DEER PRODUCTION IN NEW ZEALAND

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Deer are not native to New Zealand. Red, wapiti and fallow were introduced last century and in the early 1900's by European settlers to provide sport hunting. The populations flourished and by 1930 were out of control (Challies, 1985). The impetus to farm deer in New Zealand came from the opportunity to better manage overpopulated feral stocks and give new economic returns (Fennessy & Drew, 1983; Drew, 1992). Today red and fallow deer as well as wapiti (the North American sub-species of red deer) are managed in pastoral farming systems which are similar to those of sheep and cattle farming. It is now possible to use technologies such as artificial breeding, performance recording, animal health programmes and controlled ration feeding with deer. This paper follows on from one given to this conference in 1982 (Fennessy & Drew) and reviews the progress made by science in terms of animal biology and the products of deer farming. The dramatic rate of progress achieved by New Zealand deer farmers is also reviewed.

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Biology of the Deer

Temperate species and strains of deer have a strongly seasonal pattern of body growth, reproduction, antler growth and coat development; this means that each of these functions occurs at separate, discrete times of the year. The seasonal pattern of growth and reproduction are strongly linked to photoperiod for the control of their timing during the year. Developments in the controlled farming of deer have provided animals which are behaviourally adapted to handling so that biological research is possible. Without that opportunity, scientific investigation of the deer would not have been possible. The synergy between deer biology research and deer farming has meant that both can achieve much more than either as a separate entity.

Science of the Animal

Reproductive seasonality

Red and fallow deer exhibit highly seasonal patterns of reproduction that are entrained by changes in daylength (Asher *et al.*, 1991). After a period of anoestrus during the summer the decreasing day length in the autumn determines the timing of the new breeding season which is 5-7 months long. The circadian pattern of secretion of the pineal hormone, melatonin, mediates the effect of photoperiod on rhythms of reproduction (Karsch *et al.*, 1984). LHRH from the hypothalamus is one interface between the pineal gland (melatonin secretion) and LH and FSH released from the anterior pituitary. In deer as in other mammals, LH is released in an episodic manner and the amplitude and frequency of the release has biological significance (Asher & Fisher, 1982). There is a marked surge in LH secretion which precedes ovulation and initiates the onset of oestrus (Asher & Fisher, 1992).

Exogenous melatonin can be used to advance breeding in deer (Adam & Atkinson, 1984; Webster & Barrell, 1985). Fisher *et al.*, (1992) found that when pre-pubertal hinds were treated with two subcutaneous implants (each 18 mg melatonin) in the spring (30 November) for 60 or 90 days, all the hinds displayed ovarian activity about 4 weeks earlier than controls. Adult female deer must be treated with exogenous melatonin during late pregnancy or early lactation to advance breeding. In fallow deer the procedure has been shown to inhibit lactation (Asher *et al.*, 1988) although not so in red deer (Adam, 1989).

Stags from temperate deer species, like hinds, are also seasonal breeders which respond to photoperiod cues. Melatonin works on hypothalamic releasing factors which control pituitary hormones such as LH. Changes in LH secretion in late summer and autumn directly influence testicular activity by promoting testis growth and increasing testosterone secretion. At the end of winter LH secretion diminishes and the testes regress in size (Lincoln, 1985).

Specific knowledge about how hormones control reproduction is fundamental to developing an effective artificial breeding programme. AI in New Zealand deer farming is now very successful. As oestrus detection is difficult a more cost effective procedure is to synchronise oestrus using a controlled internal drug release (CIDR) system inserted into the vagina for 10-12 days. Differences between fallow and red deer in plasma progesterone concentration after insertion of a CIDR have been found and it is now common practise to administer 200-250 i.u. of PMSG at or near CIDR withdrawal in red deer but not fallow deer (Asher *et al.*, 1991). Exogenous melatonin can be successfully used on stags to advance the breeding season and assist the timing of semen collection in relation to AI (Webster *et al.*, 1991).

The temperament of stags during the breeding season also makes semen collection difficult. Electro-ejaculation under anaesthesia is generally used but semen is often of lower quality than from natural service. Jabbour & Asher (1990) have described the development of a prototype internal artificial vagina device that has been used successfully with fallow bucks and has the potential to be used with other deer. The advantages over electro-ejaculation include reduced risk to the buck, more frequent collections per buck and better quality ejaculates. Post-thaw motility after frozen storage can be highly variable in red deer stags and more research is needed to improve this factor.

Intravaginal insemination is possible in both fallow and red deer but an intrauterine method gives much better results with conception rates of 65-75% in fallow deer (Jabbour & Asher, 1991) and in red deer 56% or 20-89% depending on treatment (Fennessy *et al.*, 1990). Pregnancy detection by ultrasound when the foetus is 40-60 days of age is now well developed for deer (Wilson & Bingham, 1990).

Antler growth seasonality

Antlers are organs of bone which are cast and regrown annually by male deer. Although antlers as hunting trophies have been studied for a long time it is only in the last 10 years that the physiology of antler growth has been researched in New Zealand and part of the reason for this is the ability we now have to farm and handle deer. The commercial value of velvet antler and the intrinsic interest in these organs prompted research in this field. Antlers are organs of bone which are cast and regrown annually by male deer. The seasonal rhythm is strongly influenced by changes in day length and mediated by changes in the secretion of reproductive hormones (Suttie & Fennessy, 1992). The antler is unique being the only organ to be fully regenerated in any mammal. Its role as a model for human bone growth is valuable and an understanding of the factors controlling commencement and termination of growth could be important to the better understanding of bone cancer.

Suttie & Fennessy (1992) draw a clear distinction between groups or levels of hormones that control the timing of the antler cycle and those that control the trophic development of antlers. Like seasonal reproduction, daylength or photoperiod is the key factor in the seasonal antler cycle. Decreasing daylength in late summer triggers a change in pattern of hormone release from the pineal gland. In turn the hypothalamus releases hormones which stimulate the anterior pituitary gland which then act on the testis. Testosterone is secreted from the testis as the breeding season approaches, leading to calcification of the antler cartilage and a whole range of other effects such as a reduced food intake. A dramatic demonstration of the fundamental effect of photoperiod on antler growth was shown by Suttie *et al.* (1989) who kept stags on two monthly cycles of 16 hrs light; 8 hrs dark and vice versa. This pattern produced three sets of antlers in a 12 months period. LH and testosterone levels were measured and the antler cycles were considered to be due to the ability of the stags to vary release of LH and testosterone in response to changes in the artificial photoperiod.

The development of the pedicle as an out-growth of the frontal bones of the skull precedes the initiation of true antler growth and can be studied in weaned stags during their first year of life. Results of a study by Suttie *et al.* (1991) were consistent with a theory that pedicle initiation is caused by increased levels of testosterone stimulated by increasing LH pulse frequency. Exogenous gonadotrophin-releasing hormone (GnRH) has been shown to have a large effect on LH secretion during pedicle formation (Suttie *et al.*, 1991).

In the mature stag the hard antler is cast and the new velvet antler commences growth in a process that is associated with a rapid decline in testosterone levels. At this time a challenge of GnRH will produce very little increase in plasma testosterone concentration (Suttie & Fennessy, 1991). Control mechanisms on velvet antler cell growth rate are complex and not yet well understood. Growth hormone (GH) is known to have growth promoting effects on cartilage via insulin-like growth factors (IGF's) previously called somatomedin. Studies reported by Suttie & Fennessy (1992) indicate that plasma IGF1 concentration is very closely related to rate of velvet antler growth.

Spring peak of antler growth in these yearling stags (11 cm/month) came at a time when IGF1 levels had risen to 190 ng/ml from a late winter value of about 90 ng/ml. IGF1 effects on antler growth appear to be true endocrine effects because surgical removal of antler and pedicle tissue did not eliminate increases in IGF1 levels with time in spring (Suttie & Fennessy, 1992). Plane of nutrition has important effects on IGF1 levels (Breier *et al.*, 1986) and this may provide a reason why poorly fed deer grow small antlers.

Selenium (Se) concentration in the tip of the growing antler has been shown to be very high (Suttie & Fennessy, 1992) and this might be due to high levels of glutathione peroxidase (GSHPx) which contains Se and whose function is to remove harmful oxygen radicles from rapidly growing tissues. Measurements have shown however, that more than 98% of the Se in the antler cannot be associated with GSHPx. The overall picture of the antler tip is that it is very similar to some tumours which also have very low levels of antioxidant enzymes. These suggestions and many other possible growth factors in antler physiology are discussed by Suttie & Fennessy (1992).

Body growth seasonality

By the elementary procedure of feeding temperate deer year round on an unrestricted high quality diet and measuring live weight change it has long been known that red deer have a marked seasonal pattern of feed intake and weight change that has nothing to do with available feed (Blaxter *et al.*, 1974; Drew, 1976). In broad terms temperate deer grow rapidly in the spring and summer and very little in the autumn and winter. The factors that influence and the mechanisms that control the growth cycle are now under active research but are still poorly understood. Photoperiod, as previously discussed in reproduction and antler growth is fundamental to seasonality in body growth and feed intake. By manipulating photoperiod Suttie *et al.* (1991) showed convincingly that IGF1 levels were dramatically higher in deer exposed to a 16L:8D winter regime than those on a 8L:16D regime. This suggests that the mechanism working on body growth from photoperiod may be through IGF1. Melatonin secretion in response to change in photoperiod is presumably operating through neuroendocrine pathways but details are not well understood (Suttie & Corson, 1991).

The view that seasonality in deer body growth is a direct result of both growth potential and food intake cycles is reviewed by Suttie & Corson (1991). These cycles, although linked are separate events. While the growth rhythm is at least partly controlled by IGF1 via growth hormone, the feed intake cycle is partly associated with plasma prolactin secretion from the anterior pituitary.

Body gain or loss is always a mixture of change in lean tissue and fat and it has been shown that mature stags in the breeding season can lose 88% of their body fat in 2 months (Drew, 1985). In broad terms temperate deer grow rapidly in the spring and summer and very little in the autumn and winter. This phenomenon would obviously lead to marked seasonal variation in animal feed requirements and Fennessy *et al.* (1981) established that breeding hinds require about 47 MJME/day in summer while lactating compared with 24 MJME/day in the other three seasons. Stags, on the other hand required almost as much ME in the winter for maintenance as they did in the spring/summer period while growing rapidly. Little body fat, poor insulation and high metabolic rate are reasons for high winter feed requirements.

Breeding and genetics

Progress in animal breeding is dependent on variation among animals. It is fundamental in any breeding programme to have a clear measurable objective and to know that the character is heritable (Fennessy, 1987). Red deer were introduced into New Zealand from a range of British sources in the mid 1800's and had 130 years of feral breeding before some were captured for farming. Without planned breeding interference from man over very many years the deer showed wide variation in things like body and antler growth. As it became possible to record production performance in body and antler growth in farmed deer progress through selective breeding became possible. From the outset meat production was the primary objective for deer farmers but before serious selection programmes commenced the value of velvet antler began to cause confusion for selection criteria. It is well known that "the more characters you select for, the less the progress will be made by any one" (Fennessy, 1987). Even today people have problems in deciding selection priorities. Although bigger animals tend to grow faster and have bigger antlers a diffuse selection process based on correlated traits will not be as successful as concentrating on one relevant trait.

The heritability of antler growth is relatively high (0.40 - Fennessy, 1989) so rapid progress is possible in increasing herd production through breeding. In farmed red deer it has been shown that the use of a breeding stag from the top 3% of males within a herd can be expected to improve the performance of the progeny in velvet antler growth by 0.22 kg/generation (Fennessy, 1989). This is a 9% increase in yield/generation. The use of artificial insemination in deer can provide a way to compare progeny from a wide range of sires from all over the country in a consistent environment. An example of the progress which is possible in velvet yield is given by Fennessy (1989). The progeny of one sire were 0.37 kg better in velvet antler production (cumulative over ages 2 to 5 yrs) than the average while another stag produced progeny 0.46 kg worse than the average. Selection criteria such as parentage, birth date, weight of dam, weaning weight, yearling and 2 yr weight as well as velvet antler weights can all be measured and used to make breeding decisions.

In addition to selection within a strain of deer hybridisation between sub-species, within a species and even between some species is possible. This procedure is the same as the use of a terminal sire in the beef or sheep industry, ie, use a large sire over a small breeding female. Wapiti is the second largest of the cervids and can be crossbred with red deer. Mating a pure bred wapiti bull weighing 400 kg to 100 kg red hinds is possible but must be done with knowledge and caution. Fennessy (1989) has shown that the progeny of this cross can be expected to yield 1.81 kg of velvet antler extra per generation over a base red herd performance of 2.5 kg. Such a breeding programme is a very specialised operation but the use of the half-bred male as a terminal sire over red deer is becoming common and the quarter-bred progeny are around 20-25% higher in growth rate and antler production than red deer.

Health and disease

New Zealand is relatively fortunate in being geographically isolated from the most serious infectious diseases. Feral deer were not known to suffer serious disease problems but when brought together in high density farming systems the situation changed. The very process of capturing feral animals and placing them in captivity caused stress and this manifested itself in a variety of ways. Griffin *et al.* (1992) showed that transport, fasting or physical restraint can seriously compromise the animals immune system leading to increased disease susceptibility.

Internal parasites have been found to be a problem in farmed deer because of the relatively high animal density when compared with feral conditions. Drenching young stock with anthelmintics gives good control as long as drench resistant strains of parasites do not appear.

Tuberculosis (*M. bovis*) can readily affect farmed deer and is a serious problem in New Zealand. The incidence is not high but infection would spread rapidly if there were no control measures. A skin test in the neck is the primary form of test and is now required by law. Immuno-diagnostic research was done to find a blood test, which when used in conjunction with a traditional skin test, would improve specificity and prevent the slaughter of some animals which had a non-specific reaction to the skin test. The BTB blood test is now widely used within New Zealand for Tb detection in farmed deer and there is a strong demand from other countries (Griffin *et al.*, 1990).

Science of the Products

Velvet antler

Traditional eastern medicine aims at maintaining good health or preventing disease rather than curing disease problems which is often the objective of western medicine. The range of materials used in eastern medicine is wide and includes both plant and animal products. Velvet antler is one of the products of major importance in maintaining good health and is widely used for disease prevention in young children (Yoon, 1989) but it is also used in the treatment of conditions such as anaemia, arthritis and impotence (Kong & But, 1985). It is because of its use in the treatment of impotence that velvet antler has had a degree of sensational publicity in the western media as an aphrodisiac, although this is only a very minor component of its use.

Deer antlers are a marvellous model of mammalian bone growth. The hard antlers of red deer are cast off in the late winter of each year and the new season's growth takes about 120 days to reach completion. The early growth is soft cartilaginous tissue where the active growing spot is the tip. As growth proceeds, the lower region nearest the head begins a process of calcification which eventually moves up the main beam to the tip as growth is complete. To be a top quality product for medicinal purposes the growing antler must be cut before there is major calcification. Fennessy (1991) has shown in red deer that mineral content (ash) increases linearly from 43 to 67 days of growth and during that time the relative concentration of lipid declines from 1.4 to 0.7 where 1.0 is the concentration at 55 days of growth. Typically red deer velvet antlers are harvested no later than 65 days of growth to be graded top quality. Russian work has shown a very close linear correlation between velvet antler lipid content and relative biological activity (Gavrin, 1976). At the point of harvest the tip or top part of the antler, which is least calcified is the most valuable and is used as preventative tonic medicines for children and young people. The middle portion is used in the treatment of arthritis and osteomyelitis while the lower piece is regarded as being of particular benefit to older people subject to calcium deficiency (Fennessy, 1991).

The quantity and quality of velvet antler varies between strains and species of deer. The large breeds of cervids such as wapiti (elk) and Russian maral produce heavy weight high quality product. In recent years, however, there have been many importations of superior strains of red deer from Europe. These animals are much larger than the established New Zealand strain and do produce bigger antler velvet. Fennessy (1989) has shown that it is possible to achieve a 50% increase in velvet antler production from the progeny of the best 3% of a wapiti strain if mated to a well grown red hind.

The drying of velvet antler until recently has been something of an art form in countries like China and Russia. The process is a mixture of cooking and drying to preserve the biological activity. In recent years many drying plants have been built in New Zealand which are sophisticated and fully automated and the quality of dried product is extremely high. Concentrated effort is now being made to find new methods of quality assessment so that a variety of drying systems can be evaluated including vacuum and freeze drying. It is known that dried velvet antler is 33-35% of the unprocessed weight and that the processed antler still retains about 15% moisture (Fennessy & Duncan, 1992). Most of New Zealand's commercial velvet antler crop is dried before leaving the country.

Research into the chemical composition of velvet antler from a range of deer strains and stages of growth has shown that NZ red 2 year velvet, cut at 55 days of growth, has significantly more lipid and lower mineral content than that from top grade (Super A) NZ red product. Russian antler purchased from Hong Kong was significantly lower in lipid content than either NZ red deer samples (Fennessy, 1992). This information is important because of the positive linkage between antler lipid content and the biological activity.

Venison

Venison was the meat of royalty in Europe from the middle ages. In more recent times the nutritional properties of venison have shown it to have all the advantages of red meat with none of the perceived disadvantages (Drew, 1992). The meat is high in protein, minerals (particularly iron) and some B vitamins but low in fat, saturated fatty acids and cholesterol (Drew & Seman, 1987).

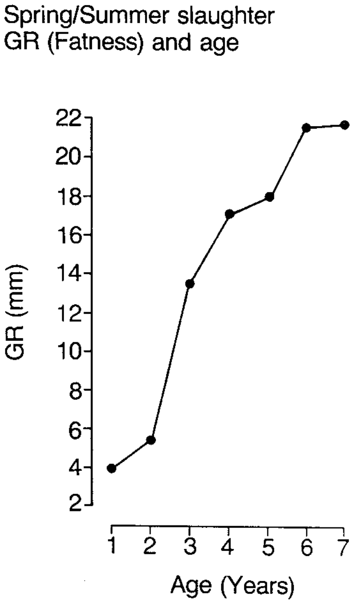

Figure 1 The effects of age on carcass fatness in red deer stags when slaughtered in spring - summer (GR=mm fat over 12th rib at a point 16 cm from mid back line).

Red deer and wapiti hybrids, the major venison producers from New Zealand, are extremely lean if slaughtered up to 2 years of age. Fallow deer can be overfat at 2 years of age. All male deer become extremely fat if they are well fed past the age of 3 years (Drew, 1985). Increasing fat with age in red stags is shown in Figure 1. The measure of GR for fatness in the minimum tissue depth over the 12th rib 16 cm round the rib cage from the mid line of the back. GR increased from 5 to 14 mm between 2 and 3 years of age. Irrespective of feeding regime the fat older stags at the end of the summer will mobilise almost all their body fat during the 2 months of the autumn breeding season (Drew, 1985). Female farmed red deer have only recently begun to be slaughtered for meat in New Zealand. Their carcasses do not often exceed 55 kg and those that do become extremely fat (Drew & Stevenson unpubl.). While venison from red deer stags which were older than 3 years became increasingly tough with age there was no evidence that the product from females changed with age even up to 13 years of age (Drew & Stevenson, unpubl.).

In New Zealand farmed deer must be legally trucked to a purpose-built deer slaughter premise (DSP) which may only process deer. Animal management in yards and in trucks is critical because deer need special handling and will readily climb on the backs of others inflicting bruising and hide damage.

Tenderness of meat is the most important thing to consumers and much of that is dependant on the quality of post-slaughter treatment of carcasses. Electrical stimulation of carcasses with low voltage current has been shown to be very effective in reducing muscle pH to less than 6.0 within 2 hrs of slaughter and protecting the meat from cold shortening toughness (Drew *et al.*, 1988). It is now standard practise in a DSP to use electrical stimulation and an instrument is available which will make certain that all carcasses receive the required current. It is possible to further improve venison tenderness by a period of conditioning at 4°C but the improvement is modest for an extra 3 or 4 days storage. If the meat is being stored and shipped "chilled" (-1°C) rather than frozen to a distant market then conditioning will continue during storage.

Red and fallow deer less than 3 years of age have been shown to yield 73-76% of the carcass as edible lean. This compares very well with chicken, pork, lamb and beef where yields range from 48.0 to 59.0% (Drew, 1992). Because of extreme leanness venison needs particular care in preparation and requires very hot cooking for a very short time to retain juiciness and tenderness.

Because of its high iron content venison can be a dark coloured meat and can appear rather like dark cutter beef which is recognised as a poor quality product. Research has begun to measure venison colour and evaluate a range of procedures that may improve market colour. A portable filter colorimeter (Minolta Chroma Meter CR200b) has been used with success (Stevenson *et al.*, 1991) and the instrument has been found to be useful in discriminating age in stag carcasses at a DSP. As stags grew older the "a" value (redness) decreased in neck muscles and Figure 2 shows the change that occurred with stags slaughtered in the spring and summer.
There was a 30% decrease in redness as animals increased in age from 2 to 3 years. The machine would offer a very practical means of distinguishing "young" (<3 yrs) from "old" (>3 yrs) animals.

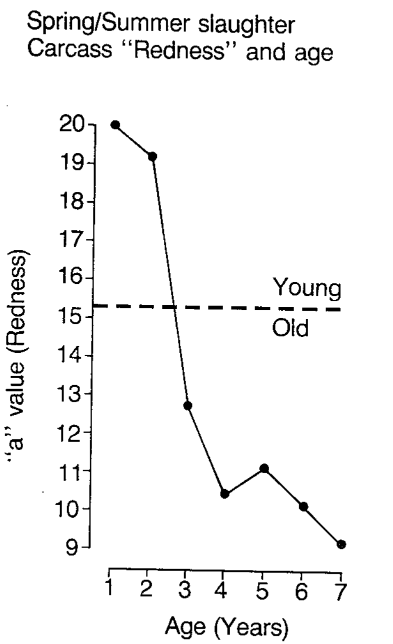

Figure 2 Changes in carcass neck colour as measured by a chromameter with age in red deer stags slaughtered in spring/summer.

Because New Zealand is so far away from its major overseas markets and there is increasing interest in chilled rather than frozen meat great emphasis must be placed on the bacteriological quality of carcasses. The procedure developed by the Meat Industry Research Institute of New Zealand (MIRINZ) to remove the animal skin mechanically from the head to the tail (inverted dressing) can be used very effectively in deer. The resulting deer carcasses have been shown to be almost sterile (bacteriological counts below 100 c.f.u./cm^2) off the slaughter line (Drew, 1992). Chilled storage of venison cuts from very clean carcasses is possible for up to 18 weeks without noticeable deterioration in eating quality but colour stability of displayed venison deteriorates quickly after long periods of storage (Seman *et al.*, 1989).

Industry Development and Marketing

In a period of 20 years the New Zealand deer industry has grown from nothing to a $120M/yr export industry. Animal numbers are now over 1 million with a breeding herd of 750,000 hinds. The national herd has recently slowed dramatically in growth rate with a large increase in slaughter of females. Between 1989 and 1992 the proportion of female animals slaughtered has risen from about 8% to 51% (GIB, 1992). Many of these female carcasses are light weight and not well regarded for current marketing plans. Special effort is now being made to locate and develop new markets for smaller venison cuts.

Velvet antler production and quality has risen spectacularly in the last four years from 20 tonnes (dry) to 115 tonnes in 1991. Current production, which mostly goes to South Korea either directly or indirectly, is now worth $50M/yr as an export product (Fig. 3). Production is expected to climb further and this will compete with Russian and Chinese product. Efforts are now being made to better understand the pharmacological properties of velvet antler in western terms and this may lead to new markets and a lesser dependence on Korea. Impressive progress has been made in New Zealand to improve velvet antler quality. Central to this process has been a comprehensive grading system developed by the NZ Game Industry Board (GIB) and now beginning to be used around the world. Instead of placing tenders after personally inspecting velvet antler, many buyers are now submitting prices (product unseen) by grade. Previously unprocessed antler left NZ in the frozen, undried, form where it was vulnerable to adulteration before processing.

Venison is another major growth industry. Volume of production increased by a massive 65% during 1991 and although prices did fall, marketing skills kept the drop to about 25%. This was quite remarkable given the very large volumes of feral venison exported to Germany from the Eastern bloc countries. Asian and American markets are showing growth and these are paying much higher prices than in Europe. Total export volume of venison in 1992 should reach 8,500 tonnes and the 1991 value rose to nearly $60M (Fig. 3).

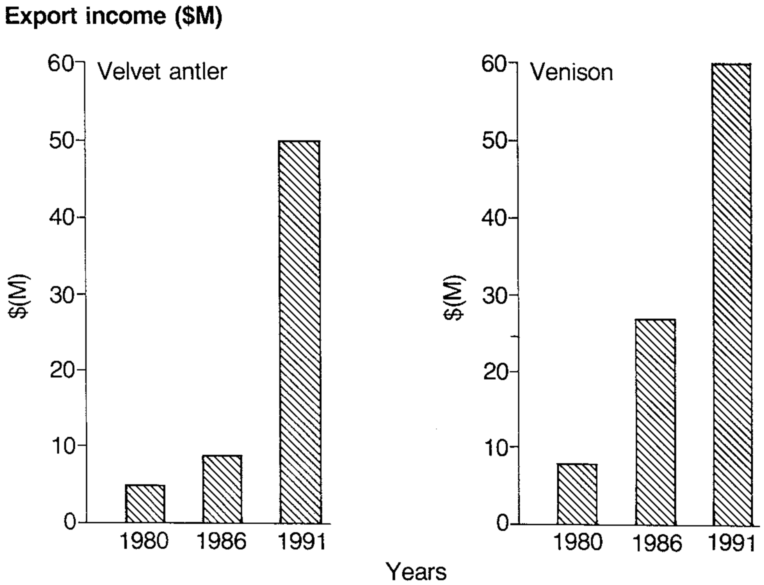

Figure 3 Export income ($M) from the sale of velvet antler and venison.

The combination of velvet antler and venison exports together with $5M from skins, tails, sinews and pizzles is shown in revenue terms in Figure 4. The $120M in 1992 is about a six-fold increase in export value during the last four years.

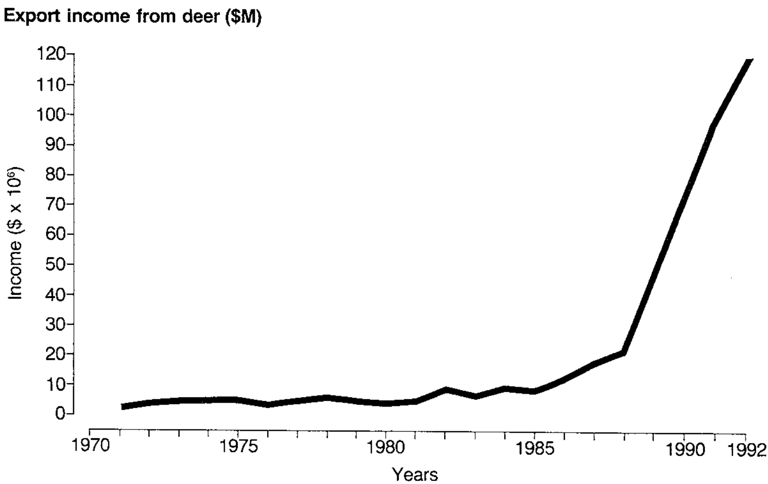

Figure 4 Export income ($M) from New Zealand.

A new marketing strategy for New Zealand deer industry products has now been formulated and will be implemented in early 1993. Central to the plan is that products branded under the GIB control will be guaranteed in quality and franchised to exporters. The appellation strategy for farm raised venison will be launched in USA and New Zealand early in 1993 and NZ venison will be repositioned in European markets by emphasising consistent quality through a certification trademark. While farm raised venison is the first product to be covered by the new marketing strategy the principles will eventually be applied to the other deer industry products.

Conclusions

Knowledge about the biology of deer has been greatly extended in New Zealand over the last ten years and most of that is due to the developments in farming. Central to the strong seasonality in reproductive, antler and body growth metabolism is daylength, its perception and its transmission through the neuroendocrine system to target organs. Research in western terms into the medicinal properties of velvet antler is in its infancy but good progress in this field may open up new non-traditional markets for velvet antler. Venison is now seen to be a healthy red meat with special nutritional properties that set it apart from other red meats. The wheel has turned the full circle with deer in New Zealand moving from pest status to the most exciting and profitable farmed animal.

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