Structure and genetic gain in the New Zealand deer industry

PETER F. FENNESSY

AgResearch
Invermay Agricultural Centre
Private Bag 50034
Mosgiel, New Zealand

INTRODUCTION

The New Zealand deer farming industry has grown rapidly since the first animals were captured in the late 1960s, and farming was legalised in 1970 (Fennessy et al. 1993). There are now around 1.3 million deer on farms, with export receipts exceeding $170 million for the year to June 1993. About one-quarter of the export income is derived from velvet antler and virtually all of the remainder from venison, with co-products such as hides making a minor contribution.

THE INDUSTRY

Background

The New Zealand industry is built around red deer (*Cervus elaphus*) descended from the numerous liberations in the latter half of the last century (Yerex 1991a,b). These deer, imported for hunting and originating mainly from Great Britain, were probably mainly the *C.e. scoticus* subspecies. North American wapiti (*C.e. nelsoni*) were liberated in the first decade of this century. Natural hybridisation between wapiti and red deer in the Fiordland National Park (Smith 1974) alerted farmers to the potential of hybridisation to improve productivity to better meet market requirements (Moore 1984; Fennessy 1992).

The first wave of imports specifically for farming were wapiti from North America in 1981. Since then, different strains or subspecies of red deer have been imported from Europe (Germany, Hungary and Yugoslavia), Scandinavia (Sweden and Denmark) and the deer parks of England. These new strains of deer are being used in breeding programmes to increase the mature body size (growth rate) and antler size in the New Zealand red (NZR) deer herd.

European fallow deer (*Dama dama dama*), which make up about 7% of the farmed deer, were also liberated last century. More recently Mesopotamian fallow deer (*D.d. mesopotamica*), a larger subspecies, have been imported and are being used to increase body size and growth rate in farmed fallow deer (Asher and Morrow 1993).

Products and Markets

Marketing within the venison industry is well organised with individual companies operating in a free market generally under an umbrella marketing strategy developed in association with the New Zealand Game Industry Board (GIB). The GIB is a statutory organisation with responsibility for promoting and assisting in the orderly development of the deer industry and the marketing of products derived from deer. It is financed by levies on products.

Usually, farmers sell live animals to the venison exporting companies, with payment on the basis of a schedule system. The pricing structure generally seeks to encourage the production of lean carcasses, principally in the early spring to meet the particular pattern of demand in the Northern Hemisphere markets. The main markets are in Europe, with Germany being the major importer, but there are very important markets in the USA and Japan. Venison is marketed in cuts designed to meet particular markets and most is sold in the frozen state, although an increasing quantity is exported in the chilled form. A new branding strategy has been developed by the GIB in association with exporters targeting the USA and local New Zealand market with

'Cervena'™, a product which is being positioned at the top of the restaurant market. Other markets are also being targeted under the 'Zeal' quality mark. The industry has a major emphasis on quality assurance which started with ISO 9000 accreditation of processing plants but which is now being extended to the farm and transport components of the industry. Venison is increasing in importance as a proportion of the total output of the New Zealand deer industry. The annual pattern of premium market requirements means that there is a growing interest in the genetics of growth rate and body size, the stimulus being that the vast majority of the traditional smaller NZR deer cannot attain the weights required to meet this market until they are 13 to 14 months old.

The major market for velvet antler is in South Korea, where it is used in traditional medicine. The market is coming under pressure, mainly due to the expansion in exports from the Commonwealth of Independent States (CIS, previously the USSR). The premium market demand is for large antlers harvested at a relatively immature stage of development. The emphasis on size has stimulated considerable interest in the genetics of antler growth. In the longer term, new markets will likely develop in non-traditional areas as the medicinal value of velvet antler becomes more widely appreciated in the natural products market (Fennessy 1991). Other co-products such as hides, tails and sinews also find a ready market, but they are unlikely to become major considerations for genetic improvement in the near future.

OPTIONS

Products and Genetic Improvement

Demand for venison features a seasonal pattern which tends to pay the highest prices per kg in the August to November period coupled with a very marked increase in the price per kg for carcasses over 50 or 55 kg. The growth rate (and growth pattern) of NZR deer is such that it is very difficult to achieve such slaughter weights at the yearling stage. The velvet antler market has parallels with the venison market in terms of requirements for larger products. The major velvet market in Korea pays the highest prices for the larger types of antler from the larger strains such as the Chinese malu (e.g. *C.e. xanthopygus*) or Siberian wapiti (e.g. *C.e. maral, C.e. sibiranicus*). This demand for the larger antler types has also stimulated interest in methods to increase antler size. Consequently the dual demands for faster growth rates and larger antlers have generated pressure to develop breeding and management practices to achieve these aims. While there is potential for improved nutritional management (e.g. Fennessy et al. 1981), the genetic route offers greater possibilities. Therefore the two breeding options for the New Zealand farmer are to genetically improve the NZR deer by selection within this strain (Fennessy 1982) or alternatively to hybridise NZR deer with larger strains or (sub)species such as Canadian wapiti (CW) (Fennessy and Pearse 1990).

The Gene Pool

The red deer family is notable for its extraordinary diversity and the capacity of its members to hybridise with one another to produce fertile offspring. This capacity for hybridisation among the various subspecies of the red deer family (e.g. wapiti and European red deer) and with other related species (e.g. Père David's deer, *Elaphurus davidianus*) coupled with the genetic diversity now available within New Zealand offers considerable potential to increase the body and antler size of the basic NZR deer to better satisfy market requirements. The NZR deer, being predominantly of the *C.e. scoticus* subspecies, is small (average adult stags weigh about 200-220 kg and hinds weigh about 100-110 kg) compared with the larger European red deer or North American wapiti subspecies. Consequently, hybridisation using a large male over the smaller NZR female can be expected to result in an increased efficiency (e.g. Fennessy and Thompson 1988, 1989). It will also offer greater flexibility in terms of the ability to meet venison market demands with a younger animal (i.e. to attain the required carcass weight at a younger age). Hybridisation will also likely increase antler size due to the positive allometric relationship between antler size and body weight within the red deer family (Huxley 1931; Schroder 1983).

Comparative evaluation of the newer imported strains/subspecies and their hybrids with the NZR deer is at an early stage although there are more substantial data for the CW and its hybrids. Table 1 presents a summary of two sets of such data from Invermay (see Fennessy 1992). The wapiti hybrid data are notable for the lack of any improvement in growth with increasing proportion of wapiti genes over 50% in males although there are some small improvements evident in females. The relatively poor performance of ¾ CW and CW is probably due to the effects of subclinical internal parasitism possibly coupled with copper deficiency (Waldrup and Mackintosh 1993). Preliminary data from on-farm comparisons are now available for hybrids between German (Schulte Wrede strain) or Hungarian red deer and NZR hinds (from Fennessy 1992) and are presented in Table 2. Data for the ¼ Père David's / ¾ red deer hybrid (Fennessy and Mackintosh 1992) are also included for comparison. The summarised data indicate that hybrids between some European strains and NZR deer may be around 20% heavier than NZR deer as yearlings, a weight similar to the ¼ CW/ ¾ NZR progeny of CW x NZR hybrid stags over NZR females.

Table 1 Relative yearling live weights for New Zealand red deer (NZR = 100), Canadian wapiti (CW) and their intermediate hybrids (from Fennessy and Pearse 1990, and Fennessy 1992).

	Relative yearling live weight	
	Males	Females
NZR	100 (108 kg mean)	100 (87 kg mean)
¼ CW/¾ NZR	117	122
½ CW/½ NZR	141	150
¾ CW/¼ NZR	142	159
CW	141	165

Table 2 Relative yearling live weights of various strains and hybrids compared with New Zealand red deer (NZR = 100), and the ratio of male to female live weight (sexual dimorphism) for each type (from Fennessy 1992).

	Relative live weights			
	Male	Female	Average	Sexual Dimorphism
NZR	100	100	100	123
¼ German/¾ NZR[1]	108	112	110	119
½ Hungarian/½ NZR[1]	*	118	118	*
¼ CW/¾ NZR	117	122	119	115
¼ Père David/¾ NZR[1]	124	128	126	120
Hungarian[1]	*	139	139	*
½ CW/½ NZR	141	150	146	121
¾ CW/¼ NZR	142	159	151	108
CW	141	165	153	111

[1] Data are very limited at this stage

Selection or Hybridisation

The decision whether to select within a strain or hybridise between strains is an important one. The expected mature live weights for progeny of a superior NZR stag are compared with the progeny of an average stag from a larger hybrid strain in Table 3. For the purposes of comparison, the hybrid strain is assumed to be 20% heavier than the NZR strain so that the selected superior sire within the NZR (i.e. a sire which is two standard deviations above average) is the same weight as the average hybrid. This demonstrates that the hybridisation option can be expected to produce markedly heavier progeny than even the intensively selected NZR sire. Although the first generation advantage to the hybridisation option is clearly apparent, there is then the question as to the options for utilisation of the hybrid females. Venison production is one option, but others include using the hybrid female as the base for generation of a larger hybrid by using an even larger sire strain over these hinds. In this respect, practical considerations mean that the sire strain should probably not be more than 50% larger than the female strain. For example, hybridisation of CW males with red deer females is not recommended in large scale commercial enterprises because of the increased managerial requirements during pregnancy necessary to minimise calving difficulties. However, use of ½ CW/ ½ NZR sires over NZR hinds is quite satisfactory (see Pearse 1992) and likewise CW sires over ¼ CW/ ¾ NZR hinds would also be expected to be quite appropriate.

Developments over the last few years would indicate that farmers appreciate the value of hybridisation. For example, increasing numbers are now using wapiti hybrids or European red deer and their hybrids as sires over NZR hinds. By comparison, the interest in selection within the NZR deer is now limited and there is a relative decline in demand for NZR stags.

Table 3 Comparison of (A) mature live weights (kg) of parental strains and their adult progeny with the situation (B) in which a superior New Zealand red (NZR) sire, an average sire of a particular hybrid strain or a superior sire of the hybrid strain is mated with NZR hinds. The hybrid strain is 20% heavier at all ages than the NZR deer strain.

	Sire	Dam	Progeny	
			Male	Female
(A) Parental strain (± phenotypic standard deviation, σ_p)				
NZR	220 ± 22	110 ± 11	220	110
"Hybrid"	264 ± 26	132 ± 13	264	132
(B) Selected sire x NZR hinds[1]				
Superior NZR	264 (+2σ_p)	110	229	114
Average "hybrid"	264 (average)	110	242	121
Superior "hybrid"	316 (+2σ_p)	110	252	126

[1] Assumes a heritability of 0.4 for mature live weight within the NZR deer and within the hybrid strain; yearling live weights would be around 55 and 80% of adult live weights for males and females respectively; zero hybrid vigour is assumed in the progeny of the hybrid sires over NZR dams.

INDUSTRY OF THE FUTURE

The deer industry is continuing to expand and while there is considerable range in the estimates of current numbers (around 600,000 hinds to calve in 1993?), an industry base of one million *Cervus elaphus* type hinds is a reasonable prediction for the future. Using this figure as a basis, Table 4 gives estimates of annual industry statistics. Such an industry would yield annual venison exports of around 45,000 tonnes (based on an 85 kg carcass for adult stags, 60 kg for adult hinds and two year stags and 52 kg for all other classes, with 80% exported).

It is very likely that the New Zealand deer industry of the future will be a hybrid-based industry. The commercial breeding herds will be based on NZR deer hinds or the slightly larger "megareds", the latter being the progeny of wapiti hybrid or European red deer males. These hinds would be mated with larger terminal sires to produce progeny for slaughter.

An industry of one million hinds would require the services of about 20,000 stags annually using natural mating. Assuming a breeding life of 2 to 4 years would mean that around 6,000 to 8,000 replacement breeding stags would be required annually. While any attempt to define the likely future structure is speculative, it is necessary in order to assess the likely demand for different types of stags. Table 5 presents an overall breakdown in which 25% of the total breeding hinds are used to breed replacements and the remaining 75% of hinds are used to produce hybrids. This split allows a sustained industry of one million hinds with the majority of the breeding female replacements being NZR. From the data in Table 5, it is apparent that 1,800-2,400 purebred European stags would be required. To produce 2,400 two-year-old breeding stags for sale annually, after allowing 50% for culling and mortality, would require 11,000 breeding hinds. The other three hybrid sire classes would account for a further 2,700-3,600 stags and would be produced from NZR, requiring up to 17,000 hinds. The majority of NZR and other purebred matings would likely involve home-bred sires although in this group there is real potential for genetic improvement within the strain. These calculations indicate that the commercial European red stag requirements could be generated from around 11,000 hinds, while up to 17,000 NZR hinds would be required to generate the hybrid sires. These figures assume a natural mating system with a ratio of 1 male to 50 females although new developments in AI could increase stag coverage.

Table 4 Estimates of annual industry statistics (in '000s) in a stable *Cervus elaphus*-based industry assuming one million hinds are mated and there is an 88% weaning rate (ie 440,000 calves of each sex are weaned annually).

	Estimated Numbers ('000s)		
	Males	Females	Total
Annual slaughters			
Yearlings	301	203	504
Two year olds	37	104	141
Adults	80	100	180
Annual deaths			
Weaning to yearling	12	10	22
Yearling to two years	1	3	4
Adults	9	20	29
Replacements required as two year olds			
Breeding	6	120	126
Velveting	83	-	83

Table 5 Estimates of total and annual breeding stag requirements for a one million hind *Cervus elaphus*-based industry (assumes a mating ratio of one male to 50 females and a male breeding life of (A) 2.5 years or (B) 3.3 years).

Type of mating	Sire breed	Percentage of hind herd put to these stags	Stag requirements		
			Total	Annual	
				A	B
Purebred	NZR and other	25	5000	2000	1500
Hybrid	Wapiti x NZR	25	5000	2000	1500
	¼ Wapiti/¾ NZR	10	2000	800	600
	European red	30	6000	2400	1800
	European x NZR	10	2000	800	600
Total stag requirements			20000	8000	6000

NEEDS

Markets and Genetics

Market requirements often change very rapidly while genetic improvement is generally a long slow process. In considering the potential for genetic improvement, an approach which allows flexibility in terms of the products while increasing the basic productivity or efficiency of the overall system is the most appropriate approach to follow. A hybrid-based system such as is developing in the New Zealand deer industry offers this possibility. In such a system the development of specialist sire and dam strains allows the breeders of the former to concentrate on product quality traits and on maintaining the flexibility to change rapidly in terms of the timing of production or product mix (e.g. in terms of carcass weight) required, while the breeders of the latter concentrate on productivity traits.

In hybridisation situations in which the sire strain is clearly superior to the dam strain for the desired character (e.g. growth rate), the genetic gain arises mainly from the between-strain difference (and possibly hybrid vigour), with the genetic merit of the individual sire relative to other individuals within its own strain playing a less important part. Therefore the potential for hybridisation to make major improvements in productivity means that there are numerous questions about the emphasis which should be placed on genetic improvement within a strain. This relates both to the development of a specialist dam strain based on the NZR and to the identification or the development/genetic improvement of appropriate specialist sire strains.

Consequently, in considering genetic improvement within the deer industry, the objective must be to improve product quality traits, flexibility, efficiency of production or other traits which might have a place in an industry structured around hybridisation. An integrated industry would utilise hybridisation to capitalise on the differences between strains as the main method for producing high quality venison or other specialist products, while also providing the opportunity for developing and utilising specialist dam strains. Therefore the specific immediate needs of the industry are comparative data on the terminal sire strains and definition of the objectives for a dam strain, and a performance recording and genetic evaluation system which will facilitate these developments.

Terminal Sire Strains

In considering the performance of the various strains as sires over the basic NZR hinds, the primary issues are productivity and the ability of the progeny to meet the market requirements (i.e. product quality). The productivity traits essentially depend on the quantity of venison produced per unit of feed consumed which is a function of hind fertility, calf survival, growth rate and efficiency (Fennessy and Thompson 1988, 1989). The actual financial returns will be a function of the productivity traits together with product quality traits. The latter will likely be a function of the carcass weight, carcass lean meat content and the timing of slaughter. Other traits which may also influence overall financial returns and which should be considered are temperament of the progeny (which may affect product quality) and the subsequent fertility of the hind rearing hybrid progeny.

An appropriate sire strain comparison would include sufficient stags to ensure an adequate sample of each strain. However there is also the issue as to what constitutes a strain. For example, are there several German, Hungarian and Yugoslavian strains or are there, to all intents and purposes, only one or two? Similarly, how many strains of English Park deer or CW are there? Performance data for stags from within their own herd of origin would also be valuable. While the task is not trivial, the overall results of a strain comparison would be of considerable value to the New Zealand deer industry struggling to come to grips with the intricacies of hybridisation. Such data would provide the basic information relevant to choosing or developing a sire strain.

Dam Strains

While there is scope for using some of the larger hybrid females as dams, practical managerial considerations may well limit the size of hinds to about 130 kg. Consequently the New Zealand industry is likely to be built around the smaller NZR (100-110 kg) or the megared (110-130 kg) hind, the latter being the product of various hybrid mating schemes (e.g. ¼ CW or ½ European red). In this respect Table 6 presents estimates of the relative yearling live weights for hinds of the various crosses.

Table 6 Relative yearling live weights (NZR = NZ red = 100) for female progeny of various mating systems (data from Fennessy and Pearse 1990, Fennessy 1992).

	Parental strain					
	NZR	½ E/ ½ NZR	¼ CW/ ¾ NZR	E	½ CW/ ½ NZR	CW
Mature live weights (kg)						
Male	220	*	*	*	310	330
Female	110	*	*	*	170	240
Parental strain	Relative yearling female live weight					
NZR	100					
½ European (E)/½ NZR	110	120				
¼ CW/¾ NZR	112[1]	122[1]	125[1]			
European	120	130[1]	132[1]	140		
½ CW/½ NZR	127	135[1]	137[1]	145[1]	150	
CW	150	*	*	*	159	165

[1] estimated as mid-point of parental yearling values

* insufficient data available

Genetic improvement leading to the development of a specialist dam strain offers considerable possibilities. Individual stag and hind evaluation and selection is the basis of such improvement. With growth rate being catered for through the choice of sire, there is no pressure to select for growth rate on the dam side in the hybridisation situation, so that there is the opportunity to make genetic progress in other potentially valuable traits. These include:

1. An altered pattern of seasonality enabling an earlier breeding season.

2. The natural ability to both produce and rear twins.

3. An improved lactation performance.

4. Fertility at first mating and after rearing hybrid progeny.

5. Resistance to diseases such as internal parasites and tuberculosis.

Intensive screening of the NZR deer population for these and other traits is a possibility. While the nature of the industry generally precludes the large scale group breeding schemes which have been so successful in the sheep industry, a more limited approach for some of these traits would be very appropriate. Screening of the population in order to identify outlier animals followed by evaluation to assess the genetics of the variation would likely be a useful approach. In this respect, one possibility for selection for early breeding would be running yearling hinds with a melatonin-treated (i.e. seasonally advanced) red stag and selecting those which have become pregnant prior to the normal breeding season. Alternatively, selection could be on the stag side assuming that the pattern of seasonality is highly correlated in both sexes. This is likely since both are daylength-entrained phenomena and the probable basis of any genetic variation would be an altered sensitivity to the change in daylength. For example, selection for stags which clean their antlers of velvet early (reflecting an early rise in testosterone) would be one possibility. This is difficult practically and it may be necessary to attempt other approaches such as selecting stags which cast their old antlers earlier in the spring (reflecting an earlier decline in circulating testosterone levels).

The principles of selection for the other traits listed are similar. For example, a number of hinds have been identified by farmers as producing twins on more than one occasion. Repeat twinning probably has a strong genetic basis as in other species (e.g. cattle - Morris et al. 1992). The long term possibilities for the use of genetic linkage and marker-assisted selection to identify elite animals need to also be considered (Tate et al. 1992). At the research level, the ¼ Père David's/ ¾ red deer hybrid is a very useful animal in which to investigate genetic linkage between genetic markers and productive traits. The ongoing investigation of genetic linkage will be extended to other hybrids so that, in the future, markers will be used in association with other forms of selection in order to accelerate the rate of genetic improvement. However, in the more immediate situation, the approach to selection being proposed involves identification of exceptional animals for the trait of interest from within the normal population. In the longer term this would likely involve a combination of screening and genetic linkage procedures.

CONCLUSIONS

The New Zealand deer industry has the opportunity to capitalise on the wide genetic base and the extraordinary capacity for hybridisation, particularly within the red deer family. On the sire side, selection can concentrate on product quality traits while, on the dam side, selection would concentrate on productivity traits. This combination of approaches will require the development of schemes to assist breeders to clarify their objectives, record their deer and select the appropriate individuals for further breeding. This initiative is critical if the New Zealand deer industry is going to capitalise on its opportunities to improve flexibility so that in the future it can respond effectively to changing market requirements and continue to develop as a dynamic livestock farming enterprise producing a range of high quality products for international markets.

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