ACHIEVING GENETIC IMPROVEMENT IN NON-CONVENTIONAL SPECIES USING THE NEW ZEALAND DEER INDUSTRY AS AN EXAMPLE

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SUMMARY

A successful programme for genetic improvement will only develop and succeed in the long term given three major outcomes. These are genetic advances within the breeding sector, transfer of these advances to the production sector, and resulting financial rewards sufficient to reimburse the relevant businesses that enable the improvement programme including research and extension components. Sound principles of biology and economics can be applied to identify the relative importance of traits to improve business profit. Research in genetics can identify characteristics that can be measured and used to rank breeding individuals that can move the population towards the industry goals. However, achievement of such a programme depends on all sectors of the industry developing a shared vision and co-operating in its implementation. This takes time to achieve, especially in emerging industries where production and economic circumstances may be rapidly changing, and in user-pays environments where research and extension must be funded by industry.

Keywords: Breeding scheme design, genetic improvement.

INTRODUCTION

Designing a comprehensive and cost-effective breeding programme involves a number of disciplines. A systematic approach to the design of breeding programmes is in Harris *et al.* (1984). This involves nine steps in a natural sequence that include: (i) Describing the production systems. (ii) Formulating the objective of the system. (iii) Choosing a breeding system and breeds. (iv) Estimating selection parameters and economic weights. (v) Designing an animal evaluation system. (vi) Developing selection criteria. (vii) Designing matings for selected animals. (viii) Designing a system for expansion. (ix) Comparing alternative programmes. For convenience in the context of this paper, these steps are addressed under four headings: (i) The production systems. (ii) The objective and economic weights. (iii) The industry structure (breeding and expansion system), breeds and mating design. (iv) The animal evaluation system, in a broad sense, including variance parameters and selection criteria.

In developing breeding programmes for non-conventional species, animal breeders are well-advised to follow the steps outlined by Harris *et al.* (1984), but this will not in itself result in a successful improvement programme unless various components of the industry including breeders, buyers, marketers and researchers are properly co-ordinated with a shared vision. Matching and co-ordinating these components can be difficult to achieve, except perhaps in a vertically integrated industry, as it involves a number of different human and market elements. This is particularly the case in non-conventional species that represent emerging industries.

The objective of this paper is to consider the application of a systematic approach to the development of breeding programmes for non-conventional species using farmed red deer in New Zealand as an example.

PRODUCTION SYSTEMS

Red deer (*Cervus elaphus*) have been farmed on pasture in New Zealand since the late 1960's using animals captured from wild populations. These wild animals originated from numerous liberations, mainly comprising *C.e.scoticus* from Great Britain, introduced to New Zealand in the latter half of the last century for hunting as a game animal. A strain of North American wapiti (*C.e. nelsoni*) were liberated in Fiordland, a remote part of the country prior to World War I. Red deer and the larger wapiti came to co-exist in Fiordland, and to naturally hybridise, initiating farmer interest in assessing the merits of alternative strains of deer. Since 1981, deer farmers have made new importations, including strains of wapiti from North America and red deer from a number of European sources (Yerex 1991a,b; Smith 1974, cited by Fennessy 1993).

Export industries for venison and velvet antlers were initially based on hunting of wild animals, venison going primarily to Germany, and velvet antler to South Korea. Produce from farmed deer, once available, was sold in these existing markets. Demand for deer for farming soon led to prices far exceeding market values of the product, until the number farmed had built up sufficiently. There was no opportunity for selection during this phase and many undesirable animals (e.g. for temperament) were retained and used for breeding. Three production systems have developed: velvetting herds based on adult stags; breeding hinds for production of weaner deer; and finishing systems for growing weaner animals through to sell for venison. In some cases, two or three of these systems may be integrated on a single farm.

The current farmed population is around 1.3 million deer, and markets have now been developed for branded venison, known as Cervena™, and sold primarily for restaurant consumption in the USA and local markets. The industry has a major focus on quality assurance, seeks out and employs strategies to minimise reliance on commodity markets.

FORMULATING OBJECTIVES AND ECONOMIC WEIGHTS

The main goal for the commercial tier of the deer industry is increasing profit for a given farmed area. Individual farmers have personal constraints, relating to risk aversion and requirements for labour and capital, that limit the scope of management and production circumstances within which they will make changes to increase profit. Few papers have been published on breeding objectives for deer (McManus and Thompson 1993; Amer and Fennessy 1998). Modeling of a velvet production circumstance would be relatively straightforward provided velvet quality attributes are ignored. A venison system can be modeled biologically (e.g. Fennessy and Thompson 1989), but economic interpretation is somewhat complicated by the scarcity of reliable information on which to base price expectations. In New Zealand there has been considerable between and within year variations in price.

Velvet antler returns are influenced by weight of velvet harvested and by quality. Quality is modified by the time of harvesting and factors such as antler circumference. Much is still to be learnt about the relationship between medicinal quality of velvet extracts and measurable characteristics on the velvet antler. Within a group of contemporary stags, larger animals produce more velvet (van den Berg and Garrick 1997) and presumably consume more feed. Feed intake influences stocking rates and should be included in the breeding objective. Producers are well aware of this list of traits that influence the breeding objective for velvet antler production, but have not defined the relative emphasis of the traits. Quantity and quality of velvet antler harvested per stag are believed to be of paramount importance.

Profits from selling weaner deer are influenced by herd reproductive rate, and average weaning weight. Twins are rare in red deer. Reproductive rates are typically in the order of 75% for hinds fawning at two years of age and 85% for mixed age hinds. Larger hinds will rear heavier weaners, as will hinds that are mated to larger strains of stags. Hind size influences winter stocking rates and therefore results in a trade-off between the number and size of weaner deer available for sale. Breeding hinds have long lifetimes (up to 10 or more parities) allowing for minimal replacement rates. The most important traits included in the breeding objective would be reproductive rate, milking ability, pre-weaning growth rate, hind mature size and temperament. The relative importance of these traits for a defined economic and production circumstance has not been formally quantified.

In a venison system, market preference is typically for 50 to 65 kg carcasses. Profits from finishing deer are largely influenced by the time of year at which the animals attain these carcass weights. Lightweight carcasses (<45 kg) are usually severely penalised. Peak schedule prices coincide with Northern hemisphere demand for venison and are influenced by the rate marketers are procuring slaughter stock in comparison with their market commitments. Stock availability is influenced by expectations for velvet antler returns. The price peak usually occurs between August and November but the rate of decline from the peak tends to vary each year, with little decline in some years. It is difficult to predict the future importance of growth rate as this depends on prices. One approach to meeting the demand for faster growing deer is to use larger strains. This may conflict with profit for breeding units if larger strains are used as breeding hinds because of their increased maintenance feed costs and consequent effect on winter stocking rates.

In contrast to so-called commercial herds, in which returns depend mainly on venison and velvet sales, some herds have specialised in breeding and selling sire stags and surplus hinds. These stud herds typically base their gene pool on one or more of the recently imported strains of deer. Such herds provide sires with large body size for terminal use (e.g. elk) or more commonly, have concentrated on velvet characteristics. There appears to be an absence of herds specialised in the production of stags to produce daughters for breeding purposes. Maternal characteristics have not specifically featured in any breeding objectives. A few sire breeding herds have specialised objectives of generating stags for trophy hunting purposes or growing extreme velvet antlers.

Some attention is currently being focused on traits including disease resistance (e.g. susceptibility to tuberculosis) (Mackintosh 1997), carcass meat yield and meat colour. These latter traits may increase in importance should there be greater vertical integration in the industry or development of retail rather than restaurant sales.

INDUSTRY BREEDING STRUCTURE

Farming began with total reliance on wild-captured or so-called New Zealand red deer. The industry was essentially unstructured, each herd using its own stags and little hind selection occurred. As hind numbers increased, larger wapiti and crossbred stags were used as terminal sires in some herds. This led to some stratification of the industry with the development of specialised herds used as a source of breeding sires. A few sire-breeding herds began performance recording, using Animalplan (Johnson *et al.* 1989), while other breeders and farmers collected records on personal computers.

During the late 1980's any within strain improvement tended to be cast aside in favour of strain comparison, fuelled by importation of a number of European strains. The use of embryo transfer and artificial insemination techniques (Fennessy *et al.* 1991) within stud herds was refined, as these techniques were important in initial importation and multiplication phases. The use of these techniques is impractical in most commercial herds. This is partly a reflection of the seasonal breeding status of stags and associated temperament problems during the breeding period.

On venison-producing farms, good management can provide sufficient weaning weights and post-weaning (winter) growth rates to finish offspring at carcass weights exceeding 50 kg, from 10 to 12 months of age, coinciding with peak market demand (Barry and Wilson 1994; Kusmartono *et al.* 1996). Finishing offspring at this age, and therefore avoiding the need for a second winter has been assisted by the use of terminal sires and by the two-fold range of mature body weights (Fennessy and Pearse 1990) available to the producer simply by choice of appropriate pure-bred or cross-bred strains. This has diminished demand for within-strain improvement in growth rate. Accordingly, velvet antler weights have assumed predominant importance in sire-breeding herds.

The conflict between body size for breeding and finishing objectives has led many farmers to crossbreed, the sire strain being different from the dam strain. This can be more complicated than simply using terminal sires, as the discrepancy in size between the largest and smallest strains are too great in some cases for this extreme cross to occur without a reduction in reproductive performance. Accordingly, an intermediate-sized strain may be used as a sire over smaller strains of dam with the resulting crossbred daughters retained and terminally mated to one of the largest strains of sires. This has led to the development of several tiers within the industry.

ANIMAL EVALUATION SYSTEM

Analysis of research and farm records has demonstrated that both velvet antler and body weights are highly heritable traits, are favourably correlated (genetically and phenotypically), and demonstrate considerable variation (van den Berg and Garrick 1997). Given their ease of measurement, these traits are amenable to improvement by selection. Parentage determination proves challenging for biological reasons, and the development of locally-developed DNA testing procedures (e.g. Tate *et al.* 1995) is increasing in popularity among stud breeders. However, for highly heritable traits, such identification probably adds little to the annual gains that can be achieved using individual selection.

Stud breeders have tended to concentrate selection on velvet characteristics, both weight of velvet antler and velvet conformation. However, the desirability of alternative velvet conformation characteristics from the end-user viewpoint remains open to debate. Genetic parameters for such attributes are unknown, as scoring tend to be into subjective categories that vary over time, with few records being made available to researchers. Many breeders have applied linebreeding techniques. They seem to believe in specific rather than general combining abilities and emphasise mate selection. A central progeny testing scheme with offspring generated over two sites using artificial insemination has been trialed to compare sires. However, too few sires were involved and insufficient offspring were obtained per sire for meaningful assessment. The test was not repeated beyond a single crop of offspring. The manner in which the best sires would be exploited by industry had not been resolved prior to the progeny test.

Currently, interest in recording and ranking procedures seems to be greater among commercial producers rather than sire breeders. Sire breeders are interested in formal strain comparison, such as through sire referencing, but such comparisons are expensive, in real terms and in relation to potential benefits. Furthermore, those breeders whose strains are identified as below average are quick to point out inadequacies of the system.

In the absence of performance recording, farmers have imposed useful selection to improve temperament that has sometimes been problematic in a subset of breeding hinds. Some farmers have identified novel approaches to improving milking and mothering ability, such as by weaning lightweight fawns early, then identifying hinds that remain in lactation at the normal weaning date, thereby selecting phenotypically superior mothers without need for identifying offspring to dams.

RESEARCH AND EDUCATION

The timely development of a cost-effective improvement programme relies on essential research being done prior to the need for the results of the research. Findings from research and commercial endeavours need to be shared among the industry players to avoid duplication. As Amer and Fennessy (1998) point out, these aspects are problematic to achieve in an emerging industry involving competitive businesses. Production, processing and marketing problems might rightly demand more attention than the development of genetic improvement programmes in an emerging industry. The most effective approach for industry improvement involves a close collaborative relationship between researchers, breeders and leading producers in the emerging industry. The personalities, inter-personal skills and extent to which these individuals can share a vision will have major impact on the rate a programme can be developed.

DISCUSSION

Livestock industries exist as the sum of all the components. The production population typically consists of a number of individual sire breeders and commercial producers. The producers decide on the breeds and dissemination system and determine the breeders that will be successful. The breeders, not the scientists, determine the manner in which selection will be used. Many naïve commentators believe that the solution for one industry is simply to mimic another (e.g. the dairy industry). However, this ignores any unique attributes of the non-conventional species and overlooks the special challenges that each industry faces.

In established industries, performance recording is often a central component of the improvement strategy. However, the act of performance recording does not result in genetic change, it is selection that causes change. Instituting an information system for performance recording will not in itself lead to change unless it stimulates the use of selection. Similarly, although selection will cause change, this change does not constitute improvement unless it represents change towards a goal. Specifying the goal and identifying the traits that influence the goal are an important aspect of ensuring that selection is focussed on improvement rather than simply on change.

In a non-conventional species, it takes some time for the production system to be refined and this limits the opportunity for reliable assessment of breeding objectives. Furthermore, the transition from an unstructured to a two-tiered industry with specialist sire-breeding herds develops slowly. The deer industry has made considerable progress in marketing, processing and production, with genetic advances primarily in the form of exploitation of strain differences. Achieving within-strain advances towards industry goals remain an opportunity to be further developed.

CONCLUSION

Garrick *et al.* (1992) identified six structural components of a sound improvement programme. These included motivated breeders; committed buyers; information and ranking systems; research; and technology transfer. Successful improvement programmes are typically characterised by three outcomes: genetic change within the breeding tier of the industry; transfer of genes from the breeding to the commercial tier; and cash rewards from the end-user of the products to reimburse costs of the programme. It is not simply a matter of establishing methods to achieve genetic change and systems for dissemination of improved livestock. In emerging industries the three outcomes tend to develop concurrently, and the activities of animal breeding scientists can do little more than encourage these developments in a particular direction. This encouragement comprises education and research which are themselves subject to a concept equivalent to genetic lag. The extent to which a non-conventional (or conventional) industry adopts a cost-effective breeding programme has much to do with the personal and human element of animal and business management, provided the appropriate scientific process of designing a breeding programme has been followed.

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