UNIVERSITY OF ALBERTA

PRODUCTION PARAMETERS OF FARMED WAPITI IN ALBERTA

BY

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To my family,

for their support and encouragement

of my educational pursuits.

ABSTRACT

Wapiti farming is one of Alberta's newest and most promising agricultural endeavors. The industry has evolved from extensive "ranching" to intensive farming where producers practice intensive animal husbandry to maximize farm profits. This study evaluated the productive performance of farmed wapiti in Alberta representing this spectrum. Data was collected on 3,117 wapiti representing 70% of the provincial herd, through a survey of over 50 wapiti producers in the Peace River, Lakeland, Buck Lake, Edmonton and Red Deer regions where 90% of Alberta's game farms are located.

The two parts to the research survey represent both the breeding herd of mixed age hinds and the stags retained for velvet antler production. Data on velvet production indicate that although patterns of antler casting and growth are comparable with the more widely farmed red deer, wapiti are more efficient velvet producers per unit of metabolic weight. Selecting stags for past velvet antler production appears to be the most accurate method of determining future velvet production.

The reproductive performance of wapiti is surprisingly high given the inexperience of many of the province's newer game farmers. Overall calving rates of 93% coupled with a 5% calf mortality rate means that Alberta producers are achieving an 88% weaning rate in their wapiti herds. Average calf growth rates of 753 and 686 g d^{-1} for male and female calves respectively for the first 100 days of life were positively influenced by hind pre-rut weight. Herd efficiency measured as the weight of calf weaned at 200 days per 100 kg of hind exposed was 46.2 kg, compared to 35.1 kg in Alberta's commercial beef industry.

A model of biological efficiency (g carcass/MJ ME) of wapiti indicated that venison production is 28% more efficient than the more widely farmed red deer and comparable to the biological efficiency of beef production on a lean tissue basis. This study has demonstrated that farmed wapiti in Alberta are indeed efficient agricultural animals and should play an important role in the development of the province's livestock sector.

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INTRODUCTION

1.1 AGRICULTURAL DIVERSIFICATION

The impetus for agricultural diversification in Alberta comes not only from softening world grain prices but the changing agricultural industry. Budget deficits of federal and provincial governments leave many of the current levels of agricultural subsidies at risk. Changing global trading practices, with a move towards both free trade and an upcoming settlement of the latest round of G.A.T.T. negotiations may spell the end of many agricultural subsidies. Alberta's agricultural industry will undergo dramatic changes in the next decade as producers adapt to life without subsidies and may follow New Zealand's agricultural industry that suffered their transformation in the mid 1980's (Fennessy et al. 1993).

Alberta has some 55,000 farmers of which 10 to 15% produce 80 - 85% of the province's exportable foodstuffs and net farm income. This changing trend towards larger corporate farms means many of the people once involved in the agricultural industry full-time have had to seek off-farm employment to supplement their farm income. These "part-time" farmers with smaller land holdings live within commuting distance of their workplace but still enjoy the values of a traditional rural lifestyle.

Most of these part-time farmers are interested in being involved in the business of agriculture but find it a major challenge to pick an industry that fits both their time schedule and limited resource base. Grain farming requires significant capital investment and there is competition for suitable cropland to ensure an adequate economy of scale. Intensified livestock production has been scrutinized but beef, poultry and swine operations are too labor intensive and the disposal of animal wastes on small acreages poses a problem. Specialty crop production has been met with some success but the consistency of small niche markets is always a concern.

Diversified animal agriculture has been looked at favorably by both part-time farmers and full-time producers wishing to diversify, with wapiti farming being one of the more popular ventures that offers economic viability (Haigh and Hudson 1993). It doesn't require an extensive resource base, and labor requirements fit the hectic lifestyle demands of the off-farm careers of one or both spouses. Indigenous ruminants offer the advantage of being adapted to the rural landscape and fit the low input agricultural systems. Most rural residents also want their own activities to fit their choice of sustainable production, and wapiti farming meets that criteria.

1.2 THE GLOBAL DEER FARMING INDUSTRY

Deer farming is not a new agricultural endeavor (Hudson 1989) but most of the industry's growth has occurred in the last two decades. Estimating the current size of the international deer industry is a difficult task as the pace of expansion prohibits precise census recording. Two distinct markets have fueled most of the recent development in the global deer farming business led by China, the Commonwealth of Independent States (CIS), New Zealand and Scotland (Fennessy et al. 1993).

Velvet antler has been used as a traditional Oriental medicine for over 2000 years (Zhou and Wu 1979) but only the recent emergence of strengthening Asian economies has led to the establishment of a substantial velvet export market. This demand for velvet in South Korea, Hong Kong and Taiwan fueled the development of large domestic industries with Korean farmers rearing 145,000 sika (*Cervus nippon*), red deer (*Cervus elaphus*) and wapiti (*Cervus elaphus canadensis*); and Taiwanese farmers raising 40,000 sika and sambar (*Cervus unicolor*) deer. This export market also spurred the growth of farmed deer populations in China and the CIS. Xu (1992) estimates China has some half million farmed sika (*Cervus nippon hortulorum*) and wapiti (*Cervus elaphus xanthopygus* and *C e. songaricus*) concentrated predominantly in Jilin, Heilongjiang and Xinjiang provinces. China's deer farmers operate very intensive "feedlots", raising deer almost solely for their velvet antlers.

Development of a farmed deer industry in the CIS has occurred over the past 100 years based historically on the use of velvet antler within country, for the production of alcohol-based extracts of pantocrin and rantarin (Fennessy et al. 1993). Estimates of the size of the deer industry are more difficult but probably number well over 750,000 (Haigh and Hudson 1993) with at least 150,000 Asiatic wapiti (*Cervus elaphus maral*) and red deer, and 600,000 sika deer kept for velvet production. Recently the destabilization of the former USSR has meant more CIS velvet antler production has found its way into the export market, causing a softening in world velvet prices. The establishment of numerous joint ventures between CIS and New Zealand, Canadian and Korean businessmen will hasten the deer industry's modernization.

Scotland's and New Zealand's industries began by supplying venison from harvested feral red deer to the venison markets of Germany (Fennessy et al. 1993). The rise in venison prices caused a shortage of easily obtainable feral deer that eventually led to the establishment of deer farms with accompanying deer research organizations in Scotland (Glensaugh) and New Zealand (Invermay). The proliferation of New Zealand's "helicapture" deer operations provided initial breeding stock and favorable tax legislation fueled speculative fever. After twenty years, New Zealand's deer industry stands at over one million animals and is estimated to export 90 million $Can worth of velvet (25 million) and venison (65 million). Scotland's industry is well established with an estimated herd size of 25,000 (Haigh and Hudson 1993).

1.3 THE NORTH AMERICAN INDUSTRY

There are over 40,000 deer farmed in the continental United States, and over 70,000 deer farmed in Canada, exclusive of Alaska's 43,000 reindeer herd (Teer et al. 1993). With an investment of almost a half of a billion dollars deer farming is here to stay and is one of agriculture's growth industries. The inception of a commercially viable game farm industry in North America followed the development of the export velvet antler market in Asia and the white table restaurant venison market in the United States. Future developments of the continent's wapiti industry will likely parallel the direction of the international venison market with velvet antler becoming a by-product sold into the growing Asian marketplace within North American.

1.4 ALBERTA'S WAPITI INDUSTRY

The initial potential for game farming in Alberta was viewed as a multi-species approach of commercial meat production on marginal lands, patterned after Elk Island National Park (Telfer and Scotter 1975; Hawley 1985, Renecker et al. 1989). Captured animals from wildlife depredation hotspots and Elk Island National Park provided a source of seedstock for this fledgling industry with operators extensively managing their herds with little regard to intensive animal husbandry practices. Increasing demand for velvet products improved wapiti prices and a change in legislation preventing the capture of wapiti from wildlife depredation areas further fueled rising breeding stock prices.

High breeding stock values and the substantial capital required for fencing and facility development changed the course of the industry. Another legislative change that reduced the minimum game farm size from 160 to 10 acres saw many potential agricultural investors with smaller land holdings and substantial investment capital, diversify into wapiti production. These changes along with the unsuitability of mule deer and moose under intensive agricultural management, saw the potential for the industry switch from extensively managed game "ranches" to intensively managed wapiti "farms".

Though wapiti farming in Alberta has undergone much change, many of the original battles in the establishment of the industry as a bona fide agricultural endeavor have been met with success. The Alberta Livestock Diversification Act was passed on July 23, 1991 which saw the legalization of the sale of venison from wapiti and transfer of responsibility of the industry from Alberta Fish and Wildlife Division to Alberta Agriculture (Queens Printer 1991). With the legislation issue settled, concerns about the potential impact of farmed wapiti on native deer species may subside.

Today, after nearly a decade of flourishing growth due to high breeding stock values and velvet antler returns, the wapiti industry lacks a sense of direction. Softening velvet prices in the Asian marketplace has reduced the demand for breeding stock and producers have begun to speculate about the potential of farmed wapiti in the global venison industry.

The most recent data available (May 10, 1993) indicate that there are 4,325 wapiti on 161 licensed game farms in Alberta (Huedepohl, pers. comm.). If growth projections of the provincial herd follow other global deer industries that have compounded 20 - 25%, annually there could be over one million wapiti within twenty-five years.

1.5 STUDY OBJECTIVES

The objective of this thesis was to evaluate the performance of farmed wapiti in Alberta. Determining the production parameters of the provincial wapiti herd will help in establishing baseline performance data as well as defining future research and extension needs.

The first chapter on the "velvet production of farmed wapiti in Alberta" was a study on the production parameters related to velvet antler growth. Its main focus was to evaluate which velvet production parameters were more useful in predicting future velvet antler performance. Establishing industry performance data will allow producers to track future gains in velvet antler performance from their selection efforts. Additionally, a feeding trial comparing the effect of additional protein on the velvet production performance of two groups of velveting stags fed whole oats or dehy alfalfa pellets, allowed for a more thorough examination of factors affecting velvet growth.

The second chapter examines the reproductive performance of wapiti on Alberta game farms. Results from an industry survey of over 50 farms provided data on calving rates, calf mortalities, weaning rates, calf and weaner growth, length of breeding season, herd efficiency and the effects of pre-rut weaning. The comparative production efficiencies of wapiti were tested against other deer and conventional livestock species.

The concluding chapter examines the future of wapiti production by modeling the biological efficiency (BE) of venison production. This exercise provides a useful comparison of the relative meat production efficiencies of wapiti with the more commonly farmed red deer and other domestic species. The model also allows for an evaluation of the impact of management changes on comparative biological efficiency. The effects of changes in the productive lifespan of wapiti hinds, reproductive performance, death loss, timing of slaughter, calf sex ratios and dressing percentages were studied to determine their effect on BE.

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2

Velvet production of farmed wapiti *(Cervus elaphus canadensis)* in Alberta

2.1. INTRODUCTION

Velvet antlers have been harvested for the Chinese pharmaceutical market for over 2000 years (Luick 1982; Kong and But 1985). Since the mid 1970's, strength in Asian economies has renewed demand for velvet antlers and these markets have encouraged the development of a global game farming industry.

Recently, the disintegration of the former Soviet republics and their demand for hard currency, along with the ever increasing supplies of red deer velvet in New Zealand has destabilized the international velvet market (Barrie pers. comm.). The global glut of velvet has meant dramatically lower prices (- 50%) in 1992 of $100/kg for fresh product in Alberta, with poorer grades suffering the worst declines. Velvet producers will have to find ways of improving velvet yields and production efficiencies to ensure profit margins in this vastly stratified marketplace. Quality improvements through better genetic selection, velvet antler harvesting and processing would allow Alberta wapiti velvet to compete with the coveted Russian maral (*Cervus elaphus maral*) velvet (up to 20 kg a stag), that demands price premiums in the Korean marketplace.

The development and adoption of velvet harvesting protocols are now complete and few gains in the husbandry of velvet antler removal are expected in the future. Velvet processing in Alberta was in past a collection of smaller cottage industries run mostly by Asian businessmen. Today's processing is more sophisticated with the development of two large velvet antler processing facilities in the province which prepare velvet for both the Asian and domestic markets. Although these ventures are important steps towards stabilizing market forces and adding value to Alberta velvet, the farmer has little control over processing and must look to genetic selection to improve velvet quality.

Once wapiti stags are fed to appetite, little improvement in velvet yields can be expected from additional nutritional supplementation (Fennessy and Suttie 1985, Muir et al. 1987; Muir and Sykes 1988). Hybridization, progeny testing, recording and genetic selection are seen as methods of improving velvet antler quality and the efficiencies of velvet production in New Zealand (Fennessy and Suttie 1985; Moore et al. 1988; Pearse and Fennessy 1991; Fennessy et al. 1992; Pearse 1992). Liveweights, growth rates, and various antler measurements have been used to estimate future velvet antler growth (Moore et al. 1988). Continued stratification of breeding stock values reflecting expected velvet production, and individual velvet price premiums for large (> 1.2 kg dry weight or approximately 3.6 kg fresh weight) velvet antler (Hutching 1993; Hegarty 1993) will force farmers to hasten the selection process.

To date, the performance of Canadian wapiti in New Zealand has been dismal (Macintosh et al. 1982, Mackintosh et al. 1986, Fennessy and Pearse 1990) with reports of ryegrass staggers and a chronic wasting syndrome. This survey establishes benchmark performance data on the velvet production potential of Canadian wapiti on commercial game farms in Alberta with a comparison to the more traditionally farmed red deer in New Zealand. Estimating which velvet production parameters are useful in predicting velvet antler performance, and their practical application in the genetic selection process is described.

2.2 MATERIALS AND METHODS

2.2.1 Velvet Antler Removal

Today's game farming code of practice (Alberta Venison Council 1992) and legislation (Queens Printer 1991) ensures the humane removal of velvet antlers. Stags are either physically restrained in a padded hydraulic crush or sedated with 50 - 80 mg of xylazine hydrocloride. The antler pedicle is anesthetized by blockage of the infractrochlear and zygomaticotemporal branches of the trigeminal nerves by injecting 24 mg of lignocaine hydrochloride. Tourniquets are applied to restrict bleeding and the velvet antler is removed 3 cm above the pedicle with a bone saw, followed by the application of a disinfecting blood stop powder on the antler stub. The sedated stag is then released or reversed by an intravenous injection of yohimbine hydrocloride, and returned to the herd minus their prospective antler weaponry, no longer a risk to others during the upcoming rut.

Individual velvet antler is then tagged with an identifying seal provided by the provincial government, and reported to the director of the Livestock Diversification Act before August 1 of that year (Queens Printer 1991). The product is immediately frozen at below -28^0 C to prevent bacteria spoilage and can later be sold to licensed velvet antler dealers or processors.

2.2.2 Velvet Survey

Benchmark performance data of Alberta's velvet industry was collected by surveying 50 game farmers raising wapiti stags for velvet production. The research questionnaires were completed by visiting farms in the Peace River, Lakeland, Buck Lake, Edmonton and Red Deer regions where 90% of all the provinces game farms are located. Data collected in the survey included age, body weight, button drop date, velvet cutting date, days of velvet growth, velvet yield and velvet price on 1,026 wapiti stags. These data were pooled and used to calculate production parameters of the province's velveting herd.

2.2.3 Feeding Trial

Interest from Canada's alfalfa processors, and speculation from commercial game farmers in Alberta and Korea on the benefits of feeding additional protein to velveting stags, led to the development of a dehy-alfalfa velvet growth trial. In January 1992, the effects on velvet antler growth of replacing whole oat concentrates in stag rations with an equal amount of dehy alfalfa pellets was examined in a commercial setting (Heinz Oldach, Easy Street Ranch, Sherwood Park, Alberta). Forty mixed-age stags were randomly allocated by age, weight, and past velvet production to each of a control (OATS) and a treatment group (ALFALFA).

Stags were weighed to the nearest kilogram with an electronic platform scale on January 11th, and both groups were fed 2.5 kg d^{-1} per stag of either oats or dehy alfalfa concentrates, and ad libitum mixed grass hay for a 100 day period. The groups were then combined on spring pasture, and velveted using accepted sedation and analgesic procedures at the morphological stage dictated by commercial practices. Data collected included; 1991 velvet production, winter weight (Jan 11, 1992), antler casting date, velveting date, 1992 velvet production, summer weight (July 17, 1992) and individual weight gains. The trial was not replicated so few conclusions can be made about the effect of diets but the data allow thorough comparison of factors affecting velvet growth.

2.2.4 Statistical Analysis

For the province-wide survey, differences of velvet production between various aged stags were tested by analysis of variance. The influence of stag age on velvet antler weights was explored by analysis of covariance fitting pre-rut stag weights as covariates. The effect of pre-rut body weight on velvet antler growth was examined by regression. Factors affecting antler casting dates, velvet harvesting date and days of velvet growth of different aged stags were examined by analysis of variance and regression. Estimates of mature body weight and asymptotic velvet production were made by non-linear regression.

Velvet production, antler casting dates, velvet harvesting dates, days of velvet growth, mid-summer weight and weight gains of stags in the alfalfa velvet trial were examined by analysis of variance with diets being the main effect. With 1991 velvet production data available, analysis of covariance was used to explore if velvet antler growth (kg) or velvet production efficiency (g $W^{-0.75}$ of stag) peaked at a particular age. Data analysis were completed using StatView, Super ANOVA, and Systat for Macintosh computers.

2.3 RESULTS

2.3.1 Velveting Herd

The average age of stags in the survey was 3.7 ± 2.2 years, with the oldest stag recorded being 15 years old. Mean pre-rut stag weight was 348 ± 61 kg. Mature body weight was estimated following Renecker's et al. (1987) formula at 493 kg [$Y = 19 + (493X)/(2.1 + X)$, $r^2 = 0.78$] where Y is asymptotic body weight, X is stag age, and 19 is the average birth weight of a male wapiti calf. Stags achieved 50% of their ultimate mature body size by 2.1 years of age.

2.3.2 Velvet Production

A total of 1,026 mixed-age stags produced 4,885 kg velvet, averaging 4.8 ± 2.2 kg/stag. Velvet antler yield was affected more by stag age ($r^2 = 0.55$) than pre-rut weight ($r^2 = 0.39$) (Fig 2.3.1, $Z = 0.441X + 0.012Y$, $r^2 = 0.59$, $P = 0.0001$) where Z is velvet yield (kg), Y is stag weight (kg), and X is stag age (yr). Velvet production increased 1.36 kg between 2 and 3 years of age, 1.12 kg between years 3 and 4, and 0.74 kg between age 4 and 5 (Table 2.3.1).

Table 2.3.1. Changes in velvet antler production of stags in the survey.

Stag age	n	Velvet (kg)	SEM
1	46	1.03	0.06
2	319	3.18	0.06
3	254	4.54	0.07
4	142	5.66	0.11
5	124	6.40	0.12
6	41	7.15	0.22
7	30	7.60	0.24
8	17	7.68	0.35
9	12	7.67	0.44
10	18	7.51	0.39
11	11	8.53	0.39
12	9	8.33	0.32

Asymptotic velvet production was estimated at 7.9 kg by non-linear regression (Fig 2.3.2) and appeared to plateau at seven years of age.

Older stags cast their antler buttons earlier (Fig 2.3.3, $Y = 111.94 - 5.08X$, $r^2 = 0.56$, $P = 0.0001$) where Y is antler casting date (Julian days), and X is stag age (yr). Seven, six, five, four, three and two year olds cast their antlers on March 13, March 18, March 21, March 29, April 9, and April 19 respectively (ANOVA, $P = 0.0001$). Antler casting date had a marked effect on velveting date across all age classes (Fig 2.3.4, $Y = 100.0 + 0.65X$, $r^2 = 0.72$, $P = 0.0001$), where Y is velveting date (Julian days) and X is antler casting date (Julian days).

Producers in the survey velveted their stags between royal and sur-royal initiation (indentation of the 4th and 5th points before antler calcification occurs) after 59, 69, 67 and 71 days of growth in 2, 3, 4, and 5-year-old stags respectively. An increase of 7 days between antler casting dates and velveting dates resulted in an additional 1.02 kg of velvet (Fig 2.3.5, $Y = 0.15X - 4.02$, $r^2 = 0.29$, $P = 0.0001$), where Y is velvet yield (kg) and X is days of velvet growth.

Velvet growth averaged 124.9 g d^{-1} and was affected by pre-rut weight ($r^2 = 0.47$) and stag age ($r^2 = 0.47$) (Fig 2.3.6, $Y = 4.24 X_1 + 0.22 X_2$, $r^2 = 0.57$, $P = 0.0001$), where Y is velvet growth (g d^{-1}), X_1 is stag age (yr) and X_2 is stag weight (kg). The rate of velvet growth expressed on a metabolic weight basis (g $W^{-0.75}$ stag) was also influenced by stag age (Fig 2.3.7, $Y = 52.9 + 5.16 X$, $r^2 = 0.37$, $P = 0.0001$), where Y = velvet growth (g $W^{-0.75}$) and X is stag age (yr).

Velvet price averaged $180/kg (fresh weight) in the survey and the total 4,885 kg harvested was worth $879,000 at the farm gate. Most velvet sold in bulk at the farm gate for a negotiated price, with little reference to individual size or quality. Velvet prices varied more dramatically between years and were highest in 1990 (Fig 2.3.8).

2.3.3 Feeding Trial

Stags on either the alfalfa or oats treatments had similar ages, weights, and past (1991) velvet production (Table 2.3.2). Diet had no significant effect on antler casting dates, velvet growth, velveting dates, or 1992 velvet production. Stags fed the dehy alfalfa pellets gained slightly more (38.5 g d^{-1}, $P = 0.1086$) over the 187 day trial than those fed oats.

Antler casting was equally correlated to stag weight in January ($Y = 151.8 - 0.22 X$, $r^2 = 0.61$, $P = 0.0001$) or subsequent post rut weight in July ($Y = 144.3 - 0.18 X$, $r^2 = 0.61$, $P = 0.0001$), where Y is antler casting date (Julian day) and X is stag weight (kg).

Past (1991) velvet production ($r^2 = 0.82$) affected velvet yield (Fig 2.3.9) more than body weight ($r^2 = 0.63$) or stag age ($r^2 = 0.44$) ($Y = 0.777 X_1 + 0.009 X_2 - 0.192 X_3$, $r^2 = 0.85$, $P = 0.0001$), where Y is 1992 velvet yield (kg), X_1 is 1991 velvet yield (kg), X_2 is stag weight (kg) and X_3 is stag age (yr). Velvet yield peaked at age seven with three, five, six and seven year olds showing increased velvet growth from 1991 to 1992 whereas older stag's velvet production declined (Fig 2.3.10, $P = 0.0001$).

Table 2.3.2. Velvet production parameters of stags fed 2.5 kg d^{-1} of dehy alfalfa pellets or whole oats.

	Alfalfa n = 20		Oats n = 20		
	Mean	SEM	Mean	SEM	Prob.
Stag Age (yr)	5.9	0.6	5.4	0.5	0.4557
91 velvet (kg)	6.3	0.4	6.1	0.4	0.7877
Weight Jan 11/92 (kg)	326	11.1	324	8.6	0.8679
Antler casting (Julian)	79.0	2.7	81.4	13.2	0.5607
Velveting date (Julian)	153.2	2.8	154.9	2.8	0.6719
Days growth	74.2	1.0	73.5	1.5	0.7042
92 velvet (kg)	6.6	0.3	6.5	0.4	0.8245
Velvet growth (g d^{-1})	89.0	4.4	87.9	4.8	0.8578
Velvet Increase 91-92 (kg)	0.3	0.2	0.3	0.1	0.9865
Weight July 17/92 (kg)	359	13.6	349	10.6	0.5565
Weight gain (kg)	33.2	3.3	25.9	2.8	0.1086

Velvet growth described as g kg^{-1} of body weight was related more to past velvet production ($r^2 = 0.33$) than days of velvet growth ($r^2 = 0.12$) or stag age ($r^2 = 0.05$) ($Y = 1.76 X_1 - 0.93 X_2 + 0.17 X_3$, $r^2 = 0.58$, $P = 0.0001$), where Y is velvet growth (g kg^{-1}), X_1 is 1991 velvet yield (kg), X_2 is stag age (yr), and X_3 is days of growth. Velvet growth relative to metabolic weight averaged 79.0 g $W^{-0.75}$, was influenced by stag age ($Y = 68.35 + 2.87 X$, $r^2 = 0.22$, $P = 0.0024$), where Y is velvet growth per unit of metabolic weight (g $W^{-0.75}$) and X is stag age (yr). Daily velvet growth (g d^{-1}) was positively influenced by stag weight on January 11 (Fig 2.3.11., $Y = 0.36 X - 29.5$, $r^2 = 0.65$, $P = 0.0001$), where Y is daily velvet growth (g d^{-1}) and X is stag weight (kg).

2.4 DISCUSSION

2.4.1 Velvet Antler Production

Velvet antler production was influenced by a stag's pre-rut body weight and age which is similar to previous findings (Hyvarinen et al. 1977; Fennessy 1982; Fennessy and Suttie 1985; Moore et al. 1988; Muir and Sykes 1988). Velvet production in the survey increased 0.12 kg for every 10 kg increase in body weight, identical to that reported by Muir and Sykes (1988) of a 0.12 kg increase in velvet weight in red deer stags for each additional 10 kg of pre-rut body weight, whereas Fennessy (1982) reported a 0.09 kg increase. Velvet antler weight of wapiti stags in our survey increased by 0.44 kg per year of age, irrespective of body weight, whereas velvet antler increases due to age in red deer were 0.26 kg between

3 and 4 year old stags and 0.30 kg between 4 and 5 year old stags in New Zealand (Muir and Sykes 1988).

The effect of age on antler casting dates (8 day increase between 5 and 4 year olds and a 11 day increase between 4 and 3 year olds) was similar to that reported by Muir and Sykes (1988) who found an 8 day increase between 5 and 4 year old stags and a further 6 day increase between 4 and 3 year olds. Differences in antler casting dates between 2 and 3 year olds or 3 and 4 year olds (both 21 days) were more pronounced in a study by Fennessy et al. (1992). Antler casting dates reported by Muir and Sykes (1988) were related to pre-rut body weight rather than age, however their trials involved mainly younger stags which may have masked the effect of age. Antler casting dates were equally related to mid winter weights or subsequent pre-rut weights in the dehy alfalfa trial, contrary to Muir and Sykes (1988) study that indicated subsequent pre-rut body weights were more related to antler casting dates than mid winter weights.

Velvet harvesting dates varied significantly between stag ages and were related to antler casting dates. Muir and Sykes (1988) found the mean times before antler velvet removal in 3, 4, and 5 year old red deer stags were similar at 69, 68, and 72 days, comparable to the results of this survey. Days between antler casting and velveting in both red deer and wapiti were similar, but the rate of growth was much higher in wapiti (124 g d^{-1}) than red deer (29 g d^{-1}). Comparisons between velvet growth can be made on a metabolic weight basis, with wapiti (79 g $W^{-0.75}$) being more efficient velvet producers per unit of metabolic weight than the smaller red deer (50 g $W^{-0.75}$) in New Zealand (Muir and Sykes 1988; Pearse and Fennessy 1991).

The variance in antler velvet production was related more to past velvet yield, than either age, body weight or antler casting dates which supports the findings of Moore et al. (1988). Within age groups, pre-rut body weights were related to velvet antler weights which indicates an effect of frame size on velvet antler growth in wapiti, similar to red deer in New Zealand (Muir and Sykes 1988). Improvements in velvet antler production in wapiti are possible if producers select stags within an age group on the basis of velvet antler yield adjusted for velvet quality that reflects velvet antler grades.

2.4.2 Peaks in velvet antler production

Velvet antler growth of Canadian wapiti plateaued at 6-8 years of age in New Zealand (Fennessy et al. 1989). Huxley (1931) described a double logarithmic relationship between antler weight and body weight in red deer that suggested antler growth increased faster than body weight and Hyvarinen et al. (1977) concluded that allometric growth of antlers was age-dependant. To the contrary, Schroder (1983) found antler growth of German red deer continued to increase after body weight had peaked at age seven. The only previous work with wapiti in Alberta, suggests a similar age and live weight relationship with hard antler weight (Fig 2.12, Flook 1967), but a lack of mature stags in that study didn't allow an examination of a peak in hard antler growth.

Data from the alfalfa-velvet-growth trial supports Fennessy et al. (1989) findings of a peak in antler growth (kg) at age seven. The production efficiency of velvet antler growth described as g $W^{-0.75}$, peaked at age seven which implies a peak in production efficiency.

2.4.3 Selecting for improved velvet production

About 35% of the variability in velvet antler weight is of genetic origin (Zhou and Wu 1979), which makes it a moderately heritable trait. While the relationship between body weight and velvet antler weight is well established, individual variation of antler weights within an age group is a better prediction of subsequent velvet growth and are the best selection index if the sole objective is to improve velvet growth (Pearse and Fennessy 1991).

The process of genetic selection for improved velvet quality and quantity has been described by Fennessy (1987), Fennessy (1989) and Fennessy and Pearse (1991). The selection process requires that producers know the mean ± standard deviation of velvet production within an age group to determine selection differentials, after which the expected rate of increase can be calculated (Table 2.4.1) using Fennessy's (1987) equation for estimating gains in velvet antler production:

$$\textbf{Genetic gain per year} = \frac{\textbf{Heritability x Selection differential}}{\textbf{Generation interval}}$$

If generation intervals increase, the expected rate of genetic gain slows (Fennessy 1987). However, within Alberta's wapiti industry there appears to be a higher selection differential among older aged stags which suggests that there is more variability in velvet antler production as stags age. Faster rates of genetic progress depends on higher selection differentials and once game farmers place more emphasis on selecting for improved velvet antler production, these differentials will likely decrease.

Annual rates of genetic gain may seem insignificant to many producers but the implications of selecting better velvet producing three year old stags for breeding would improve velvet growth in progeny born ten years hence by 1.5 kg yr^{-1}. Wapiti stags born in 2003 producing 1.5 kg yr^{-1} more velvet during their productive lifespan (aged 2 to 11), would yield a farmer an additional 15 kg of velvet antler.

Table 2.4.1. Expected annual rates of genetic gain in velvet antler yield from following a progeny recording and selection program.

Breeding stage	Velvet (kg)	Heritability	Selection[1] differential	Generation[2] interval (yrs)	Expected genetic gain (kg yr^{-1})[3]
Ave 2 yr olds	3.18 ± 1.10	0.35	0	4.0	0
Top 3%	5.88	0.35	2.70	4.0	0.12
Ave 3 yr olds	4.54 ± 1.16	0.35	0	4.5	0
Top 3%	7.84	0.35	3.30	4.5	0.13
Ave 4 yr olds	5.66 ± 1.31	0.35	0	5.0	0
Top 3%	8.82	0.35	3.61	5.0	0.13
Ave 5 yr olds	6.40 ± 1.38	0.35	0	5.5	0
Top 3%	9.93	0.35	3.53	5.5	0.11
Ave 6 yr olds	7.15 ± 1.43	0.35	0	6.0	0
Top 3%	10.52	0.35	3.73	6.0	0.10

1. Selection differential is the relative difference of velvet antler production between selected and average stags 2 yr olds = (5.88 - 3.18) = 2.70

2. Generation interval is the average age of parents when the progeny are born [2 yr old breeding stags = (3 yr old stags + ave 5 yr old hinds)/2] = 4

3. Expected genetic gain assumes a farmer is breeding average hinds with a selection differential of zero so: Genetic gain of top 2 yr olds = .35 x [(2.70 + 0)/2]/4 = 0.12 kg /yr

2.5 CONCLUSIONS

Many of the conclusions of past research on the velvet production of red deer hold true for the larger Canadian wapiti. Patterns of antler casting and velvet growth are comparable once the influence of age is considered. Wapiti are more efficient velvet producers per unit of metabolic weight than the more traditionally farmed red deer. Velvet production efficiency peaked at age seven which has important implications in an agricultural setting. The survey established baseline data from which wapiti producers can compare velvet production performance. Selecting stags for past velvet antler production is the most accurate method of determining future velvet production performance. Determining the mean and variability of velvet production allowed for a calculation of the selection differentials of various aged stags, from which future genetic gains in the velvet antler industry can be estimated.

Velvet growth is not strongly influenced by diet in well-fed stags. Velvet production performance of stags fed dehy alfalfa pellets was comparable to the performance of stags fed the standard whole oat concentrate rations. While these findings have little significance in the domestic industry, the information is useful to Canadian dehy-alfalfa producers who are interested in marketing alfalfa products to the Asian deer industry.

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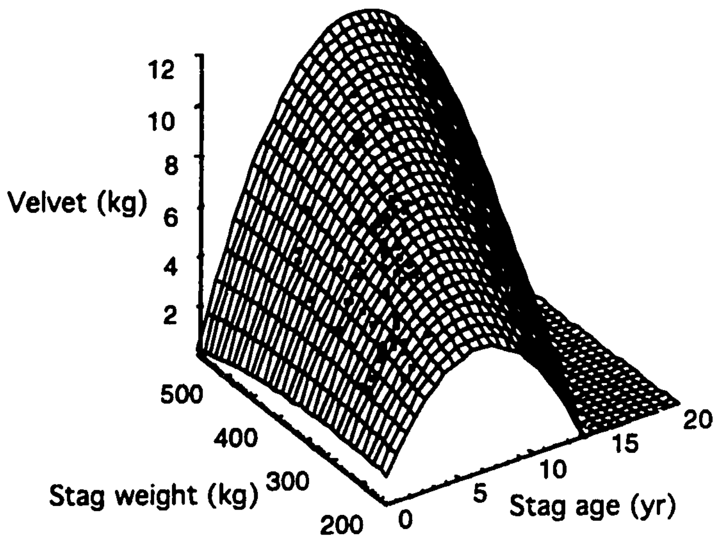

Fig 2.3.1. The effect of stag age and pre-rut weight on velvet antler production.

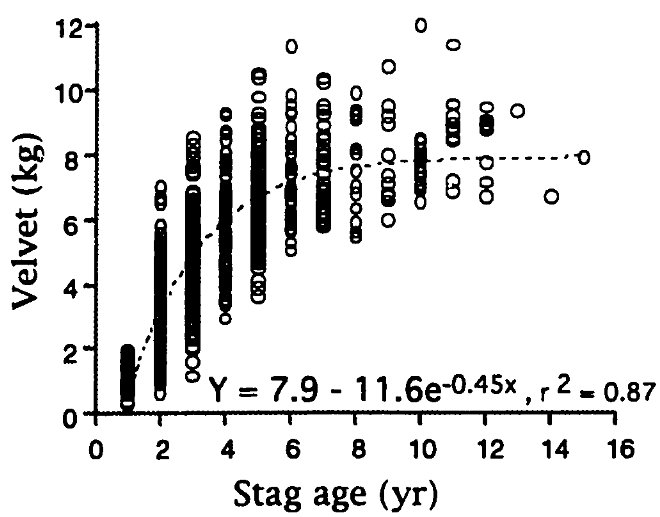

Fig 2.3.2 Asymptotic velvet production of wapiti stags in the survey.

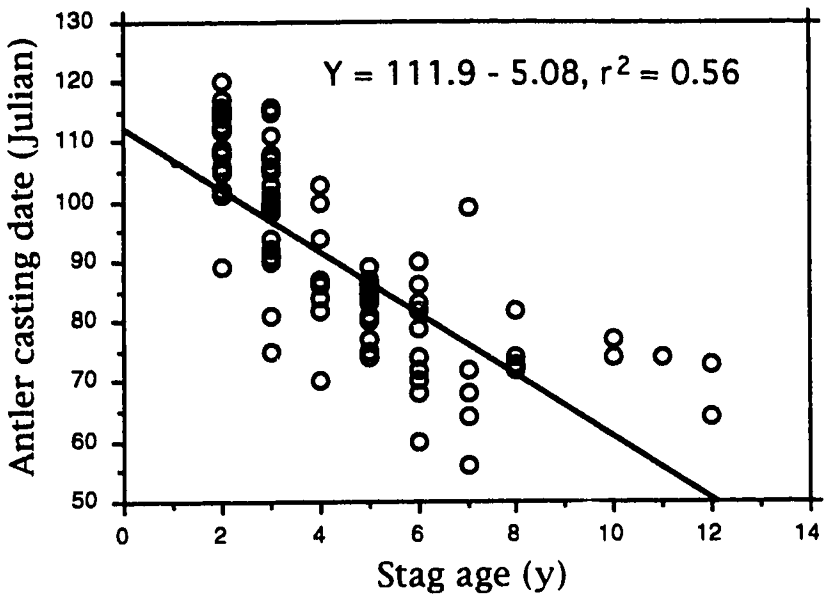

Fig 2.3.3. The effect of stag age on antler casting dates.

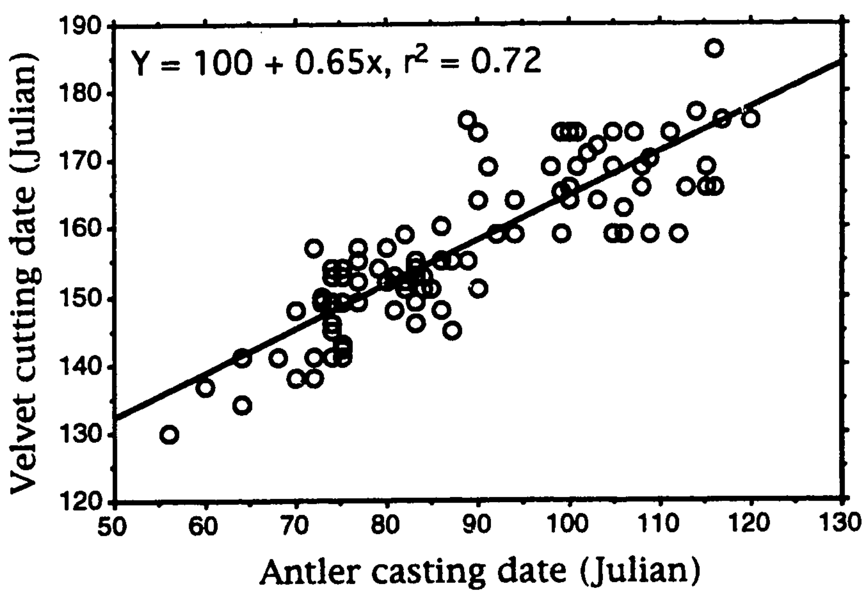

Fig 2.3.4. The influence of antler casting date on velveting date.

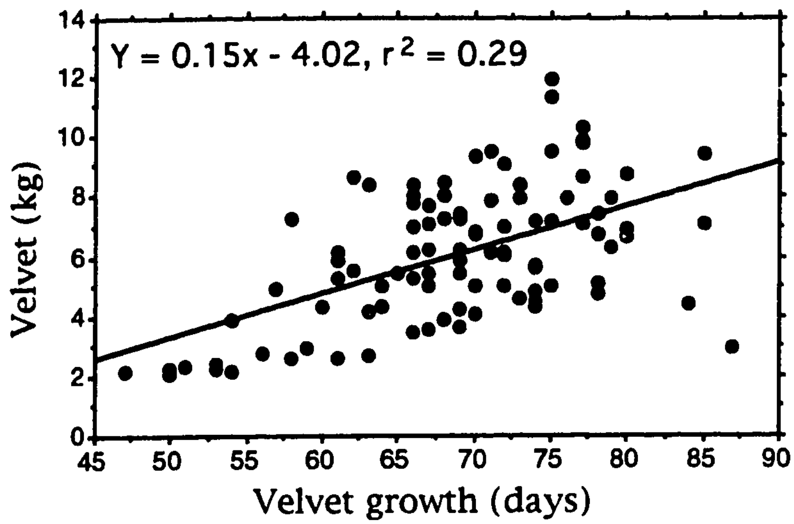

Fig 2.3.5. The effect of days of velvet growth on velvet production.

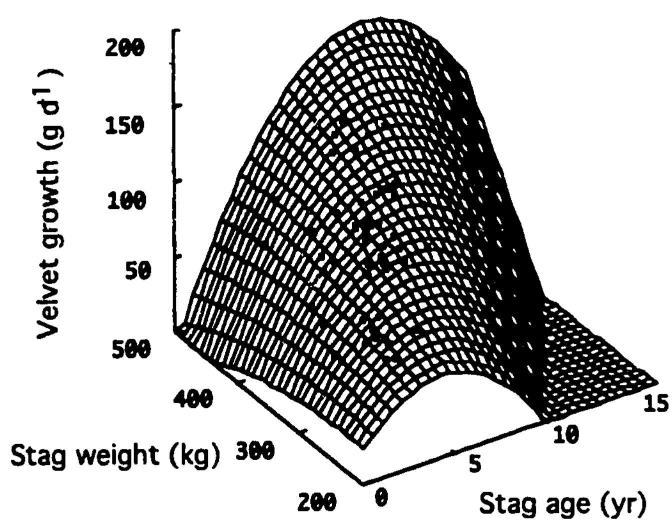

Fig 2.3.6. The effect of stag age and weight on the rate (g d^{-1}) of velvet growth [Velvet growth (g d^{-1}) = 4.24 (stag age) + 0.22 (stag weight), r^2 = 0.57, P = 0.0001].

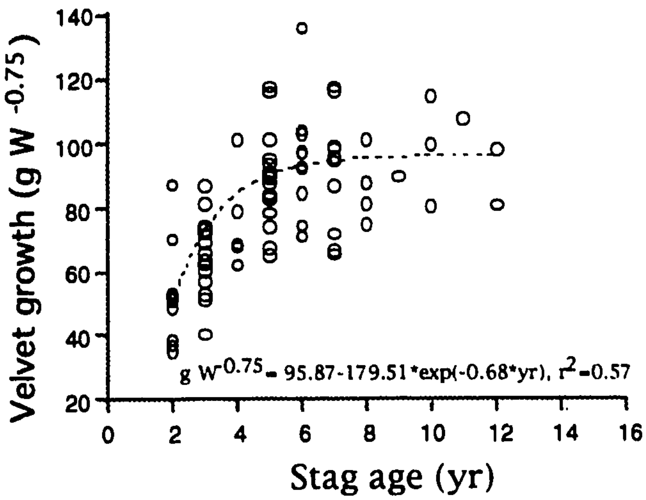

Fig 2.3.7. The influence of stag age on the metabolic efficiency of velvet growth.

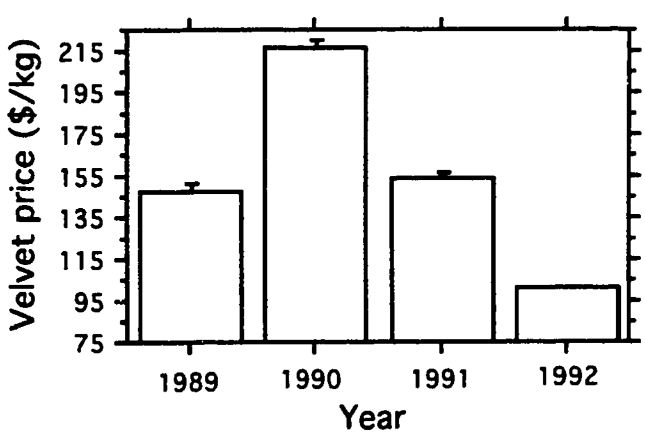

Fig 2.3.8. Fresh velvet antler prices in Alberta.

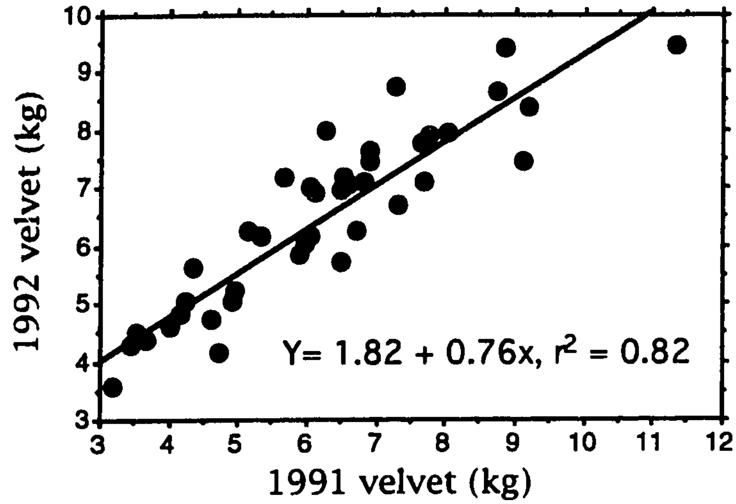

Fig 2.3.9. The effect of past velvet antler performance on velvet production.

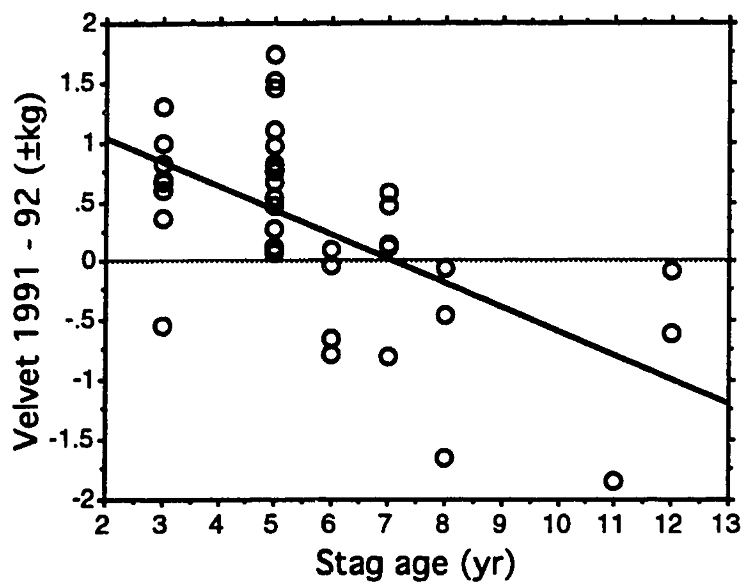

Fig 2.3.10. The effect of age on the change in velvet production.

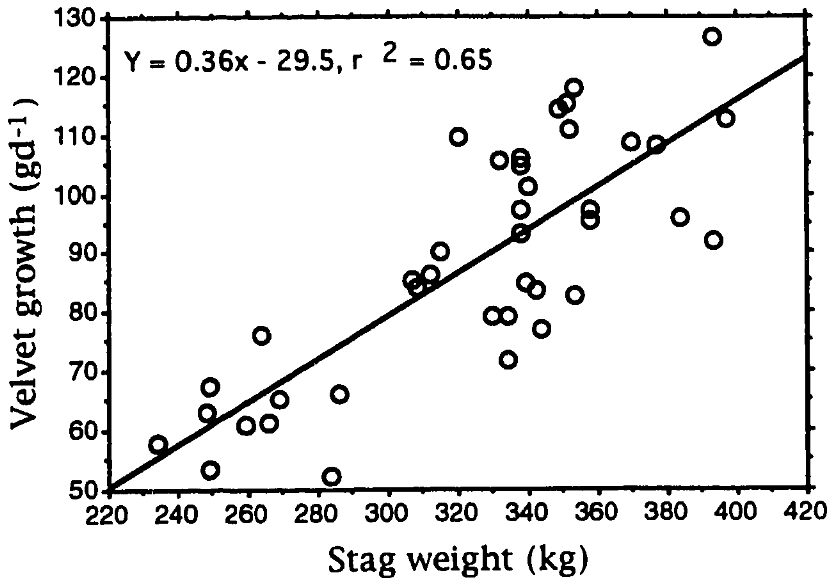

Fig 2.3.11. The influence of stag weight on the rate of velvet growth.

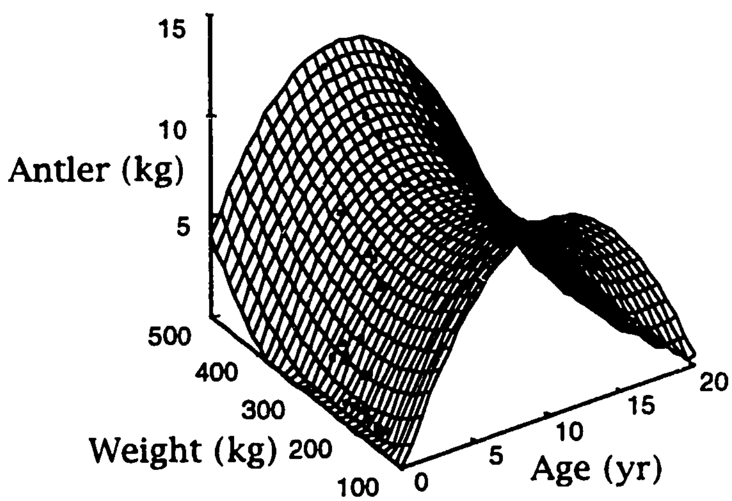

Fig 2.3.12. Stag age, live weight and hard antler weight allometry of wapiti (Flook 1967) in Alberta, with live weight affected by the season of harvest.

3

Production parameters of farmed wapiti in Alberta

(Cervus elaphus canadensis)

3.1 INTRODUCTION

The Canadian deer industry has grown to over 70,000 animals including 11,000 wapiti (*Cervus elaphus canadensis*), 28,000 fallow deer (*Dama dama*), 4,500 red deer (*Cervus elaphus*), 15,000 reindeer (*Rangifer tarandus*) and 12,500 white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*) and moose (*Alces alces*) (Hudson and Burton 1993). Despite the challenge of adapting husbandry practices to these unfamiliar species, new game farmers have experienced few production problems and surprisingly high productivity.

There is good reason to emphasize reproductive performance in any analysis of the prospects for this fledgling industry. After capital investment and feed costs, reproductive efficiency in a beef herd has the biggest influence on profitability (Basarab and ZoBell 1989). Gross returns can be improved by increasing beef calf weaning weights by 10% returning another $21 per cow, whereas a 10% increase in reproductive efficiency returns beef farmers an additional $60 per cow. Although these projections will differ quantitatively, the conclusions should hold for farmed game.

Reproductive performance of commercial red deer and fallow deer farms have been studied by Asher and Adam (1985) and Mulley and English (1991). The reproductive performance of research herds has been reported for wapiti (Hudson et al. 1991), and red deer (Kelly and Moore 1977; Hamilton and Blaxter 1980; Blaxter et al. 1988; Moore et al. 1988a). Recent research in New Zealand has focused on the reproductive manipulation of deer through hybridization, inducing twins, altering sex ratios and advancing the calving season in hopes of attaining earlier market weights (Fennessy et al. 1986; Fennessy and Thompson 1989; Fennessy et al. 1990; Pearse 1992).

Comparable studies have not been done on wapiti farmed under commercial conditions. This paper is a summary of the productive performance of wapiti on Alberta game farms with a comparison to the more traditionally farmed red and fallow deer operations in New Zealand. I tested the claim that domestically farmed wapiti have higher productive efficiencies than other deer and conventional livestock species by comparing calving rates, weaning rates, death loss, and growth. I also explored the implications of pre-rut weaning and its subsequent effects on calving and weaning rates of hinds; calf mortalities; birth dates; and growth rates of calves.

3.2 MATERIALS AND METHODS

Data were collected through a survey of wapiti producers in the Peace River, Lakeland, Buck Lake, Edmonton and Red Deer regions where 90% of Alberta's game farms are located. Survey questionnaires were completed in 1990/1991 by visiting each farm individually and reviewing production records for that herd. The research data were compiled by visiting over 50 operations representing 70% of all the farmed wapiti in Alberta.

3.2.1 Farm Records

Relevant production information was recorded on a total of 1,084 hinds. Records included hind ages and weights; stag ages; calf sex, birth dates, birth weights, weaning weights and dates, post rut weights; deaths and dystocias; beginning, end and length of rut; number of hinds exposed per stag; open hinds; and annual stocking rates (fenced area per wapiti) were collected.

These data were pooled and used to calculate calving rates, calving seasons, sex ratios, weaning rates, 100 day adjusted weights, 200 day adjusted weights, rates of gain, death loss, and production efficiency:

Calving rates: births per 100 hinds exposed to breeding;
Death loss: calf mortalities including dystocias, still-births, non-viable calves, accidental deaths, predation loss, disease, and unknown;
Weaning rates: calves weaned per 100 hinds exposed;
100 day weights (kg): calf pre-rut weights adjusted to 100 days;
200 day weights (kg): calf post-rut weights adjusted to 200 days;
Growth to weaning (g d^{-1}): (100 day weights - ave. birth weights) per 100 days;
Weaner growth (g d^{-1}): (200 day weight -100 day weight) per 100 days;
Hind efficiency (kg calf/100 kg hind): kg calf at 200 days per 100 kg maternal weight;
Herd efficiency (kg calf/100 kg hind): Average hind efficiency x weaning rate.

3.2.2 Statistical Analysis

Differences in two year old and adult (> 2 yr) hind pre-rut weights were examined by analysis of variance and mature body weights were estimated by non-linear regression. Factors affecting calving and weaning rates; open females; and calf mortalities between young and adult hinds were tested by analysis of variance and covariance. Sex ratios were tested non-parametrically in relation to hind ages using Spearman's rank correlation coefficient. A comparison of two year old and adult hind weights, calving dates, calf birth weights, calf weaning weights, calf growth, breeding dates, stocking rates and efficiency were made by analysis of variance and are reported as means ± standard errors. Regression was used to test the same production parameters in the combined breeding herd. Computations were done using SYSTAT, SuperANOVA, and StatView for Macintosh computers.

Differences between male and female calf birth dates and weights and subsequent calf growth from both young and adult hinds were compared by regression and analysis of covariance. Pre-rut weights of hinds were fit as covariates since these factors proved important in previous studies (Blaxter and Hamilton 1980; Hamilton and Blaxter 1980; Hudson et al. 1991). The practice of weaning, stocking rates, length of breeding season, stag age, and hind to stag ratios were examined by analysis of variance and covariance to determine their effects on various production parameters.

3.3 RESULTS

3.3.1 Breeding Herd Profile

The average age of wapiti hinds in the survey was 4.7 ± 2.8 years, and the oldest female was 16 years old. Because most farms are building their breeding herds, young females are retained so the industry has a relatively young herd profile (Fig 3.3.1). The age of the herd sires was slightly older at 5.3 ± 2.0 years and ranged from 2 to 10 years old. The average female weighed 239 ± 27 kg with a range in body size from 160 to 300 kg. Mature hind weight was estimated at 247 kg by non-linear regression ($Y = 17 + (247.3 \times X)/(0.44 + X)$, $r = 0.33$) where Y represents asymptotic mature hind weight, X equals hind age and the average birth weight of a female calf is 17 kg.

3.3.2 Calving Rates

A total of 876 mature and 208 fifteen month old hinds were exposed to stags resulting in 1,012 calvings from 1,007 hinds for a 93% calving rate (Table 3.3.1). Calving rates among two year old hinds were lower than mature hinds with 81% of two year olds and 96% of mature hinds calving respectively (ANOVA, $P = 0.0001$). Hind weights, breeding season length, age of breeding stag, the number of hinds per stag, and stocking intensity had no impact on calving performance. Herds in which pre-rut weaning was practiced had higher calving percentages (94% vs 91%, ANCOVA, $P = 0.0091$).

Table 3.3.1. The reproductive performance of wapiti hinds in the survey.

Hinds	Two Yr Olds (n = 208)	Adults (n = 876)	Herd (n = 1,084)
Calving Rate (%)	81.3	96.2	93.4
Calf Mortality (%)	9.5	4.4	5.2
Weaning Rate (%)	73.6	91.4	88.0
Open (%)	18.8	4.3	7.1

3.3.3 Calf Mortality

Calf mortality averaged 5.2% within the herd and two year olds experienced a higher death loss (9.5%) than mature hinds (4.4%) (Table 3.3.1, ANOVA, P = 0.0704). Considering the effect of hind age, producers who practiced pre rut weaning had a 3.9% calf death loss whereas farmers who did not wean experienced calf mortalities of 7.1% (ANCOVA, P = 0.0007). Dystocia accounted for 62.3% of all neo-nate losses (Table 3.3.2) and factors like hind weight, birth weight, birth date, and stocking rate had no affect on calf mortalities.

Table 3.3.2 Calf mortalities of wapiti in the survey.

Reason	Dead (n = 53)	Percent
Dystocia	33	62.3
Accidental	5	9.4
Disease	3	5.7
Predation	4	7.5
Unviable	5	9.4
Unknown	3	5.7

3.3.4 Weaning Rates

The percentage of weaned calves was influenced by the age class of hind, the practice of weaning, and stocking rates. Weaning rates of adult wapiti hinds (91.6%) was better than young two year old hinds (73.6%) (Table 3.3.1, ANOVA, P = 0.0001). Pre-rut weaning the preceding year improved weaning success from 78.7% to 86.8% (ANOVA, P = 0.0020). There was a significant interaction (Fig 3.3.2) between age class of the hind and the practice of weaning (ANOVA, P = 0.0384). Weaning improved calf rearing success among mature hinds by 2.6% (92.9% vs 90.3%) and among two-year old hinds by 13.4 % (80.4% vs 67.0%). For each additional hectare of pasture that was provided to every wapiti hind, weaning percentage improved by 3.6% (Regression, $Y = 0.825 + .0.036x$, $r^2 = 0.01$).

3.3.5 Production Parameters

Calving information, growth, breeding seasons, stocking rates and efficiency are summarized in Table 3.3.3.

Table 3.3.3. Production parameters of wapiti in the survey.

	Two Year Olds (n = 208)				Adults (> 2 yr) (n = 876)				Total Herd (n = 1,084)				
Calf Sex	Male	(S.E.)	Female	(S.E.)	Male	(S.E.)	Female	(S.E.)	Ave	(S.E.)	Min	Max	Range
Hind weight (kg)	220	4.9	214	4.5	241	2.0	243	2.2	239	1.4	160	300	140
Calving date	11-Jun	1.6	11-Jun	2.0	6-Jun	1.0	6-Jun	1.2	7-Jun	0.6	21-Apr	10-Sep	142
Birth weight (kg)	17.4	0.8	16.2	0.8	18.5	0.3	16.9	0.5	17.7	0.3	11.5	22.2	10.7
100 day weight (kg)	88.4	2.9	82.0	2.7	95.6	1.4	86.3	1.2	89.5	0.9	57	126	69
Growth (g d^{-1})	694	30	650	27	766	14	693	12	720	10	390	1070	680
200 day weight (kg)	127	4.2	114	4.0	130	1.7	122	1.5	125	1.1	90	170	80
Gain (g d^{-1})	315	19	342	22	476	18	426	12	430	10	201	730	529
Exposed	4-Aug	8.9	7-Aug	7.9	31-Jul	4.4	7-Aug	3.7	5-Aug	2.4	1-Jan	15-Sep	258
Unexposed	23-Nov	2.5	24-Nov	2.2	24-Nov	1.3	25-Nov	1.3	24-Nov	0.8	14-Oct	31-Dec	78
Rut (days)	110	10.6	109	9.4	115	5.4	109	4.6	111	2.9	48	365	317
Stag/Hind	18.2	0.8	18.2	0.8	22.3	0.6	22.6	0.6	21	0.2	4	47	43
Stag age (yrs)	4.5	0.2	4.5	0.2	5.6	0.1	5.5	0.1	5.3	0.1	2	10	8
hectares/wapiti/yr	1.2	0.1	1.4	0.1	1.3	0.1	1.2	0.1	1.2	0.1	0.7	15.5	14.8
Hind efficiency (%)	56.1	1.5	51.6	1.4	54.4	0.8	50.6	0.7	52.5	0.5	37.9	73.6	35.7

3.3.6 Birth Dates

Birth dates of male and female calves were the same. Fitting hind pre-rut weights as a covariate, there was no difference between the calving dates of young (June 7) and adult (June 5) hinds that could not be explained by differences in weight. Regressing birth dates (Y) on hind pre-rut weights (x) showed that for every additional 10 kg of hind weight, calves were born 2.1 days earlier ($Y = 206.9 - 0.21\ x$, $r^2 = 0.11$).

Farmers that pre-rut weaned had calves an average of 5 days earlier than those who separated their calves and hinds after the rut (June 4 vs June 9, ANCOVA, $P = 0.0017$). Calving dates of young and adult hinds responded differently to weaning (Fig 3.3.3). Older wapiti hinds whose calves were pre-rut weaned subsequently calved an average of eight days earlier (June 2 vs June 10) than hinds that were bred with their calf at foot (ANCOVA, $P = 0.0001$), whereas two year olds calved 5.6 days later (June 13 vs June 7) if they were pre-rut weaned as calves.

3.3.7 Birth Weights

Male calves were heavier (18.3 ± 0.3 vs 16.7 ± 0.4 kg, P = 0.0043) than female calves, and neither age of the hind nor pre-rut weight had a significant impact on birth weights. Weaning, length of breeding season, birth date, and variable stocking rates had no detectable influence on calf birth weights.

3.3.8 Weaning Weights and Calf Gains

Male calves were heavier at 100 days (94.3 ± 1.3 vs 85.6 ± 1.1 kg, P = 0.0001) than females with corresponding growth rates since birth of 753 ± 13 g d^{-1} and 686 ± 11 g d^{-1} respectively (ANOVA, P = 0.0001). Pre-rut hind weight influenced 100 day weaning weights and postnatal gain, with every 10 kg increase in hind weight increasing 100 day weight by 1.9 kg and calf gain by 30 g d^{-1} (Fig 3.3.4 and 3.3.5, P = 0.0001).

The birth date of wapiti calves had an affect on 100 day weights and subsequent postnatal gain. Every 10 days earlier that a calf was born, the adjusted 100 day weight increased by 2.6 kg and calf gain increased by 30 g d^{-1}. Stocking rates had no apparent influence on 100 day weaning weights or postnatal gain.

3.3.9 200 day Weights and Weaner Gains

The adjusted 200 day weights for male and female calves were 131.3 ± 2.0 kg and 120.6 ± 1.7 kg respectively, with hind pre-rut weight exerting a significant influence (Fig 3.3.4, P = 0.0001). Male calves gained more (456 ± 18 vs 413 ± 12 g d^{-1}, P = 0.0359) than females, but post weaning gain was not affected by hind weight (Fig 3.3.5). Calves that were pre-rut weaned were 8% heavier (Fig 3.3.6) than calves that had been separated from their dams after rut (ANCOVA, P = 0.0001). Neither birth dates, nor stocking rates had any effect on 200 day adjusted weights or weaner gains.

3.3.10 Hind Efficiency

Hinds raising male calves produced 54.5 ± 0.6 kg of calf per 100 kg of maternal weight, while those rearing female calves produced 50.8 ± 0.6 kg (ANOVA, P = 0.0001). Expectedly, this ratio was negatively related to hind weight and positively related to 200 day calf weight. However, both numerator and denominator of this ratio are interrelated so multiple regression was used to reveal partial effects of hind and calf weight. Individual hind efficiency was related to the pre-rut hind weight and the 200 day adjusted calf weight (Regression, Y= 53.86 - 0.231 (hind weight) + 0.431 (200 day calf weight), P = 0.0001). The practice of pre-rut weaning improved maternal efficiency from 50.1% to 52.4%

(ANCOVA, P = 0.0001). Stocking rates, birth date and age of hind had no bearing on maternal efficiency.

3.4 DISCUSSION

Deer of the subfamily Cervinae (fallow, sambar, rusa, sika, red deer, and wapiti) have a long history of economic association with man. They are hardy, adaptable, and productive animals in an agricultural setting. Despite the relatively recent emergence of the industry in Canada, the wapiti is remarkably productive although little is yet known about their husbandry. All indices of productivity compare very well against those used to parametize the beef industry.

3.4.1 Reproductive Performance

Calving rates were higher than those reported for farmed European red deer of 41% in 2 year olds and 90% for mature hinds (Hamilton and Blaxter 1980) and for a research wapiti herd of 48% for young and 90% for adult hinds (Hudson et al. 1991). Many of the young two year-old cohorts at these research stations were hand reared, weighing less at first rut than the 66% of mature body size necessary for a 50% probability of conception (Haigh and Hudson 1993). Adult hinds received less supplemental nutrition and were handled more frequently at the research stations than those in a farm setting which may explain the better calving rate in the industry survey.

Calving rates of 93% for herds in our survey were also higher than those reported in a survey of commercial farms by Asher and Adam (1985) fo- red deer (86%) and fallow deer (84%) in New Zealand, and by Mulley and English (199 for fallow deer (87%) in Australia. Lower calving success in the New Zealand study may have been due to red deer and fallow deer farmers underestimating calf death losses in their postal surveys. Australian fallow deer farmers provide very little supplemental feed at any time of the year which might have lowered conception rates and increased the number of light weight, unviable fawns. Most Alberta wapiti producers make a concentrated effort to flush their breeding hinds with high energy concentrates during the rut and monitor weight gains/losses up to calving. Fecundity was affected more by hind weight at breeding than age, and could be improved by pre-rut weaning.

Weaning rates of commercially farmed wapiti were higher than those reported by Hudson et al. (1991) of 33% for 2 year olds and 76% for adults in a research herd, due to both lower conception rates and higher calf mortalities. Wapiti hinds weaned more calves than red deer (80%) and fallow deer (73%) in New Zealand (Asher and Adam 1985) and fallow deer (82%) in Australia (Mulley and English 1991). Certainly the high commercial value of breeding stock may have played a role in these superior weaning rates as Alberta farmers were attempting everything within their power to rear more calves.

Mortality rates among wapiti calves in the survey were lower than those reported by Hudson et al. (1991) of 31% and 17% for 2 year old and adult hinds, respectively. Frequent handling during experimental trials and intensive stocking rates resulted in higher calf death losses in the research setting. Calf mortalities in commercial wapiti herds were lower than the 12% in European red deer (Blaxter and Hamilton 1980), New Zealand red (7%) or fallow (14%) deer (Asher and Adam 1985), and were similar to farmed fallow deer (< 6%) in Australia (Mulley and English 1991).

Red and fallow deer often experience higher calf mortalities with the birth of smaller unviable fawns in the absence of supplemental nutrition. Non-viable wapiti calves were rare, causing only 9.4% of all neonatal mortalities and were often born during multiple births (1 set of dead triplets, 3 dead twins). While dystocia due to malpresentation was reported, calving problems in tame overweight hinds was more common and farmers vowed to rectify the problem by feeding less concentrate and making expectant mothers exercise more. Farms that pre-rut weaned calves were generally more intensively managed operations and had only half as many calf mortalities.

3.4.2 Birth Date, Birth Weights and Sex Ratios

Wapiti calves on commercial farms were born an average of 7-10 days later than those at the Ministik Wildlife Research Station (Hudson et al. 1991). There was no tendency for females to be born earlier than males and there was no difference between calving dates for young and adult hinds that could not be explained by differences in pre-rut weight, contrary to previous findings (Hudson et al. 1991).

Mature hinds calved an average of eight days earlier if their calves were weaned before the the preceding rut. However, two year olds themselves weaned as calves, tended to calve five days later. This might be explained by the importation of large numbers of American stock in the late 1980's which had vastly extended calving seasons (reports of December calves). Producers who pre-rut weaned the current 2 year old hinds in the survey as calves, were weaning as young as 60 days in order to advance the calving season of their adult imports to correspond to existing Canadian stock. Young calves removed from their dams may have suffered slower growth, resulting in 15 month old hinds reaching pubertal weights later in the rut than unweaned cohorts.

Clearly, if farmers pre-rut wean calves from adult hinds, the breeding herd will calve earlier next year and will wean heavier calves. Given adequate care and nutrition, these calves with higher growth rates than unweaned counterparts will have a better chance of meeting the target breeding weights the following rut. Heavier hinds calve earlier, which is similar to Hamilton and Blaxter's findings (1980) of advancing the calving date by 2.2 days for every 10 kg increase in pre-rut weight among all age classes of red deer.

Since wapiti hinds are very aggressive mothers, less than ten percent of the producers have regularly recorded birth weights due to the threat of mis-mothered calves and physical injury to their person. Birth weights are related to calf gender (Blaxter and Hamilton 1980; Asher and Adam 1985; Hudson et al. 1991; Mulley and English 1991) and indeed male calves were heavier than female calves in our study. With insufficient data we were not able to conclude if hind weight or age influenced birth weights, or if the differences in 100 day weights could be partially explained by variance in birth weights.

The sex ratio of wapiti calves in our survey was 50:50 and there was no tendency for different aged hinds to have male or female young contrary to previous research (Flook 1970; Blaxter and Hamilton 1980; Clutton-Brock et al. 1982; Hudson et al. 1991). The sex ratio varied widely among farms but remained 50:50 once all survey data were pooled. Since female offspring were worth two to three times that of males, producers attempted to manipulate the sex ratio in favour of female calves by such things as using older more experienced stags; fewer hinds per stag; replacing main breeding stags with backups at the first sign of fatigue and picking high libido stags that may serve hinds earlier in standing estrus. There were as many skeptics as believers of these techniques so the process made for interesting debate.

3.4.3 100 day Weaning Weights and Calf Growth

The 100 day adjusted weaning weights of wapiti calves was a more useful comparison of growth than actual weaning weights as producers weighed calves at different times. Hudson et al. (1991) reported comparable growth rates with male calves being 7.8% larger and gaining 821 g d^{-1} while female calves gained 737 g d^{-1}. The difference between male and female red deer calves at weaning was 13% at the Invermay Research Station in New Zealand, and weight gains reported for males (384 g d^{-1}) and females (336 g d^{-1}) were about half of those for wapiti calves (Moore et al. 1988b). Calf weights at 100 days in the Alberta industry are lower than target weights (140 kg for males and 120 kg for females at 110 days) set by Haigh and Hudson (1993). As producers do a better job of performance selection and animal husbandry, weaning weights will likely increase as was the case at Invermay where a 10 kg or > 20% increase in red deer weaning weights were observed over 10 years (Moore et al. 1988a).

Hind pre-rut weights influenced weaning weights and calf growth rates which is comparable to Blaxter's and Hamilton's (1980) findings of a 10 kg increase in pre-rut weight of red deer hinds improved calf gains by 17.5 g d^{-1} and to Moore's et al. (1988b) data of a 10 g d^{-1} improvement in gain with a 10 kg increase in hind weight. Early born wapiti calves grew faster than later cohorts with both hind and calf making better use of the spring flush of grass before the onset of Alberta's frequent late summer drought.

3.4.4 200 day Weights and Weaner Growth

Male wapiti calves were 9% larger than female calves at 200 days and had a 10% better average daily gain which is comparable to New Zealand red deer where male calves at Invermay gained 8% faster than females during autumn (Moore et al. 1988b). This slight difference in growth rate means that the genders need not be preferentially fed through their first winter. Pre-rut hind weights still influenced calf frame size at 200 days but not weaner gains as calves coming off their mothers after a stressful rut would probably have exhibited slight compensatory growth from day 150 to day 200.

3.4.5 Efficiency

Individual hind efficiency in younger 2 year olds (0.53 kg of calf $W^{-1.0}$) was higher than adult hinds (0.52 kg of calf $W^{-1.0}$), rearing 5.4% smaller calves at 200 days but weighing 10.2% less. Producers who had imported smaller framed size American stock were quickly upgrading by crossing hinds with larger Canadian stags with mature body weights of 400 - 500 kg. These smaller hinds in the 200 to 220 kg category showed impressive individual efficiencies but often came up barren if stressed by poor pasture, high stocking rates and the demands of lactation.

Commercial livestock production efficiency has often been described on the basis of a ratio of calf produced per unit of maternal weight at a certain time (Basarab and ZoBell 1989). These descriptive parameters allow farmers a comparison between various livestock production systems and may be useful in highlighting the productive efficiency of the commercial wapiti industry. Herd efficiency at 200 days can be calculated by multiplying weaning rate (0.88) by maternal efficiency (0.53 kg of calf $W^{-1.0}$) to estimate herd productivity at 0.46 kg of calf $W^{-1.0}$ of hind exposed. This is higher than the production efficiency of 0.35 kg of calf $W^{-1.0}$ for beef cows in an Alberta beef industry survey (Basarab and ZoBell 1989).

Estimates of production efficiency can also be made by comparing calf production at a certain time with the metabolic weight of the female. Moore et al. (1988a) described Invermay red deer weaning weights (46 kg) and pre-rut hind weights (95.7 kg) which can be used to compare metabolic efficiency of red deer and wapiti at weaning. Data from New Zealand would estimate individual maternal efficiency to be 1.51 kg of calf kg/$W^{-0.75}$ for red deer hinds weaning calves (84%) and a herd efficiency of 1.26 kg calf kg/$W^{-0.75}$ for breeding age hinds exposed to a stag. Efficiency of wapiti in the Alberta survey can be estimated at 1.57 kg of calf kg/$W^{-0.75}$ for hinds rearing calves, with a herd efficiency of 1.37 kg of calf kg/$W^{-0.75}$ of hind exposed to a stag.

Comparative estimates between the wapiti and beef industry are more difficult due to the seasonality of growth of indigenous ruminants, and the large variation in husbandry practices. We can compare metabolic efficiencies of the two species using 200 day adjusted weaning weights and mature female weights, but the true test of efficiency should be measured in monetary terms. Basarab and Zobell (1989) found that the average 200 day estimated weaning weight of beef calves to be 236.3 kg, weaning rates of 84% and average mature cow weights were estimated at 608.7 kg. Metabolic efficiency for a beef cow weaning a calf would be 1.93 kg of calf /kg$W^{-0.75}$ with a herd efficiency of 1.62 kg of calf /kg$W^{-0.75}$ per cow exposed. Metabolic efficiency in wapiti is comparable with 2.00 kg of calf weaned at 200 days kg/$W^{-0.75}$ and a breeding herd efficiency of 1.76 kg of calf kg/$W^{-0.75}$ of hind exposed to a stag.

Past comparison of production efficiencies (Basarab and ZoBell 1989; Moore et al. 1988a) relating calf weight at a specified date to dam size, discriminates against larger females. The biological modeling process (Fennessy and Thompson 1989) which predicts the ratio of inputs to outputs (g carcass/MJ of M.E.) and takes into account metabolic efficiencies, may be a more useful estimation of relative efficiency.

3.4.6 Pre-rut Weaning

Pre-rut weaning of wapiti calves has been a highly controversial and frequently debated issue in the wapiti industry in Alberta. Maximizing reproductive performance by rearing more females of larger frame size having a better chance of conception at 15 months is the goal of many game farmers. This survey suggests that the practice of pre-rut weaning increases calving rates, decreases calf mortalities, increases weaning rates, advances the calving season and results in larger calves at 200 days. These factors when combined should help wapiti producers improve reproductive performance of their breeding herds. However, the large variation in the intensity of management on the surveyed farms may have contributed to the apparent affects of weaning and further comparative trials on this practice will be required.

3.5 CONCLUSIONS

This study establishes a benchmark of performance data against which future gains in the science of wapiti farming can be measured. It provides a yardstick for individual producers to measure their own herd productivity on as well as establishing the need for the industry as a whole to adopt a standardized performance record keeping program.

The reproductive performance of this relatively new wapiti industry is higher than the more mature deer farming ventures in Europe, New Zealand, and Australia. Once inflated breeding stock prices soften, farmers should be able to compete in the global venison markets based on the high inherent productive efficiency of wapiti.

With high breeding stock values farmers have not yet culled their herds to improve reproductive performance and variations between herds suggest opportunities for some improvement. Once the industry matures and producers cull old and open hinds and lightweight weaner calves, conception rates should increase. Setting goals of improving reproductive efficiency by condensing the calving season, limiting the length of the rut, targeting pubertal weights and decreasing calf mortalities would move producers a long way towards the target 95% weaning rate. The practice of pre-rut weaning on the more intensively managed farms does appear to improve reproductive performance.

3.6 ACKNOWLEDGEMENTS

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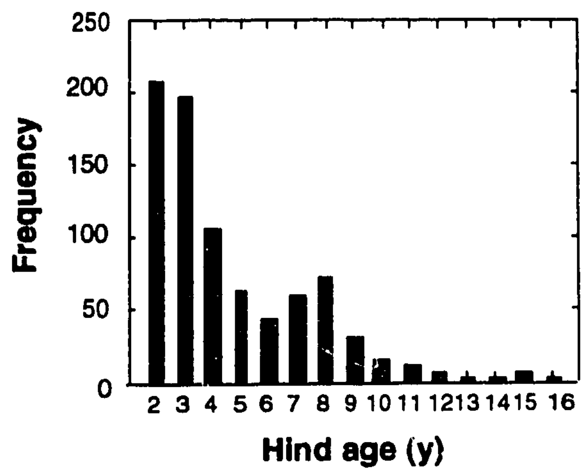

Fig 3.3.1. Age distribution of wapiti hinds in the survey.

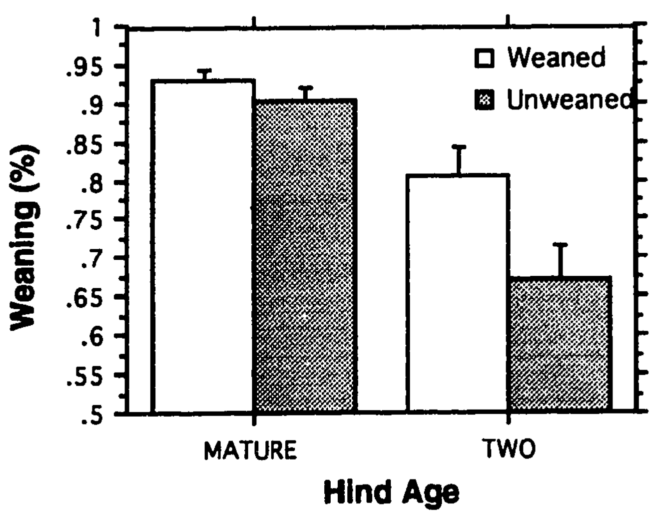

Fig 3.3.2. Weaning rates of wapiti hinds.

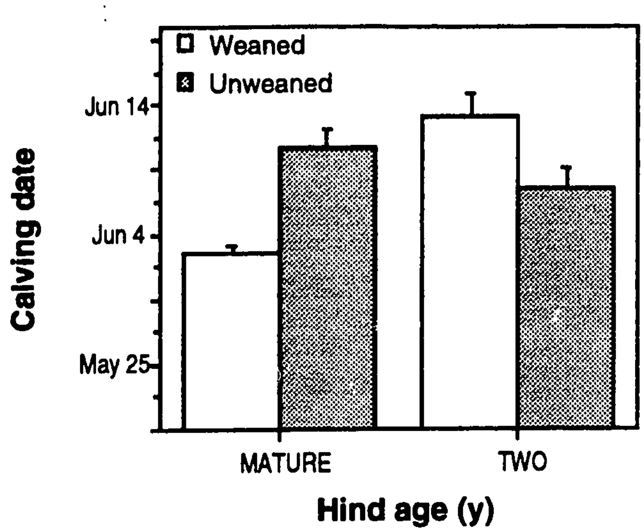

Fig 3.3.3. Weaning vs calving date.

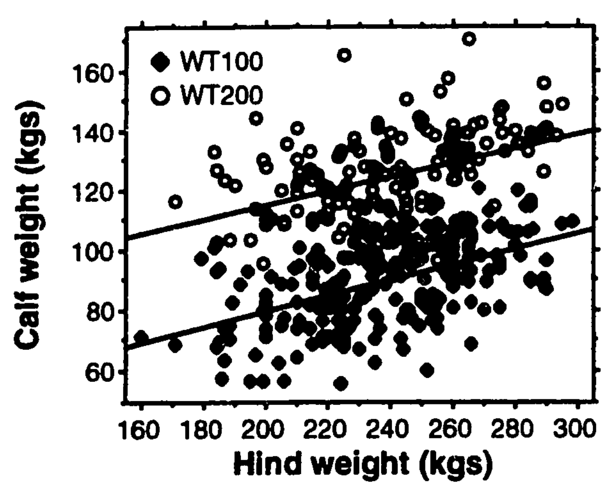

Fig 3.3.4. Hind weight vs 100 & 200 day calf weights.

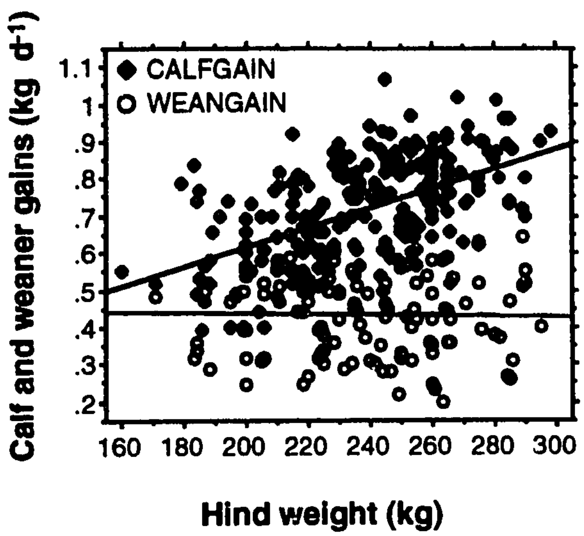

Fig 3.3.5 Hind weight vs calf and weaner gains.

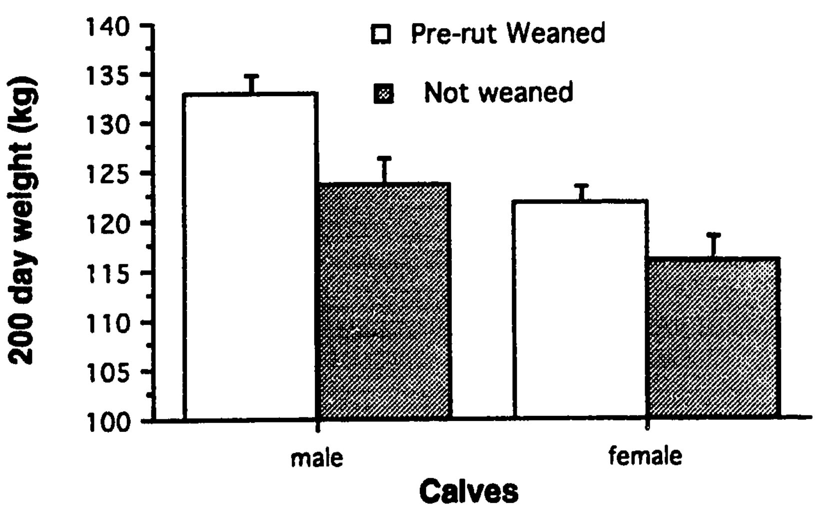

Fig 3.3.6. Pre-rut weaning vs 200 day weight.

4

Biological efficiency of wapiti:

An extension and applied research model.

4.1 INTRODUCTION

As the global deer industry continues to expand, velvet markets will become saturated and there will be increasing emphasis on improving venison production efficiencies in Alberta's wapiti herd. Research into the production efficiency of Alberta's beef herd suggests that improvements in growth, conception rates, length of calving season and calf mortality impact both biological efficiency (BE) and economic efficiency (Basarab and Zobell 1989). Taylor et al. (1985) modeled the efficiency of food utilization in beef production systems by manipulating calf sex ratios, reproductive rates, degree of maturity at first calving, and reproductive lifespan (age of dams at culling) with interesting results.

Parks (1982) described a biological efficiency model based on feed intake and animal growth equations that measured output/input ratios over the productive life of a breeding female. Fennessy and Thompson (1988) applied this model to examine the impact of changes of various genetic options on BE, including selection within strains for increased size and hybridization between sub-species (wapiti and red deer). Fennessy and Thompson (1989) also predicted the BE of venison production in red deer by manipulating reproductive lifespan, calving rates, twinning rates, changes in sex ratio and changes in calving date.

Evaluating the impact of management changes on biological efficiency helps researchers assess future research and extension priorities, and producers to develop breeding and management objectives. This chapter examines the effects of changes in productive lifespan, reproductive performance, death loss, timing of slaughter, calf sex ratios, and dressing percentages on the BE of wapiti.

4.2 MATERIALS AND METHODS

Lifetime biological efficiency of venison production for the wapiti hind/calf unit was calculated following Fennessy and Thompson (1989) model of predicting the ratio of outputs and inputs for both the hind and her lifetime progeny. The equation used to calculate biological efficiency (BE) was:

$$\mathbf{BE = (CW_P + CW_H)/(ME_P + ME_H)} \text{ where;}$$

BE = lifetime biological efficiency for meat production of the hind/calf unit,
$\mathbf{CW_P}$ = carcass weight of sale progeny (liveweight x 59% dressing percentage),
$\mathbf{CW_H}$ = carcass weight of the hind at slaughter (liveweight x 59%),

ME_P = ME consumed by progeny to slaughter (excluding replacement hind),
ME_H = ME consumed by the hind.

Fennessy and Thompson (1989) used the cumulative feed intake approach, following Parks (1982) model, of predicted metabolizable energy (ME) intake for the hind and her progeny calculated as an exponential function of age. Superimposed on this basic intake function were two sine oscillations which represented the changes in intake due to varying daylength and seasonal climatic conditions. They then estimated live weight from weaning to maturity as an exponential function of cumulative ME adjusted by a factor for the conversion of ME to live weight. An oscillation in the efficiency of conversion of ME to live weight in red deer was apparent, and was included in the model as a sine function. Their model did not incorporate the depression in intake associated with the first rut starting at 15 months in males (spikers).

To simplify that approach, post-weaning metabolizable energy intake for wapiti hinds and their progeny were calculated from seasonal target live weights and daily energy requirements (Table 4.2.1) estimated by Haigh and Hudson (1993). This model may be a more accurate representation of actual metabolizable energy intake as it accounts for seasonal variations of energy intake due to target live weight, sex, rutting activity, day length, and climatic variation.

Energy inputs (MJ of ME) and outputs (g carcass) were calculated for a wapiti hind with all her progeny (minus one replacement female) being sold for slaughter. Calculations involving productive lifespan accounted for annual death losses (2% in the "standard" model) of the breeding herd. Herd structure was then simply a yearly sum of the productive performance (number of calvings) of a particular hind (s) before culling [$((X_1 + X_2 + ... + X_n)/n$ number of calvings) where: $X_2 = X_1 \times .98$, $X_3 = X_2 \times .98$, etc for example: (100 (2 yr olds) + 98 (3 yr olds) + 96 (4 yr olds)/3 calvings)].

Total progeny slaughtered was the sum of all successful weanings minus the required female replacements (determined by the number of cull hinds slaughtered each year plus the appropriate margin for annual death loss). Biological efficiency of venison production in wapiti was calculated from weaning at 15 weeks until slaughter of progeny at ages up to 27 months (if slaughter progeny were retained until 27 months, hinds were not bred at 15 months).

Table 4.2.1. Seasonal target weights* and metabolizable energy requirements of wapiti used in calculating biological efficiency.

Females	Birth	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr	11yr
Summer (May 15-Sep1)												
Target weight (kg)	17	168	230	250	255	265	275	275	275	275	275	275
MJ ME/day	0	49	80	84	85	86	87	87	87	87	87	87
Autumn (Sept 1 - Nov1)												
Target weight (kg)	120	220	250	260	270	280	290	290	290	290	290	290
MJ ME/day	27	35	39	40	41	42	43	43	43	43	43	43
Winter (Nov 1 - Apr 1)												
Target weight (kg)	130	225	250	260	270	280	290	290	290	290	290	290
MJ ME/day	28	32	35	36	37	38	39	39	39	39	39	39
Spring (Apr1 - May15)												
Target weight (kg)	150	225	240	250	260	270	270	270	270	270	270	270
MJ ME/day	41	50	51	51	52	53	54	54	54	54	54	54
Males												
Summer (May 15-Sep1)												
Target weight (kg)	19	195	266	286	306	326	346	366	386	406	426	446
MJ ME/day		68	58	49	49	50	51	52	53	54	55	56
Autumn (Sept 1 - Nov1)												
Target weight (kg)	140	280	300	320	340	360	380	400	420	440	460	480
MJ ME/day	32	33	40	40	41	42	43	44	45	46	47	48
Winter (Nov 1 - Apr 1)												
Target weight (kg)	150	260	280	300	320	340	360	380	400	420	440	460
MJ ME/day	32	39	48	48	49	49	50	51	52	53	54	55
Spring (Apr1 - May15)												
Target weight (kg)	168	260	280	300	320	340	360	380	400	420	440	460
MJ ME/day	54	59	53	53	54	55	56	57	58	59	60	61

Adapted from Haigh and Hudson 1993.

*Weights are given at the start of each season.

4.3 RESULTS

The model was then used to examine the effects of various management changes on the biological efficiency of the wapiti hind/calf unit (g carcass/ MJ of ME). There were two peaks in BE; a minor peak at weaning, and a major peak at 15 months of age after stags had attained 60% and hinds 76% of their mature body weight. With the "standard" wapiti system (10 calvings, first mating at 15 months, 91% weaning rate in adult hinds and 73% weaning rate of two-year-old hinds, 1:1 calf sex ratio, weaning at 3 months and 2% annual mortality thereafter) the second peak was 11% higher than the first (Fig 4.3.1).

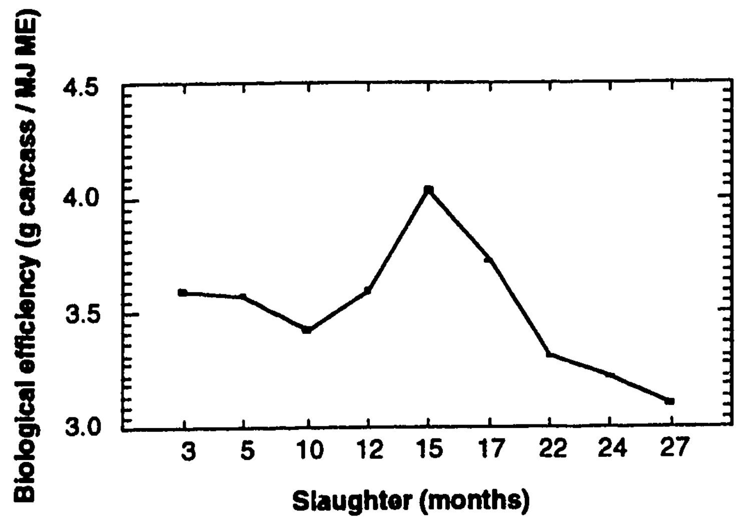

Fig 4.3.1. Effect of age of slaughter on the biological efficiency of the "standard " wapiti system of 10 calvings, first mating at 15 months, 91% weaning rate in adult hinds and 73% weaning rate of two-year-olds, 1:1 calf sex ratio, weaning at 3 months, 2% annual mortality thereafter.

Individual biological efficiency of slaughter progeny declined with maturity (Table 4.3.1), as animals diverted a higher proportion of metabolizable energy towards maintainence instead of growth. There was little contrast in individual BE between sexes with hinds being slightly more efficient than stags in earlier growth stages.

Table 4.3.1. The effect of age on individual biological efficiency.

Age of progeny at slaughter (Months)	Biological Efficiency Stags	Hinds
10	14.6	15.1
12	12.6	12.9
15	10.0	10.0
17	8.3	8.8
22	6.3	6.6
24	5.8	6.1

Decreasing the reproductive lifespan of the breeding hind (Table 4.3.2) by culling earlier, resulted in the highest biological efficiency after only three calvings (2 calvings was not sustainable as it did not produce enough replacement females at a 1:1 calf sex ratio).

Differences in BE between 3 and 10 calvings with slaughter at 5 months was 10.3%, whereas differences in BE decreased to 9.5% if progeny were slaughtered at 15 months and 8.9% if slaughter was delayed to 27 months.

Table 4.3.2. The effect of the reproductive lifespan of hinds on the lifetime biological efficiency of the hind/calf unit (g carcass/MJ of ME) with progeny slaughtered at 5, 15 or 27 months.

Calvings	Outputs (15 mo) (kg carcass)	Inputs (15 mo) (MJ ME)	Biological efficiency (g carcass / MJ ME) 15 months	5 months	27 months
2*	260	60566	4.29	4.08	3.76
3	391	92114	4.25	3.98	3.49
4	520	123375	4.22	3.90	3.37
5	646	154348	4.19	3.84	3.30
6	764	184933	4.13	3.75	3.23
7	880	214905	4.10	3.69	3.18
8	994	244279	4.07	3.64	3.15
9	1105	273065	4.05	3.60	3.12
10	1214	301275	4.03	3.57	3.10

*Non sustainable system

Increasing average weaning rates of both two-year-old and adult hinds improved biological efficiency (Table 4.3.3) of venison production. A 5% increase in overall weaning rates of both two-year old and adult hinds, increased efficiency by 3.1% in a standard wapiti system of first breeding at 15 months, 10 calvings, 1:1 calf sex ratio, 2% annual mortality and average weaning rates of 73% in two-year-olds and 91% in adult hinds.

Table 4.3.3. The effect of changing weaning rates on lifetime biological efficiency of the "standard" wapiti hind/calf unit (g carcass/MJ of ME).

Weaning rates	Biological efficiency (g carcass/MJ ME)
average	4.03
5% increase in 2 yr-olds	4.04
5% increase in adults	4.15
5% increase overall	4.16
5% decrease in 2 yr-olds	4.01
5% decrease in adults	3.91
5% decrease overall	3.89

Increasing the proportion of male progeny by 10%, increased biological efficiency at 5 months by 0.04 g carcass/MJ ME or 1.1% (Table 4.3.4). The same 10% increase in the male sex ratio at 15 months, resulted in a 2.2% increase in biological efficiency (0.12 g carcass/MJ ME) due to the relatively higher growth rates of stags during their second summer.

Table 4.3.4. The effect of sex ratio on the lifetime biological efficiency of the "standard" wapiti hind/calf unit (g carcass/MJ of ME) with first breeding at 15 months, 10 calvings, 73% weaning rate among two-year-olds and 91% in adults, 2% annual mortality thereafter and varying sex ratio.

% Males	Biological Efficiency (5 months)	Biological Efficiency (15 months)
0	3.36	3.73
20	3.44	3.85
40	3.53	3.97
60	3.61	4.09
80	3.70	4.20
87*	3.78	4.23

* A sustainable system with 10 calvings

Changes in dressing percentage had considerable impact on the BE on the "standard" wapiti hind/calf unit (g carcass/MJ of ME) with each additional 1% increase in carcass yield (%) improving BE by 1.7% (Table 4.3.5).

Table 4.3.5. The effect of dressing percentage on the lifetime biological efficiency of the "standard" wapiti hind/calf unit (g carcass/MJ of ME).

Dressing Percentage (%)	Biological Efficiency (g carcass/MJ of ME)
56	3.82
57	3.89
58	3.96
59*	4.03
60	4.10
61	4.17
62	4.23

* Standard dressing percentage

Each additional 1% increase in annual death loss decreased the lifetime biological efficiency by 0.91% in the "standard" wapiti hind/calf unit (g carcass/MJ of ME) with first breeding at 15 months, 10 calvings, 1:1 calf sex ratio, weaning at 3 months and average weaning rates (Table 4.3.6).

Table 4.3.6. The effect of death loss on the biological efficiency of the "standard" wapiti hind/calf unit (g carcass/MJ of ME).

Death loss (%/yr)	Biological Efficiency (g carcass/ MJ of ME)
1	4.07
2*	4.03
3	3.99
4	3.95
5	3.90

* Standard annual mortality

4.4 DISCUSSION

The target weights in the model are representative of the productive performance of pure Canadian wapiti but may be overly optimistic for the Alberta industry, with some smaller American and hybrid wapiti. This model accounts for variable energy intakes and liveweight changes due to seasonal environmental conditions and may be more accurate than Fennessy and Thompson's (1988; 1989) biological efficiency model. They calculated metabolizable energy intake as an exponential function of age, and resulting liveweight as an exponential function of cumulative energy intake. Their model did not account for depressed appetites of stags during rut but did incorporate estimates of changes in energy intake due to lactation and seasonal environmental influences in hinds.

The maximum biological efficiency of venison production in wapiti occurs when progeny are slaughtered at 15 months of age which supports Fennessy and Thompson's (1989) findings of a similar peak in BE at 15 months in red deer. Their "standard" red deer system of 10 calvings, first mating at 16 months, 98% calving rate, 1:1 sex ratio, 5% pre-weaning mortality, weaning at 13 weeks and 2% annual mortality thereafter resulted in a BE of 2.89 g carcass/MJ of ME if progeny were slaughtered at 63 weeks. In comparison a "standard" wapiti system of 10 calvings, first mating at 15 months, 73% and 91% weaning rate in two-year-old and adult hinds respectively, 1:1 sex ratio, weaning at 15 weeks, and a 2% annual mortality thereafter produced a BE of 4.03 g carcass/MJ of ME. That suggests wapiti venison production systems are 28% more efficient than venison production in New Zealand red deer.

Peak BE in the red deer system was 3.02 g carcass/MJ of ME, reached after three calvings (Fennessy and Thompson 1989), whereas peak BE in the wapiti system which was reached after three calvings was 4.25 g carcass/MJ of ME, some 29% higher than venison production efficiency in red deer.

Comparisons with other meat production systems are more difficult without standardization of the modeling exercise. Taylor et al. (1985) estimated the biological efficiency of a beef production system (omitting the environmental oscillation of energy intake and growth), to be 2.3 - 2.6 g lean tissue per MJ of ME and Naazie (1992) determined the BE of four different beef production systems to be 2.4 - 2.9 g lean tissue/MJ of ME. Since wapiti have a propensity to produce more lean (76%) carcass tissue (Drew 1991) than beef (59%) the estimated biological efficiency of lean tissue production in the "standard" wapiti system would be 3.06 g lean tissue/MJ of ME, similar to the efficiency of beef production.

4.4.1 Improving Biological Efficiency

A decrease in the productive lifespan of wapiti hinds from ten calvings to three improved BE by 5.2% which is comparable to Fennessy and Thompson (1989) findings of a 4% increase in red deer. Taylor et al. (1985) found that BE improved by 13 - 15% and Naazie (1992) found that BE improved from 8.5 - 19% in four different beef breeds, with a comparable decrease in productive lifespan in beef cattle. Fennessy and Thompson (1989) proposed that this difference between deer and cattle was due to red deer attaining a higher proportion of mature body weight at first mating (80%) than beef cattle (65 - 70%).

Improving reproductive performance is an obvious way of increasing BE and a resulting 5% increase in the weaning rates of both two-year-old and adult hinds increased BE by 3.1% in wapiti. Fennessy and Thompson (1989) found that a 10% increase in calving rate resulted in a 5 - 7% improvement in BE in red deer, similar to that of wapiti. Taylor et al. (1985) found a 2.4% increase in BE in beef cattle with a 5% improvement in calving rate, while Naazie (1992) reported a 2 - 3% increase in BE of beef cattle for an equivocal improvement in reproductive rate.

If producers could manipulate the sex ratio of the progeny born to hinds in favour of the stags, they could expect a 1.5% increase in BE for every 10% increase in male offspring if progeny were slaughtered at 15 months. This is lower than the 3.5% increase reported by Fennessy and Thompson (1989) for red deer but is higher than that reported for cattle (Taylor et al. 1985). The practicality of exerting this much effort and expense to secure male progeny that have a greater mature size and faster growth rate is at this time unwarranted.

While farmers have little control over changes in dressing percentage, and annual mortality rates of the breeding herd, they still affect everyday management decisions. Canadian farmers considering red deer should be aware that the dressing percentage of red deer (57%) is 2% lower than wapiti (59%) (Drew 1991), and that a 2% increase in dressing percentage improves BE by 3.2%. Annual mortality rates affect not only one season's productivity but lifetime productivity of the female herd, and hence have a significant impact on biological efficiency.

4.5 CONCLUSION

Producers who are aware of the magnitude of management changes on the efficiency of their production systems will soon focus their efforts on those areas that will have the greatest immediate impact on their operations. Ranking the relative importance of production parameters will assist researchers and extensionists to prioritize their research and extension programs. Using computer models to predict the impact of reproductive lifespan, reproductive performance, and the timing of slaughter should assist in the development of more efficient production systems.

Further improvements in a future modeling program may include economic parameters that would assist in the strategic comparison of the profitability of various management options. With today's inflated breeding stock values in Alberta's wapiti industry, examining the biological efficiency of venison production may be a more useful approach in determining relative production efficiencies than an economic modeling exercise would provide.

4.5 LITERATURE CITED

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