, the number of offspring at this age is not only an expression of the female reproduction capacity but includes also a remarkable dam effect as well as general and litter bound environmental effects.

Body size, which is used as prediction of pelt size, can be evaluated in different ways. Weighing the animals is an easy and objective method and results in normal distribution of information. Several investigations are found about the correlation of body weight, body length and subjective evaluation of size with pelt size. The highest phenotypic and genetic correlations to pelt size are achieved with body weight in October-December (Lagerkvist, 1993; Hansen et al., 1992).

PRESENT STATUS FOR BREEDING VALUE EVALUATION

In the present computer systems, different methods are used for evaluation of breeding values, even within countries. The choice of method has earlier depended on computer capacity. At present, fairly large farms and more complicated models can easily be handled in personal computers. In the Nordic countries, the breeding value estimation is based on traditional selection index theory or an Animal Model BLUP. A theoretical comparation of mass selection, traditional selection index and Animal Model is shown in table 1. Table 1 shows the asymptotic selection response obtained by mass selection and the relative asymptotic response obtained by selection index using own, full- and halfsib records and an Animal Model. Response is calculated by the methods of Wray and Hill (1989) where a selection index approximating an animal model is used. The effect of selection on genetic variance is taken into account, the heritabilities given are those in the unselected basic population. The generation interval is 1 year.

Table 1. Absolute response of mass selection (MS) in units of genetic standard deviation in the basic population and relative response in percent of mass selection for a selection index (SI) using own, full- and half-sib records and a selection index approximating an Animal Model (AM).

h^2	MS	SI	AM
0.1	0.379	133	137
0.2	0.510	119	121
0.3	0.600	111	113
0.4	0.671	107	108
0.5	0.731	104	105

Introducing selection index greatly increases the response to selection and an Animal Model further extends the advance by 1 to 4 percent. However, these results only reflect that an Animal Model utilizes all information, but not the additional advantages of simultaneous correction for fixed effects, non-random mating and genetic trend. Further improvements of the model thus can make the Animal Model even more superior.

Implementations of selection index generally utilize data from own, full- and half-sib performances. For litter size it is based on records of the dam and sisters of the dam and the sire. For the fur traits, the data used are registrations on live-animals and/or skin-classifications from the auction. Both the selection index and the animal models used are single trait models, i.e. correlations between traits and between measurements on live animals and skins are not utilized.

The repeatability of subjective grading varies significantly between judges and under different environmental conditions for grading with repeatabilities as low as 0.2 for some judges (Jezewska & Maciejowski 1982; Kenttämies & Käyhkö 1992; Kenttämies & Smeds 1992a, 1992b). It seems reasonable to assume that this also causes a variation in the genetic parameters. This can also explain a part of the variation in heritabilities found in the literature (see Berg 1993). The good results achieved by mass selection in improving pelt traits give reason to suspect that objective, accurate information of traits would reveal higher heritabilities. Maciejowski et al. (1992) showed that the definition and number of traits have an effect on the use of the scores and thereby on the differentiation between animals. It is a common problem that only part of the defined scale is used.

These problems cause a heterogeneity in genetic parameters which is presently not taken into account. It is likely that the heterogeneity is not only between populations (with different judges) but also between years due to different environmental conditions (Kenttämies & Smeds 1992b) and possibly the time between gradings.

Gradings at the auction are performed by highly specialized people and under standardized conditions with a high repeatability. Use of auction gradings has been limited because gradings are performed on selected skins, and gradings for different traits are dependent (e.g. skin defects disqualify the skin for the best quality grades). Further selection would have to be on a pedigree index, and in an effective scheme superior families would have the smallest amount of information.

Many traits are subjectively graded, some only into a few classes. However, all traits are analyzed with a linear model applicable for a continuously and normally distributed trait.

FUTURE PERSPECTIVES

Due to the problem of heterogenous parameters an important aspect of an index is robustness to the quality of subjective gradings, especially gradings on live animals.

Implementations of Animal Model BLUP would allow the utilization of all available information in prediction of breeding values as quantified in Table 1.

Further a multiple trait Animal Model could incorporate classifications on skins as this model takes account of selection. Only animals not selected as breeding animals (based on live-animal gradings and possibly a pedigree index for skin classifications) get a classification on the auction. Animal Model BLUP gives optimal solutions given that the genetic parameters are known at least to proportionality. This might be a strong assumption when grading is done on the farm by the farmer. The gradings are strongly dependent on the grader (e.g. Kenttämies & Smeds 1992a, 1992b). With on-farm evaluations of breeding values it could be an advantage to assume heterogenous variance among farms, instead of using the same estimates in all situations. However, relatively little information will be available to estimate genetic parameters in most situations.

There is a need for efficient algorithms to predict breeding values under an threshold Animal Model. A promising algorithm to solve some of these problems is the use of Markov Chain Monte Carlo methods such as the Gibbs sampler (e.g. Gelfand & Smith 1990; Smith & Roberts 1993).

A common assumption is that the use of single trait models just ignores information on other traits. However, it is assumed that the traits considered are uncorrelated. This can cause a bias in the estimated breeding values when selection on other traits are not taken into account (Sorensen & Johansson 1992).

Auction classifications could be used in several ways. They could serve as a control on the live-animal grading and thereby improve live animal grading. Further the information could be utilized to increase the accuracy of the breeding value estimates. The increase in accuracy would be small, but it would improve the robustness of the index to effects of the live-animal grading.

The use of repeated gradings increases the accuracy of estimated breeding values (Kenttämies 1992). This would increase selection response by 3% to 15% depending on mainly repeatability (unpublished results). A realistic constraint could be the number of gradings possible. By deterministic simulation with a modification of Wray & Hill (1989) it was found that the best strategy was to grade all animals once compared with a smaller fraction graded twice (resulting in a lower selection intensity). The use of multi-stage selection and repeated gradings in later stages seems a possibility for increased selection response with a limited capacity for grading.

CHALLENGES IN DEVELOPING A MULTI-TRAIT MODEL

As described earlier, one of the challenges that could improve methods of predicting breeding values is to take inhomogenous variances between farms into account. With on-farm evaluation of breeding values this is equivalent to allowing for different genetic parameters on different farms. But to estimate breeding values across farms one further has to establish genetic links between farms, and at the moment these are not registered, and to take the genetic covariance between environments into account. Breeding values estimated across farms would further allow for an optimal use of genetic differences between farms and the advantage of selection in multiple open populations (Smith & Banos 1991, Shepherd & Kinghorn 1993).

There is possibly a greater uncertainty about the future economic situation than in many other kinds of animal production. Defining breeding goals and deriving economic weights is a great challenge for an efficient breeding scheme. In optimizing breeding schemes robustness could be an additional important variable along with the expected gains and costs.

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