Causes of variation in growth rate of reindeer calves

C. J. Petersson* and **B. Danell**

Dept. of Animal Breeding and Genetics, The Swedish University of Agricultural Sciences, Box 7023, S-750 07 Uppsala, Sweden

Abstract: Weights of individual reindeer calves were registered on 3 or 4 occasions from the July roundup to the last slaughter roundup in January during each of four consecutive years (1986 to 1989). The observations were made in a tagged herd located in the southern part of the reindeer area in Sweden (63° N, 12° E). A total of 10 400 live-weight measurements were made, and the relationship between pre-slaughter weight and carcass weight was estimated using data from 109 individuals. Variation in weight and weight gain between weighing occasions was related to sex, number of days in the corral, scale and year. Non-linear growth curves were fit to the adjusted weights. For each sex, smoothed average weights and dispersions, both within and between year, as well as the coefficient of variation were calculated from data generated from the estimated functions. Individual calf weights were shown to be influenced by sex, weighing day within occasion, and by year.

Reindeer calves gained between 20 and 25 kg in live body weight from two to 6–8 months of age. Male calves were heavier than female calves over the whole period and they gained in live weight on average 10 g/day more than female calves. Between year coefficient of variation was between 1.5 and 7 % with the largest variation between years for July and January weights and the lowest variation for September weights. The growth curves showed that the major increase in weight was between July and September. From September to December/January the additional increase was only 5 %. Dressing-percentage was influenced by live weight prior to slaughter. A positive relationship between live weight and dressing percentage was shown.

Key words: live weight, dressing percentage

Rangifer, 13 (2): 105–116

Introduction

Production in reindeer husbandry can be enhanced by improving flock management practices. Flock composition and slaughter strategy are two important factors influencing production. The most common way to increase the production and raise the income has, up to now, been to increase the number of animals in the population. However, the amount of winter pasture is often a limiting factor for the size of the population. Other restrictions on population size are set by the society. Roads, traffic, tourism etc. compete with the reindeer industry and has considerably limited the area which can be used for free-ranging reindeer. Long-term improvements in reindeer farming can therefore, in most parts of Sweden, no longer be achieved by increasing population size. Optimization of

* Correspondence.

population structure, slaughter strategy and culling of poor producers have become interesting alternatives. Model analyses (Petersson & Danell, 1992) have shown that meat production can be increased by changing the structure of the flock without necessarily increasing the total number of animals. In addition, experience from this work showed that simulation of the dynamics of the reindeer herd could be a powerful and useful tool for the reindeer extension service.

In order to develop the optimal strategies, knowledge of several parameters is necessary. The growth rate of calves, production capacity of females at various ages, relationships between weight and age, and between the live weight and productivity of females are examples of such parameters (e.g. Movinkel & Prestbakmo, 1969; and Reimers, 1983a, 1983b). Optimization of the calf selection for breeding purposes requires knowledge of individual growth as well as about the effects on adult weight and female reproductive capacity.

However, the production parameters which are necessary for application of a model suitable for the entire area are not available. Petersson & Danell (1993b) have reviewed important input production parameters for a flock model and noted that comparable data from different regions was lacking.

Growth in reindeer calves is difficult to calculate. Due to genetic (Reimers, 1983b) and climatic differences (e.g Movinkel & Prestbakmo, 1969) and highly variable nutrition supply, weight is expected to differ between animals, areas and years. Reimers (1983b) clarified the causal factors behind body weight and established that environmental factors have a significant influence on growth. Little data is available on individual growth in reindeer calves, and most information of this type obtained under natural conditions is from studies lasting one year or less. Furthermore, most data concerns captive animals; for example, Krebbs & Cowan (1962), Rydberg (1971), Espmark (1980), Reimers (1983b), Rognmo *et al.* (1983) and Parker (1989). McEwan (1968) studied both wild and captive caribou calves and Timisjärvi *et al.* (1982) studied partly free-living reindeer. Other results are based on a low number of observations with insufficiently defined background material. Nonetheless, observations of captive reindeer can include detailed records including birth weight and age at time of weighing (e.g. Espmark, 1971; Varo, 1972; Timmisjärvi *et al.*, 1982; Rognmo *et al.*, 1983).

The purpose of this study is to provide production parameters of both live- and carcass-weights and growth in calves to be used in the optimization studies.

The study will i) present results from analysis of about 10 400 calf weight records, collected in the same area during 1986–1989, ii) elucidate the causes of variation in weight and growth between calves, and identify the age at which calves stop growing and iii) present dressing-percentage figures in calves.

Material and methods

Data collection in the Tännäs study herd

The data used in this study were recorded from 1986 to 1989 in a reindeer herd in Tännäs sami village, in the souther part of the reindeer farming area in Sweden. The winter herd included about 5000 animals.

In the early 1980s, reindeer owners in the village introduced a new system of reindeer production based on a Norwegian model (Lenvik, 1989). In this system, calves were harvested, whereas previous harvest consisted primarily of adults. The heaviest calves were retained for breeding. The selection criterion was live weight at time of slaughter; thus all calves had to be weighed (see Petersson *et al.*, 1990). A new tagging system, described by Lenvik & Fjellheim (1988a), was also introduced. The system allows individual animals to be identified and enables dams to be paired with their calves.

During 1982–85, calves were weighed only once (at the time of slaughter in December). Starting in 1986, up to four weighings were made yearly. In July, the new batch of calves is traditionally owner-marked, ear-tagged and weighed. In September, another roundup is made to tag and weigh calves that had been missed during the July roundup. In addition, some of the previously weighed calves were re-weighed. The calves were weighed again in December and in January when the registered weight also was used as the selection criterion. The abbreviations for the four weighing occasions, i.e. JUL(year), SEP(year), DEC(year) and JAN(year), will henceforth be used in the text.

The data for JUL(86) were subdivided into two groups: records obtained between the 1 and 8 of July in the Rödfjäll area (A) and those obtained between 10 and 12 of July in the Långbrottsfjäll area (B).

In connection with slaughter in 1987 the dressing percentage for 109 calves was obtained.

At the JUL(86) occasion the individual weights of the calves were registered with the help of an assistent who held the calf while standing on a bathroom scale. In all, three weighing stations and three different persons were available. Each person was referred to a specific scale. From SEP(86) rebuilt lamb scales (Poldenvale Lamb-weight) with electronic weight-heads (Farmertronic) were used. To avoid errors in the electronic system due to low temperatures during winter weighings, the weight-heads were provided with electric heaters, which consisted of built-in 12V/5W electric bulbs. In both systems, the scales were calibrated daily according to the weight intervall of the calves.

Statistical analysis

It was assumed that the calf weights registrations would be affected by sex as well as by geographic location, time spent in the main corral and scale used. Since it is not possible to consider all these factors simultaneously when fitting non-linear growth curves to the data, preadjustments of the data had to be made. Body weight and the change in body weight between weighings are also influenced by dam age and weight. For 1986–87 little information on these factors were available; therefore they could not be considered in this study. Starting in 1988, both the identity and age of the dams were recorded.

The first step was to perform a separate weight analysis for each weighing occasion, where upon and adjustment was made for the different fixed effects. Means and standard errors were then computed for each sex on each occasion, using the adjusted data. In the second step, non-linear growth curves were fitted separately to data from each year based on the number of observations and the means at each weighing. In the last step, an overall average curve was fitted to the data generated by the year-specific curves.

Analysis of weights on different occasions.

The statistical models set up for the analysis of the recorded calf weights were partly chosen based on information obtained in a survey made during 1983–1985 in the same herd (Petersson, 1988). The analyses were performed with the GLM procedure of the SAS statistical package (SAS, 1985) using the model

$$Y_{ijkl}=\mu+s_i+v_j+o_k+e_{ijkl}$$

where

Y_{ijkl} = weight of the *ijkl*th calf
μ = overall mean
s_i = fixed effect of *i*th sex, *i=1-2*
v_j = fixed effect of *j*th scale, *j=1-3 (max)*
o_k = fixed effect of *k*th length of waiting period (days), *k=1-14 (max)*
e_{ijkl} = random residual effect with mean = 0 and variance = σ^2_e

Using the estimated constants the observed weights were adjusted for the effect of scale and number of days waiting in the corral as follows:

$$Y^*_{ijkl}=Y_{ijkl}+v^*_j+o^*_k$$

where

Y^*_{ijkl} = adjusted body weight for each calf of sex *i*
Y_{ijkl} = unadjusted weight for each calf
v^*_j = adjustment for *j*th used scale
o^*_k = adjustment for *k*th length of waiting period

The adjustment for scale was made only for the JUL(86) data since no effects of scale were found in the other datasets.

The scale adjustments were:

$$v^*_j=-(\hat{v}_j-\sum_{j=1}^{r}\hat{v}_j/r)$$

where

v^*_j = adjustment for *j*th scale, *j=1-3 (max)*
$\hat{v}_j$ = the estimate for *j*th scale obtained in Model 1, *j=1-3 (max)*
r = number of scales

The adjustments for the stay in the corral were made towards the day with the highest weight. For the July data the highest weights were observed at the end of the weighing periods. For the December and January data it was assumed that the calves were heaviest on the first day in the corral. The September weighings lasted more than one day only in 1986, and these weights were adjusted towards the first day of weighing. Table 1 gives the actual dates towards which the observed weights were adjusted.

Grouping of the calves

To determine the relation between July weights and growth rate during the summer and autumn, calves were placed into one of three groups, based on their adjusted July weight. The grouping was made using the mean weight (X), the product of the standard deviation (SD) and a variable, Z $(=0.43)$. The value of the variable was chosen so that one third of the calves fell into each of the three groups. Group 1 consisted of animals with weights less than (X-$SD \times Z$) kg, group 2 of animals with weights within ($X \pm SD \times Z$) kg and group 3 of animals with weights greater than ($X + SD \times Z$) kg. The procedure demands that a normal distribution of weights could be assumed. Weight gain from July to December was computed within groups.

Estimations of growth curves

For each combination of year, sex and weighing occasion the means and standard error (SE) of adjusted weights were computed. The results were used to describe the growth rate between July and January for the male and female calves. The following non-linear functions (1 and 2) were fitted to the mean values using the NLIN weighted least-square procedure in the SAS package and the Marquardt iteration method (SAS, 1985):

$$Y_x = b_0(1 - b_1 e^{-b_2 X})(1 - b_3 e^{-b_4(200-X)}) \qquad \textit{(Model 1)}$$

and

$$Y_x = aX^{b_1} e^{b_2 X}$$

(The «Gamma function»; Wood, 1967) *(Model 2)*

where

Y_x = observed mean weights on day X
X = day number, with X=0 for the weighing in July
a = initial weight on the JUL occasion
b_0-b_4 = constants
e = base of the natural logarithm

Table 1. Weighing occasion, date, number of calves weighed and average weight with standard deviation.

Occasion/year	Date[1]	Male calves			Female calves		
		n	X	SD	n	X	SD
JUL(86)A	Jul 5	319	18.76	3.32	352	17.51	3.06
JUL(86)B	Jul 12	155	22.01	3.39	165	20.12	3.33
SEP(86)	Sep 16	73	42.75	4.11	113	39.26	3.66
DEC(86)	Dec 7	299	45.65	4.60	337	43.01	4.65
JAN(87)	Jan 20	120	45.75	4.16	153	42.80	3.95
JUL(87)B	Jul 23	531	22.58	3.97	529	21.42	3.37
SEP(87)	Sep 16	62	41.15	5.43	51	38.00	4.25
DEC(87)	Dec 8	398	43.73	4.72	427	41.67	4.03
JAN(88)	Jan 10	174	42.49	4.76	155	39.63	4.31
JUL(88)B	Jul 18	761	20.72	4.71	797	19.69	3.96
SEP(88)	Sep 16	44	42.91	4.65	39	38.21	3.03
DEC(88)	Dec 9	549	42.76	4.61	569	40.69	4.23
JUL(89)B	Jul 20	949	23.74	3.60	872	22.23	3.00
SEP(89)	Sep 15	79	42.97	4.44	85	39.62	4.89
DEC(89)	Dec 11	629	45.58	5.10	609	42.63	4.37

1) Date towards which the weights were adjusted in the analysis.

Table 2. Analyses of variance in observed weights of the reindeer calves at JUL, SEP, DEC, JAN.

Occasion	Mean squares and degrees of freedom for								Coefficient of determination
	Sex	df	Scale	df	Day	df	Residual	df	
JUL(86)A	286.5***	1	38.0*	2	60.7***	6	9.6	661	9.8
JUL(86)B	316.1***	1	21.3ns	2	46.4**	2	10.8	312	13.6
JUL(87)	334.1***	1	-		434.1***	10	9.4	1048	32.4
JUL(88)	316.8***	1	-		109.4***	12	8.5	1533	11.1
JUL(89)	1047.4***	1	-		242.5***	13	9.4	1806	19.8
SEP(86)	564.8***	1	-		17.4ns	1	14.8	178	18.0
SEP(87)	337.6***	1	-		-		23.8	112	11.3
SEP(88)	183.7***	1	-		-		12.3	47	24.9
SEP(89)	459.8***	1	-		-		21.9	162	11.5
DEC(86)	1134.2***	1	-		177.5***	2	21.3	629	9.6
DEC(87)	896.4***	1	-		29.6ns	4	19.1	820	6.0
DEC(88)	1064.5***	1	-		127.0	4	19.1	1112	7.4
DEC(89)	2776.2***	1	-		48.7ns	5	22.5	1229	9.6
JAN(87)	591.2***	1	-		19.0***	3	16.4	272	12.6
JAN(88)	674.5***	1	-		-		20.6	327	9.0

ns = not significant; * = ($p \leq 0.05$); ** = ($p \leq 0.01$); *** = ($p \leq 0.001$).

The functions were chosen after visual inspection of the data pattern. Model 1 was used for the 1986 and 1987 data when four weighings were made each year. For 1988 and 1989, when no weighings were made in January, Model 2 had to be used.

Goodness of fit to the data was calculated using $R^2 = 1\text{-SSR/SST}$, where SSR and SST are the residual and total sums of squares, respectively.

The non-linear growth functions for each year were used to compute average live weights for each sex for the period from 20 July to 15 January. Those dates, as well as 20 September and 10 December were chosen as typical days for handlings connected to breakpoints in the reindeer production year («seasonal break dates»). Arithmetic means over the four years were then calculated for each fo the four dates. Within-year dispersion was calculated from pooled estimates of sample variances for the adjusted weights described previously. Estimates of between-year dispension were obtained i) using the standard deviation olf the average weights for each year - «seasonal break dates» combination, and ii) from the between-year ranges of computed average weights (Rohlf & Sokal, 1981).

Coefficients of variation (C.V. %) were obtained from the estimated means and standard deviations.

Dressing percentage

The relationship between live weight and dressing percentage was estimated as a linear regression according to the model

$$Y_i = \mu + b(W_i + W) + e_i$$

Where

Y_i = the dressing percentage of the ith calf
μ = overall mean dressing percentage
b = regression coefficient
W_i = pre-slaughter body weight for ith calf
$\bar{W}$ = mean pre-slaughter body weight
e_i = residual term

Results

The discrepancy in number of reindeer weighed between occasions (Table 1) reflects the large variation in roundup efficiency. This variation is partly an effect of season. During autumn, especially at the beginning of the rutting period, the reindeer are present in both the mountain and forest areas. Therefore, rounding them up is more difficult during this period than during summer and winter.

Results from analyses of variance (Table 2) shows that, for all year-weighing occasion combinations, the *sex* effects were significant. Animals often spent five to seven, up to fourteen days in one case, in the main corral at the end of the roundup session. In the December and January gatherings, the animals were kept in corrals that had been heavily grazed previously and therefore had a limited supply of lichens. The stay in the main corral was therefore expected to result in weight losses in the calves, although dry hay was provided as a feeding supplement. In July roundups, the main corral is affected very little by previous grazing and the vegetation consists of young green plants. Calves are still suckling at this time although they graze as well. *Waiting time in the corral* was significant in three cases out of five during winter handling and in all cases during summer handlings. *Scale* had a significant effect in one of the data-sets from JUL(86). The scale effect was not included for data from SEP(86) because better scales, as mentioned above were used. The coefficients of determination (R^2, Table 2) were rather low, with the highest values obtained on the JUL and SEP occasions. Although the low R^2-values could have due to environmental effects, no such effects were considered in the model.

The estimated sex-related difference in body weight for each year-occasion combination (Table 3) shows that the differences was greatest in September and lowest in December. The fact that some of the male calves were heavy and mature enough for active rutting participation in late September might explain this finding. Active participation in rutting leads to weight losses, which might be large enough to influence the average weight of the male calves on the following weighing occasion (e.g. Rydberg, 1982). The difference between the sexes increased again from December to January.

As can be seen, the distributions of the calves among the three adjusted-July-weight groups for each year (Table 4) are skewed to the left and differs from the intended 33.3 %. However, a normality test of the material as reported in Petersson & Danell (1993a) showed that weights in the population sample were normally distributed. Differences between groups in weight gain between July and December calculated over all years were not significant (Table 5). In general, daily weight gain tended to be higher in the heaviest group (3) than in the other two groups. During each of the years, the average weight gain was about 10 g/day greater in male calves compared with female calves.

Growth curves and computed mean weights

Number of calves, LS-means and standard errors of adjusted body weights for male and female calves in different year-occasion combinations are presented in Table 6. In 1986, some of the lightest calves were selected for slaughter on the SEP and DEC weighing occasions. SEP-weight in the SEP(86)–DEC(86) combination was significantly greater than that in the JUL(86)–SEP(86) combination. Similarly, the DEC-weight in the DEC(86)–JAN(86) combina-

Table 3. Estimated sex differences in body weight (male–female) with degree of significance. The figures in parantheses show the superiority of the male calves expressed in percentages.

Year	Weighing occasion			
	JUL	SEP	DEC	JAN
86	1.49***(7.5)	3.40***(8.6)	2.86***(6.5)	3.26***(7.5)
87	1.24***(5.2)	3.42***(9.1)	2.16***(5.2)	3.06***(7.7)
88	0.82***(4.1)	3.98***(10.4)	2.09***(5.1)	– –
89	1.50***(6.2)	3.21***(5.1)	2.97***(6.9)	– –

*** = $p \leq 0.001$

Table 4. Number of calves in July for each year and their distribution among three groups, intended to be of equal size. Group 1 consists of animals with weight < *X-SD* x Z, group 2 of animals with weight within *X-SD* x Z ≤ and ≤*X+SD* x Z and group 3 of animals with weight > *X+SD* xZ *(Z=0.43* and X=*adjusted weight).*

Year	Male (%)				Female (%)			
	n	1	2	3	n	1	2	3
1986	243	32.1	31.7	36.2	293	29.0	31.1	39.9
1987	310	30.3	35.5	34.2	318	28.6	37.7	33.7
1988	534	31.8	34.5	33.7	583	30.4	33.6	36.0
1989	623	31.6	32.4	36.0	594	25.9	40.4	33.7

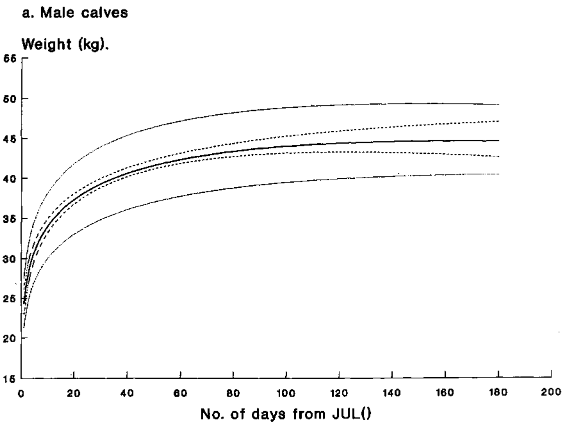

Fig. 1. Average growth curves and ranges for one standard deviation between years (—) and within year (....), respectively.

The entire fig. 1, see page 116.

tion was significantly higher compared with that in the SEP(86)-DEC(86) combination. The differences were due to the strategy of selecting the lightest calves for slaughter. Data on selected calves were excluded when fitting growth functions to the data.

Table 7 shows the coefficients for the fitted functions of Model 1 and Model 2 and the goodness of fit. In all cases the goodness of fit obtained when fitting the adjusted weights to the non-linear functions was high, as demonstrated by the R^2-values (Table 7). The main reason for this is that the mean weights for each point on each occasion was used instead of single observations.

The predicted average weights for each of the four «seasonal break dates» during the four years together with corresponding estimates of standard deviations and coefficients of variation within and between years, are presented in Table 8. Fig. 1 is based on data presented in Table 8, with Model 2 fitted to the weights for each of the sexes. As shown, body weight increased rapidly during about the first 20 days; thereafter the growth rate decreased gradually and the body weight remained relatively constant during the last month and a half. At the end of the period a small weight loss was observed for the male cohort. The two outer lines represent ± one residual standard deviation in live weight (within year) and the two inner lines around the mean weight curve represents ± one standard deviation of live weight based on year means.

Table 5. Estimated daily weight gain (gram) from July to December in 3 groups of calves. Figures within parentheses give the deviation from the LS-mean estimate of group 3.

	1	2	3
Year			
Male			
1986	165.0 (+8.8)	161.2 (+5.0)	156.2
1987	124.4 (-6.3)	126.2 (-4.5)	130.7
1988	138.8 (-3.1)	139.1 (-2.8)	141.9
1989	131.5 (-3.4)	128.0 (-6.9)	134.9
Female			
1986	145.8 (-2.8)	148.7 (+0.1)	148.6
1987	120.0 (-1.9)	120.0 (-1.9)	121.9
1988	130.5 (-2.3)	132.5 (-0.3)	132.8
1989	121.3 (+0.6)	118.5 (+2.2)	120.7

Dressing percentage

A plot of observed values and the linear regression of dressing percentage on pre-slaughter body weight are presented in Fig. 2. No effect of sex on the regression line was found ($p > 0.05$).

Discussion

Overall growth

Seasonal pattern of change in body weight and growth rate in reindeer are shown by e.g. McEwan (1968) (caribou); Dauphiné (1976) (caribou); Moen (1980); Ryg & Jacobsen (1982) and

Table 6. LS-mean (kg) and SE for pairwise combinations of weighing occasions.

Weighing occasion	Male calves			Female calves		
	N	1st weigh.	2nd weigh.	N	1st weigh.	2nd weigh.
JUL(86)A	229	19.8±0.19		262	18.4±0.18	
JUL(86)B	111	22.5±0.29		118	20.9±0.28	
JUL(86)-SEP(86)	53	20.7±0.45	- 42.7±0.51	75	19.0±0.38	- 39.0±0.43
JUL(86)-DEC(86)	211	20.6±0.32	- 46.3±0.41	234	19.1±0.31	- 43.3±0.35
JUL(86)-JAN(87)	76	20.8±0.34	- 45.9±0.46	71	19.2±0.35	- 42.6±0.48
SEP(86)	55	42.8±0.50		88	39.4±0.40	
SEP(86)-DEC(86)	13	45.7±1.09	- 47.9±1.14	26	41.4±0.78	- 45.3±0.86
SEP(86)-JAN(87)	4	46.0±1.43	- 46.5±1.09	10	41.3±0.90	- 42.4±0.69
DEC(86)	236	46.6±0.30		281	43.8±0.28	
DEC(86)-JAN(87)	23	51.1±0.84	- 48.3±0.86	53	46.9±0.54	- 44.2±0.56
JAN(87)	103	44.8±0.25		134	43.2±0.37	
JUL(87)	443	25.1±0.14		439	23.8±0.14	
JUL(87)-SEP(87)	33	24.8±0.56	- 40.7±0.79	36	23.8±0.34	- 38.5±0.36
JUL(87)-DEC(87)	308	25.1±0.17	- 44.0±0.24	316	24.0±0.16	- 41.8±0.24
JUL(87)-JAN(88)	128	24.9±0.27	- 42.4±0.38	116	23.4±0.28	- 39.7±0.40
SEP(87)	56	41.4±0.65		49	38.0±0.69	
SEP(87)-DEC(87)	38	41.2±0.78	- 42.4±0.73	32	38.5±0.85	- 40.2±0.80
SEP(87)-JAN(88)	16	42.5±1.23	- 43.7±1.24	11	35.4±1.49	- 35.9±1.50
DEC(87)	321	43.9±0.24		324	41.7±0.24	
DEC(87)-JAN(88)	2	41.6±3.37	- 40.5±4.03	2	38.7±3.37	- 38.5±4.03
JAN(88)	136	42.6±0.38		121	39.5±0.41	
JUL(88)	546	21.6±0.12		564	20.8±0.12	
JUL(88)-SEP(88)	26	23.3±0.55	- 42.5±0.69	21	20.6±0.61	- 38.5±0.77
JUL(88)-DEC(88)	534	21.7±0.12	- 43.0±0.19	553	20.8±0.12	- 40.9±0.18
SEP(88)	26	42.5±0.69		21	38.5±0.77	
SEP(88)-DEC(88)	18	42.3±0.76	- 43.5±0.81	15	38.4±0.83	- 40.6±0.88
DEC(88)	534	43.0±0.19		554	40.9±0.18	
JUL(89)	662	25.6±0.12		630	24.1±0.12	
JUL(89)-SEP(89)	79	26.1±0.30	- 43.4±0.52	85	24.3±0.29	- 40.1±0.50
JUL(89)-DEC(89)	626	25.6±0.12	- 46.0±0.19	600	24.1±0.12	- 43.0±0.19
SEP(89)	79	45.8±0.53		85	40.2±0.49	
SEP(89)-DEC(89)	70	43.4±0.52	- 46.4±0.51	77	40.0±0.50	- 42.9±0.49
DEC(89)	626	45.6±0.19		597	43.0±0.19	

Table 7. Coefficients for the growth function estimated from data given in Table 4.

Year	Calf sex	Model parameters						
		a	b_0	b_1	b_2	b_3	b_4	R^2
Model 1								
1986	male		49.02	0.591	0.023	0.065	0.016	99.4
	female		45.55	0.593	0.020	0.067	0.037	99.8
1987	male		44.21	0.449	0.036	0.156	0.052	99.8
	female		42.90	0.457	0.025	0.277	0.046	99.5
Model 2								
1988	male	21.71		0.1909	-.0018			99.9
	female	20.81		0.1652	-.0010			99.9
1989	male	25.67		0.1380	-.000725			99.9
	female	24.16		0.1308	-.000520			99.9

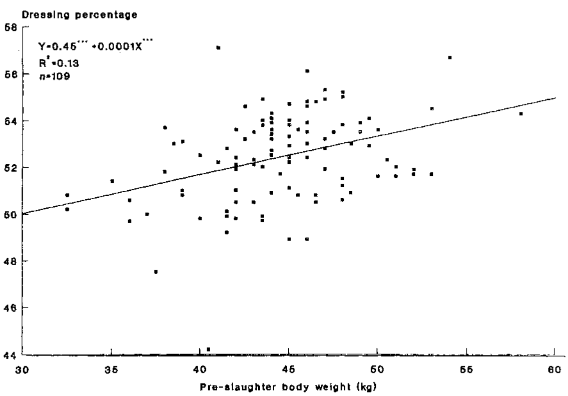

Fig. 2. Relationship between pre-slaughter body weight in reindeer calves and dressing percentage.

Timisjärvi *et al.* (1982). In calves, body weight increases continuously until around 6 months of age. Thereafter it decreases until around 10–12 months of age (e.g. McEwan, 1968 (caribou); Varo, 1972; Timisjärvi *et al.*, 1982; Leader-Williams, 1988). Changes in weight in the present study are in accordance with earlier results although the late decrease in February–April/May was not observed in the present one owing to a lack of registrations. Fitting the same non-linear growth function (Model 1) to weight records observed between 60 and 180 days (Rydberg, 1971) and between 42 and 175 days (Timisjärvi *et al.*, 1982) gave growth curves on the same shape as those obtained in the present study. The approximate weights on around 10 December were calculated to be 48.8 kg and 44.6 kg for male and female calves respectively using the data obtained by Rydberg (1971) and 38.8 kg on average for all calves using the data from Timisjärvi *et al.* (1982). These weights are within the range predicted from the study herd.

Table 8. Predicted weights (kg), standard deviations and coefficients of variation (%) within (w) and between (b) years for male and females calves.

Date	Sex	Mean	SD(w)	SD(b)	C.V.(w) (%)	C.V.(b) (%)
Jul 20	male	24.31	3.13	1.60	12.9	6.6
	female	22.90	2.81	1.10	12.3	4.8
Sep 20	male	42.65	4.62	0.63	10.8	1.5
	female	39.23	4.07	0.67	10.4	1.7
Dec 10	male	44.81	4.74	1.75	10.5	3.9
	female	42.30	4.30	1.31	10.2	3.1
Jan 15	male	44.86	4.17	2.12	9.3	4.7
	female	41.49	4.17	2.93	10.1	7.1

Annual differences in calf weight are known to occur. In the study herd, calf weight in July had a coefficient of variation of 23 %, which is similar to results from Haukioja & Salovaara (1978). For DEC the weight dispersed 7 %. The irregular patterns are the result of variation in environmental conditions, e.g. climate, food availability, stress caused by insects and adverse snow conditions. These factors appear to restrict calf growth and constitute and uncontrolled part of the reindeer production system.

The proportion of dams in the herd, that had been selected on their calf weight, increased during each successive year. The impact of this increase on the observed calf weights was considered to be larger each year. However, since the effect of the applied selection strategy could not be separated in the analyses it constitutes a part of the year-effect, but probably only as a minor part. Lenvik *et al.* (1988b) attributed an improvement in calf weight over a 5-6 year period to their selection strategy, which was similar to the one practiced in our study herd.

Since weight gain in calves can be predicted from the growth curves such curves help in determining the optimal time for slaughter. For example, in situations where considerable losses of calves are expected during the autumn it might be preferable to slaughter the calves before they have reached their maximum weight.

Sex

Krebbs & Cowan (1962) found in Canadian reindeer that male calves were heavier than female calves throughout the year. The same was found in a study on domestic reindeer in Finland (Eloranta & Nieminen, 1986) and in Newfoundland caribou calves (Bergerud, 1975). Haukioja & Salovaara (1978) found that, on average, summer weights of male calves were 10 to 15 % higher than those of females calves. This difference is slightly greater than the corresponding one ine the Tännäs herd. Our results are in accordance with those calculated form Lenvik *et al.* (1988b), showing that male calves in November were about 7% heavier than female calves.

Dressing percentage

Our finding that the dressing percentage was higher in the heaviest calves than in lighter ones corresponds with data presented by Jacobsen *et al.* (1980) and is also in accordance with results obtained with other domestic ruminants as reported in Persson (1985)

Unrecorded causes of variation in weight

Weight and growth in the individual calf are influenced by genetic as well as by non-genetic factors. Non-genetic sources of variation in growth between calves include age of the calf as well as the age, physical status, parity number and social rank of the dam (Varo & Varo, 1971; Espmark, 1980; Jacobsen *et al.*, 1981; Kojola, 1989). Correlations between the size of the mother and the weight development of the calves as well as correlations between birth time and birth weight and later weights of the calves have been reported (e.g. Varo & Varo, 1971, Espmark, 1980; Rognmo *et al.*, 1983; Eloranta & Nieminen, 1986). Eloranta & Nieminen (1986) showed that females weighing more than 90 kg produced calves that, on average, weighed 40 % more than calves from females weighing less than 60 kg. Similarly, results from Rognmo *et al.* (1983) showed that the birth weight of calves from females weighing more than 90 kg was 70 % higher than that from females weighing less than 60 kg.

One important «seasonal break date«, uncontrolled in the study herd, is the birth date of the individual calf. A range in age of 10 days for example can account for a difference of 3–4 kg in weight between two calves in July since weight gain during the first month is 300–400 g/day (e.g. Dobrotvorsky *et al.*, 1939 (in Krebbs & Cowan, 1962); Varo & Varo, 1971; Timisjärvi *et al.*, 1982, Rognmo *et al.*, 1983). In addition, the birth weight of early-born calves is, on average, higher (Eloranta & Nieminen, 1986) than that of calves born later.

It can be concluded that the variation in birth date between calves contribute to the variation in weight. The coefficient of within-year variation in July weights, unadjusted for weighing day (from Table 1), was approximately 50 % higher than the coefficient of within-year variation for the adjusted July weights (Table 8). Adjusting weights toward the same day seems to lower the age-related variation in weights. It can also be concluded that calf age affect July weights more than it affects weights measured on later dates. From Table 8, it can be seen that the coefficient of within-year variation in weights were 2 to 3 percent points higher at the July weighing as compared with later occasions. This is in agreement with results from Finland (Varo, 1972). For C.V. % values calculated using the raw data (Table 1) the corresponding difference was 6 to 7 percent points greater.

Concluding remarks

The main results of this study are the presented data on reindeer calf weights with dispersions connected to the «seasonal break dates». These results are going to be incorporated into a model for optimizing reindeer herd structure as discussed, both in terms of mean weights at different ages and sexes and the dispersion within year and from year to year. Our results emphasize also the importance of information on individuals for the application of efficient culling strategies.

References

Bergerud, A. T. 1975. The reproductive season of Newfoundland caribou. - *Can. J. Zool. 53:* 1213–1221.

Dauphiné, T. C. 1976. Biology of the Kaminuriak population of the barren-ground Caribou. - *Canadian Wildlife Service Report Series. 38:* 71 pp.

Eloranta, E. & Nieminen, M. 1986. Calving of the experimental reindeer herd in Kaamanen during 1970–85. - *Rangifer. Special Issue No. 1:* 115–121.

Espmark, Y. 1971. Mother-young relationship and ontogeny of behavior in reindeer. (*Rangifer tarandus* L). - *Tierpsychology.* 29 (42): 42–81.

Espmark, Y. 1980. Effects of maternal pre-partum undernutrition on early mother-calf relationships in reindeer. - *In: Proceedings of the 2nd International Reindeer/Caribou Symposium, Röros, Norway 1979.* Direktoratet for vilt og ferskvannfisk, Trondheim. pp. 485–496.

Haukioja, E. & Salovaara, R. 1978. Summer weight of reindeer (*Rangifer tarandus*) calves and its importance for their future survival. - *Rep. Kevo Subartic Res. Stat. 14:* 1–4.

Jacobsen, E., Bjarghov, R. S. & Skjenneberg, S. 1980. The ability of reindeer (*Rangifer tarandus*) calves to gain weight in the winter. - *Scientific Reports of the Agricultural University of Norway.* 59 (32): 1–7.

Jacobsen, E., Hove, K., Bjarghov, R. S. & Skjenneberg, S. 1981. Supplementary feeding of female reindeer on a lichen diet during the last part of pregnancy. - *Acta Agric. Scand. 31 (1):* 81–86.

Kojola, I. 1989. Maternal investment in semi-domesticated reindeer (Rangifer t. tarandus L.). - *Biological Research Reports from the University of Jyväskylä.* University of Jyväskylä. Jyväskylä, Finland. 12: 1–25.

Krebbs, C. J. & Cowan, I. M. 1962. Growth studies of reindeer fawns. - *Canadian Journal of Zoology 40:* 863–869.

Leader-Williams, N. 1988. *Reindeer on South Georgia. The ecology of an introduced population.* Cambridge University Press, Cambridge. 319 pp.

Lenvik, D. & Fjellheim, A. 1988a. *Utvalgsstrategi i reinflokken. 1. Standard tilleggskode for rein.* (Selection strategy in domestic reindeer. 1. Standard tag system for reindeer). Reindriftsadministrasjonen, Alta, Norway. pp 251-261. (in Norwegian).

Lenvik, D., Bøe, E. & Fjellheim, A. 1988b. *Utvalgsstrategi i reiflokken. 3. Reinkalvens høstvekt relatert til mødrenes vekt og alder.* (Selection strategy in domestic reindeer. 3. Weight of reindeer calves in autumn related to maternal body weight and age). Reindriftsadministrasjonen, Alta, Norway. pp. 65–69. (in Norwegian).

Lenvik, D. 1989. Utvalgsstrategi i reinflokken. - *Norsk landbruksforskning, Supplement No. 4,* 26 pp. (in Norwegian).

McEwan, E. H. 1968. Growth and development of the barren-ground caribou. II. Postnatal growth rates. - *Canadian Journal of Zoology. 46:* 1023–1029.

Moen A. N. 1980. Growth and metabolism rhythms of individuals and populations of deer and caribou. *In: Proceedings of the 2nd International Reindeer/Caribou symposium Røros, Norway 1979.* Direktoratet for vilt og ferskvannfisk, Trondheim. pp. 291–296.

Movinkel, H. & Prestbakmo, H. 1969. Variations in the carcass weight of reindeer in some summer pasture districts in Finnmark and Troms counties. - *Scientific Reports of the Agriculture college of Norway.* 48 (21): 1–26.

Parker, K. L. 1989. Growth rate and morphological measurements of porcupine caribou calves. - *Rangifer.* 9 (1): 9–13.

Persson, L. 1985. *Kompendium i nötkreatursavel.* Inst. för husdjursförädling och sjukdomsgenetik, ed. L. Persson, Uppsala, Sweden. 11 chp (in Swedish).

Petersson, C. J. 1988. *Kalvvägningar i Tännäs sameby.* Inst. för husdjursförädling och sjukdomsgenetik, Uppsala, Sweden. 14: 1–7. (in Swedish).

Petersson, C. J., Lenvik. D. & Nissen, Ø. 1990. Data systems for improvement of reindeer production. - *Rangifer. Special Issue. 5*: 22–28.

Petersson, C. J. & Danell, Ö. 1992. Simulated production losses in reindeer herds caused by accidental death of animals. - *Rangifer.* 12 (3): 143–150.

Petersson, C. J. & Danell, B. 1993a. Value of earlier weight measurements as predictors of body weight at later ages in reindeer. *(In manuscript).*

Petersson, C. J. & Danell, Ö. 1993b. Simulation of production capacity in reindeer flocks: Submodels and review of available production data. (*In manuscript*).

Reimers, E. 1983a. Calving time, growth rate, and body size of Norwegian reindeer on different ranges. - *Artic and Alpine Research* 15 (1): 107–118.

Reimers, E. 1983b. Growth rate and bodysize differences in Rangifer, a study of causes and effects. - *Rangifer.* 3 (1): 3–15.

Rognmo, A., Markussen, K. A., Jacobsen, E., Grav, H. J. & Blix, A. S. 1983. Effects of improved nutrition in pregnant reindeer on milk quality, calf birth weight, growth, and mortality. - *Rangifer.* 3 (2): 10–18.

Rohlf, F. S. & Sokal, R. R. 1981. *Statistical tables (2nd ed.).* San Francisco: Freeman and Comp. 219 pp.

Rydberg, A. 1971. Tillväxten hos renar. - *Röbäcksdalen meddelar, Rapport från Norrlands Lantbruksförsöksanstalt.* Röbäcksdalen, Umeå. 3: 1–8. (in Swedish).

Rydberg, A. 1982. Preliminära resultat från slaktkroppsundersökningen av ren, säsongen 1981–82 inom Arvidsjaurområdet. - Sveriges lantbruksuniversitetet, Renförsöksavdelningen. Mimeo, 21 pp. (in Swedish).

Ryg, M. & Jacobsen, E. 1982. Seasonal changes in growth rate, feed intake, growth hormone, and thyroid hormones in young male reindeer (*Rangifer tarandus tarandus*). - *Canadian Journal of Zoology. 60:* 15–23.

SAS Institute Inc. 1985. *Users's Guide Statistics.* Version 5 Edition. SAS Institute Inc. Cary N. C. 956 pp.

Timisjärvi, J., Nieminen, M., Roine, K. & Koiskinen, M. 1982. Growth in the reindeer. - *Acta. Vet. Scand. 23:* 603–618.

Varo, M. & Varo, H. 1971. The milk production of reindeer cows and the share of milk in the growth of reinder calves. - *Journal of the Scientific Agricultural Society of Finland. 43:* 1–10.

Varo, M. 1972. Investigations on the possibilities of reindeer breeding II. - *Journal of the Scientific Agricultural Society of Finland. 44:* 234–248.

Wood, P. D. P. 1967. Algebraic model of the lactation curve in cattle. - *Nature* 216: 164–165.

Manuscript accepted 15 April, 1993.

Correction to Fig. 1.

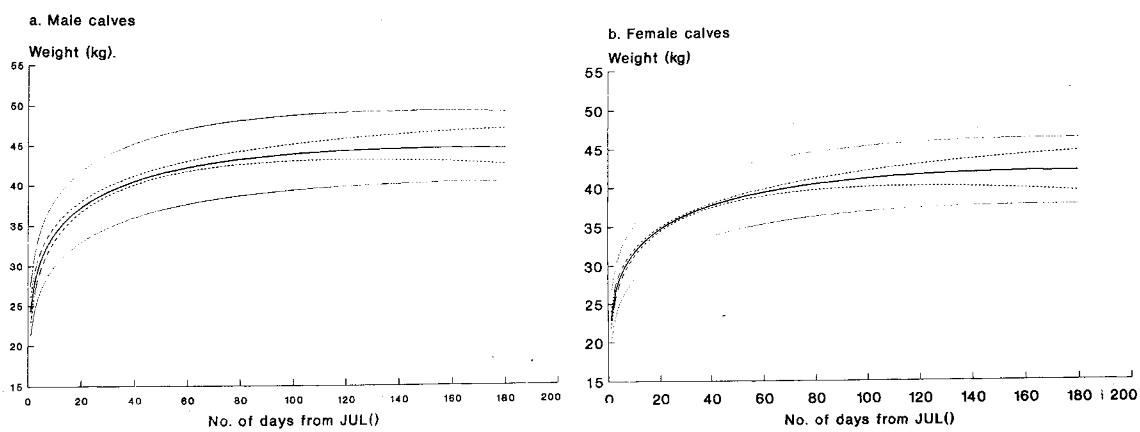

Fig. 1. Average growth curves and ranges for one standard deviation between years (---) and within year (....), respectively.