Value of early weight measurements as predictors of body weight at later ages in reindeer.

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Abstract: Phenotypic variances in live weight in a reindeer population and repeatabilities of the weights were estimated. The population consisted of 1847 and 1878 unselected male and female calves respectively, for which data from weighings at 2 and 7 months of age were available. All individuals in a selected population, consisting of 469 of the heaviest females, were weighed at 2, 7 and 19 months of age. The data were colleted during four successive years, 1986 - 1989. An indirect selection model for improving female weight at 19 months of age was proposed.

Variance in the unselected population was higher between animals than within animals. Repeatability was estimated to be 0.636 for the male calves and 0.609 for the female calves. In the selected population, within-individual variance was higher than between-animal variance. Repeatabilities were, after correction for the effect of selection, 0.316 (between 2 and 19 months) and 0.548 (between 7 and 19 months).

The aim of the selection model was to increase the average weight in the primiparous group to improve their calf production ability. Using the model, the number of animals weighing equal to or more than a certain threshold weight and the number needed for recruitment at 19 months of age could be determined.

Key words: selection, repeatability.

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Introduction

The weight and classification of slaughtered animals in reindeer husbandry are of great economic importance to the producers. Growth rate and live weight are therefore important paramenters that must be taken into account when trying to optimize the production system in a reindeer herd (Petersson & Danell, 1993). From an economic viewpoint, it is also essential that the replacement dam starts to produce vigorous calves with a low mortality rate as soon as possible. It has been demonstrated that dam body weight (i.e. 19 month-weight) strongly influences calf production ability (e.g. Rognmo *et al.*, 1983; Eloranta & Nieminen, 1986; Lenvik, 1990).

In some production systems calves are slaughtered at around 7 months of age, and only the heaviest ones are kept for breeding purposes (Lenvik, 1988, 1988a; Petersson *et al.*, 1990). The selection intesity in these systems can be kept high, and the proportion of calves culled can reach 75% for males and 50% for females without disturbing the herd structure (e.g. Petersson & Danell, 1992). One expected effect of this type of selection is an increase in the mean weight of the primiparous group. To predict this effect it is necessary to know how live weight varies with calf age.

The first objective of the present study was to determine the phenotypic variance in the live weight of female reindeer at 2, 7 and 19 months of age, and to estimate the degree of repeatability of the weights. For male reindeer, only weights at 2 and 7 months were available for analysis.

The impact of the weight of the primiparous group on calf production ability (Eloranta & Nieminen, 1986; Lenvik 1982, 1988, 1990) can be realized in harvesting systems where females are selected based on their weights before 7 months of age. Lenvik proposed that calf losses increase rapidly and calf live weight decreases as dam live weight falls below a certain threshold level. If these hypotheses are correct, then selection should strive not only to reach a certain weight but also to maximize the porbability of reaching it.

Knowledge of the pattern with which weight varies with age and the repeatability can be used to predict the short-term effect of early selection on adult female weight. The long-term effects are even more important, but to determine them requires that the heritabilities be known.

The second purpose of this study was therefore to develop a model for selecting female calves at 2 or 7 months of age in order to minimize the proportion of females below a given weight at 19 months of age.

Material and methods

Estimation of repeatability of weights

A detailed description of the study herd is presented in Petersson & Danell (1993). Calf weights determined in connection with roundups in July (2 months of age) and November-/December (7 months of age) were used. The weighed calves could be considered as a random sample of all calves in the flock. In one of the years some selection had taken place in September, but the effects on December weight were small (Petersson & Danell, 1993). At the December weighings, however, only the calves needed for replacement were kept. Culling was based on a comparison of the observed weight with a threshold weight (Petersson *et al.*, 1990): Calves with weights equal to or greater than the threashold were kept while the others were slaughtered. The females weighed at 19 months of age therefore constituted a selected group of animals.

The analyzed material was adjusted for various factors, such as days spent waiting in the main corral, and the scale used, as described by Petersson & Danell (1993).

Since the data consisted of two or three consecutive individual weight measurements, the phenotypic variance could be separated into variance within individuals and variance between individuals. The between-individual component (σ_u^2) is partly environmental and partly genetic and measures permanent differences between individuals. The within-individual component (σ_e^2) is entirely environmental in origin and measures the differences between the performance of the same individual. The ratio of the between-individual component to the total phenotypic variance, $t = \sigma_u^2/(\sigma_u^2+\sigma_e^2)$, measures the correlation between the measurements on the same individual and is referred to as the repeatability.

The model used to estimate the variance components was

$$Y^*_{ij}=\mu+f_i+u_j+e_{ij}$$

where

Y^*_{ij} = adjusted body weight
μ = mean
f_i = fixed effect of *i*th occasion, $i=1,2$
u_j = random effect of *j*th calf with mean = 0 and variance = σ_u^2
e_{ij} = random residual effect with mean = 0 and variance = σ_e^2

The analysis was done using Harvey's LSML76 program (Harvey, 1977). The material was divided into subsets which were analyzed separately. There was one subset for each sex and year. The weight records were dealt with two at a time. For unselected male and female calves there was only one such pair: 2 and 7 months of age. For selected females there were pairs: 2 and 7, 2 and 19 and 7 and 19 months of age.

The mean and variance of body weight differed between weighing occasions.

Therefore, to counterbalance the unequal variances, analyses for estimating the repeatability were based on standardized observations. The standardization was made according to

$$X' = ((X-\mu)/\sigma^2)\cdot\sigma^{2\prime}+\mu'$$

where

X' = standardized observation
X = adjusted single observation
μ = mean within group and occasion
σ^2 = variance within group and occasion
$\sigma^{2\prime}$ = standardized variance
μ' = standardized mean weight

Following Cochran (1954), the observed correlation between two variables is reduced after selection based on one of them is reduced. The reduction is proportional to the reduction in variance and the true correlation between the traits.

The intra-class correlation or repeatability *(t)* is consequently also reduced as a result of culling at 7 months of age. The observed correlation *(t')* is a function of the true *t*.

$$t' = t \sqrt{\frac{1-k}{1-t^2k}}$$

where $k = i(i-x)$, with i being the mean of selected animals and x the threshold in standardized variables.

After rearerangement the true t can be computed as

$$t = \sqrt{\frac{t'^2}{(1-k) + t'^2k}}$$

where

t = true repeatability unaffected by selection
t' = observed repeatability
k = $(V(Y) - V(Y)') / V(Y)$ (corresponding to $i(i-x)$)
V(Y) = variance among all calves on each occasion
V(Y)'= variance in the selected group on each occasion

An adjusted repeatability was calculated for each of the combinations of weights and was weighted based on the number of observations for each year. The observations for selected female calves for 1986 could not be utilized owing to a lack of their weights at 19 months of age.

Prediction of weight at 19 months - a selection model
When optimizing the production in a calf harvesting system, as practiced in the study herd, the number of calves kept after selection should be minimized. At the same time, the live weight of the replacement females should not be lower than a recommended threshold weight at 19 months of age. To obtain a large enough proportion of replacement females equal to or above this threshold, extra females need to be kept at the early cullings.

A model to compute the minimum proportion (Pr_c) of calves that should be kept to obtain a specific proportion (Pr_b) of females at or above a targeted weight at 19 months of age is given below.

In the first step the culling responses for different levels of selection intensities are calculated as

$$\Delta v = t \cdot i \cdot \sigma_n$$

where

Δv = response from culling at 2 or 7 to 19 months of age
t = repeatability
i = selection intensity
σ_n = standard deviation of *n*th (2 or 7 months of age) weight, $n = 1, 2$

In the next step the expected deviation from the threshold weight at 19 months is computed as

$$S = (\Delta v + X_{19\ months}) \cdot X_{TH}$$

where

$X_{19\ months}$ = mean weight of the females at 19 months of age when no culling is practised
X_{TH} = threshold weight at 19 months of age

When S is known and under the assumption of a normal distribution of weights, the truncation point (Z_0) can be computed as below. Further, the fraction *(P1)* of the females below threshold weight can be found in standard tables.

$$Z_0 = S/\sigma_{19\ months}$$

where

$\sigma_{19\ months}$ = standard deviation for weight at 19 months of age

Finally, the proportion of the heaviest calves that should be selected at 2 or 7 months of age to obtain a specified proportion of females weighing equal to or above a threshold weight at 19 months of age can be computed as

$$Pr_c = Pr_b \cdot S_c$$

where

Pr_c = proportion of the heaviest calves that should be selected
Pr_b = proportion of breeding females weighing equal to or more than the threshold and needed for replacement

$$S_c = 1+(P_1/P_2)$$

P_1 = proportion of females weighing less than the threshnold weight at 19 months of age

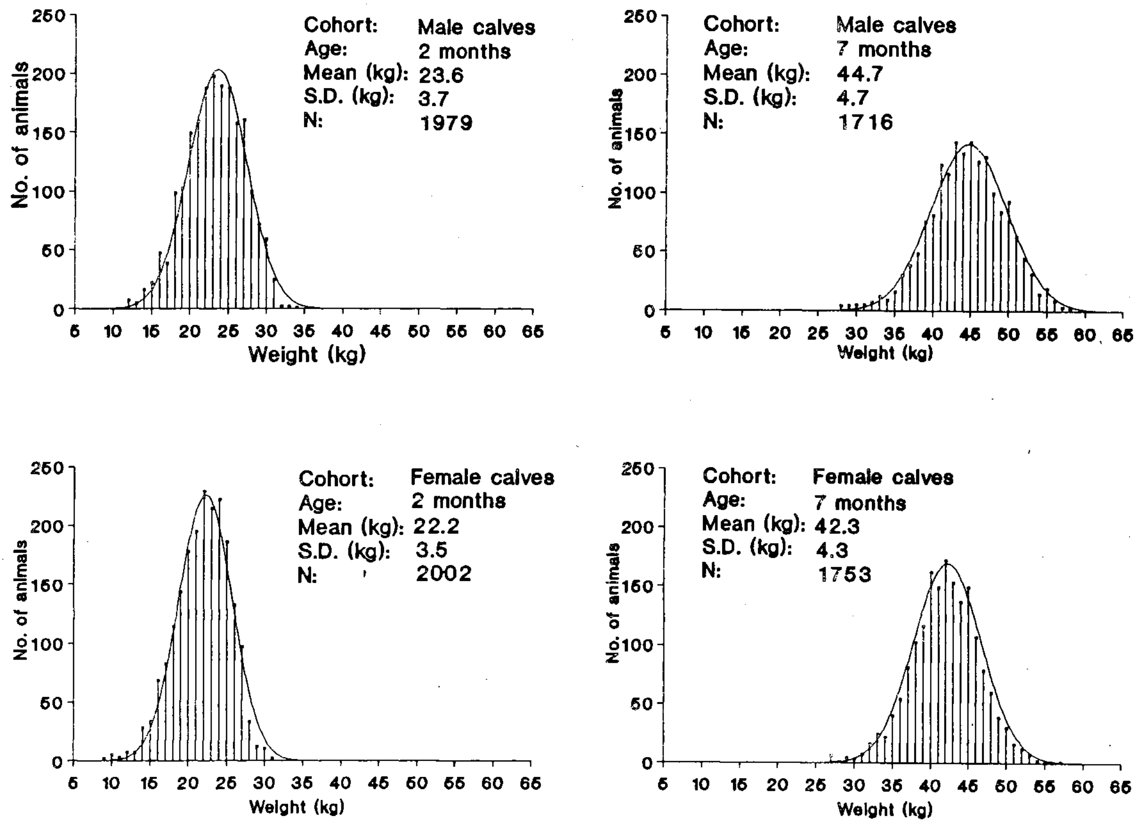

Fig. 1. Numerical distribution of male and female calves in different weight classes at 2 and 7 months of age.

P_2 = $1-P_1$; proportion of animals weighing equal to or more than the threshold weight at 19 months of age.

The selection intensity *(i)* used in the first step depends on the proportion *(p%)* of the population included in the selected group. This holds, provided that the observations are normally distributed (e.g. Falconer, 1981). Statistical tests for normality were made using the procedure Univariate in the Statistical Analysis System (SAS, 1985). The data were tested against a normal distribution with the mean and variance equal to the sample mean and variance.

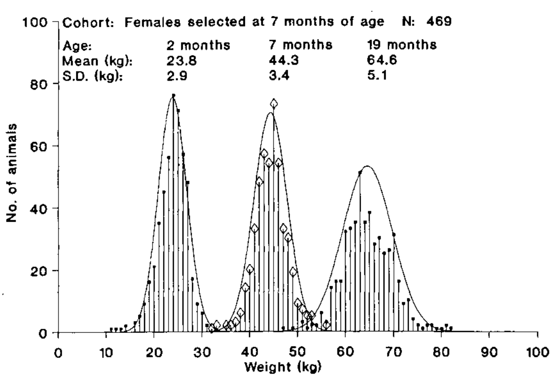

Fig. 2. Numerical distribution of selected females in different weight classes for weights observed at 2, 7 and 19 months of age.

Results

Characteristics of the data

All adjusted 2-month weights are shown in the histograms for male and female calves respectively (Figs. 1a and 1b). Corresponding histograms for weight at 7 months are given in Figs. 1c and 1d, and in Fig. 2 the histograms of weights for selected female calves at 2, 7 and 19 months of age are presented. The continuous approximations are also presented in the figures.

In all cases the observations had a normal distribution.

The number of slaughtered calves and the number of calves selected for breeding are given in Table 1. The proportion selected and the selection intensity are also given.

Table 1. Number of calves slaughtered, number selcted, proportion selected and selection intensity from 1986 to 1989.

	Number of animals				
	Total	Slaughtered	Selected	Proportion selected (p%)	Selection intensity (i)
Male	2413	1833	580	24.0	1.295
Female	2489	1283	1209	48.5	.83

Table 2. Mean weight and standard deviation of the selected females at 19 months of age

Year	N	Mean (kg)	S.D. (kg)	Range
1987	116	65.53	4.93	51–80
1988	145	63.62	5.27	49–81
1989	208	64.70	4.93	47–83
Weighted mean and SD		64.57	5.04	

The mean and standard deviation of body weight at 19 months of age for the selected females for each of the three years is given in Table 2. The dispersion in weight for each of the years was quite similar, with the lowest weights ranging from 47 to 51 kg and the highest from 80 to 83 kg. The successive increase in number of observations over the study period can be explained by the fact that the 19-month weight became a more and more interesting selection criterion, thereby encouraging the reindeer owners to weigh their animals.

Variance components and repeatability estimates

Components of variance between and within calves as well as the repeatability figures are given in Table 3. For body weight the variance between calves was consistently greater than the variation within calves.

In the selected females, variance components between and within animals as well as the repeatability figures between 2 and 7 and 7 and 19 months of age, respectively, are given in Table 4. In all data sets the adjusted repeatabilities (for the selection made at 7 months of age) were 8 to 25% higher than those computed as unadjusted estimates. The coefficient of variation for females at 2 months of age was 16%

Table 3. Variation between (σ^2_u) and within calves (σ^2_e) and repeatability (t) of body weight between 2 and 7 months of age.

Year	Male calves				Female calves			
	N	σ^2_u	σ^2_e	t**	N	σ^2_u	σ^2_e	t**
1986	288	8.62	6.47	0.599	331	9.80	5.75	0.665
1987	377	10.23	4.20	0.719	377	7.15	3.72	0.656
1988	538	8.65	5.39	0.626	556	7.44	5.06	0.602
1989	644	11.21	7.12	0.611	614	6.89	5.91	0.557
Mean*		9.86	5.92	0.636		7.82	5.19	0.609

* calculated as a weighted average
** estimated on standardized variances

Table 4. Variation between (σ^2_u) and within animals (σ^2_e) and repeatability (t) of body weight of females calves.

	N	2 to 19 months			7 to 19 months		
		σ^2_u	σ^2_e	t*	σ^2_u	σ^2_e	t*
1987	116	4.69	10.12	0.366	10.83	6.64	0.703
1988	145	4.63	12.20	0.308	9.99	9.64	0.596
1989	208	3.78	1.06	0.292	5.93	11.80	0.430
Weighted mean		4.27	11.18	0.316	8.40	9.85	0.548

* calculated on standardized variances and adjusted for selection.

Table 5. Example of expected response, measured as the difference [1] in mean weight ($\triangle v$) between selected and slaughtered groups, when weight-based selection of the calves was performed at 2 or 7 months of age.

	$\triangle v_{2\ months}$ (t_0)	$\triangle v_{7\ months}$ (t_1)	Observed difference selected-slaughtered
Male	2.56	6.13	5.53
Female	1.42	3.57	3.24

[1] The intensities of the selection were 1.295 for male calves and 0.830 for female calves, as given in Table 1. The standard deviations (kg), as given in Petersson & Danell (1993), at 2 months of age were 3.13 and 2.81 for the male and female calves respectively. Corresponding figures at 7 months of age were 4.74 and 4.30.

[2] Repeatabilites used were t_0= .636 (male), t_0= .609 (females) as given in Table 3, t_1=1.

in the unselected and 12% in the selected group. At 7 months of age corresponding values were 11% and 8%.

Culling responses measured as differences in mean weight between groups of selected and slaughtered calves for both sexes are examplified as a case study in Table 5. As can be seen, the mean weight in the selected groups was lower when the selection was made on 2-month weights. The observed differences between the mean weights of the selected and slaughtered groups are consistent with a theoretically computed response at 7 months of age. This would be expected in cases where the weights are normally distributed.

Selection towards a threshold weight at 19 months. An example in which the selection model was applied to the results is also demonstrated.

The average weight of unselected female calves at 7 months of age was estimated to be 42.30 kg (from Petersson & Danell, 1993). The weight gain from 7 to 19 months of age was estimated at 20 kg. Thus, the weight at 19 months of age averaged 62.30 kg and the corresponding standard deviation was 5.04 kg (from Table 2). The assumption was made that 400 calves were weighed at 7 months of age and that 200 of them (Pr_h=50%) would be retrieved weighing more than of 62.00 kg at 19 months of age. The culling response was calculated to be 1.88 kg based on the repeatability (t=0.548; Table 4), the standard deviation at 7 months of age (4.30 kg at December; Petersson & Danell, 1993) and the selection intensity (i=0.798 when Pr_h=50%; Falconer, 1981). The superiority of the selected group at 19 months of age is thus 64.18 kg (62.30+1.88) which in turn is 2.18 kg above the threshold weight. In standard deviation units this is 0.43 (2.18/5.04) (Z_0) on the standard normal scale. The proportion of females weighing less than the threshold weight is then 0.3336 (P_1) (e.g. Falconer, 1981), and the proportion of females weighing equal to more than the threshold weight is 1-P_1 or 0.6664 (P_2). Thus the proportion that has to be selected at 7 months of age ($Pr_c = Pr_h \cdot S_c$) is 75% (1+(0.3336/0.6664)· 50). Obviously, an extra 100 animals (75% of 400 is 300) has to be kept to obtain 200 females with a weight equal to or greater than the threshold weight in this case. The corresponding figure, when selection is based on the weight recorded at 2 months was calculated to be 80.9% (Pr_c) (the dispersion for July weights (2.81 kg) and the repeatabilities for 2 to 19 months are given in Petersson & Danell (1993) and in Table 4, respectively).

Estimates of the proportion of female calves that has to be selected at 2 and 7 months of age, respectively, for eleven different intensities of selection, are given in Table 6. The threshold weight at 19 months of age ranged from 57 to 65 kg, and the production parameters were the same as those used above. Assumed female weight gain was 39.4 kg for the 2 / 19 months combination and 20 kg for the 7 / 19 months combination in accordance with Fig. 2, yielding an average weight at 19 months of age of 62.30 kg. As can be seen, the proportion of selected calves is smallest in the combinations with both a low 19-month threshold weight and a low intensity of selection. In the first alternative, with a need for 30% replacement, the simulation succeeded in calculating selection constants (Pr_c) for all threshold weights included. In the combinations with a high threshold weight and a high selection intensity, the proportion of calves selected increased dramatically and exceedced 100%, as shown by the empty cells in Table 6.

Proportions of females selected at 7 months of age for different average weights at 7 months and different threshold weights at 19 months of age at three replacement rates (30, 50 and 70%) are given in Figs. 3a, 3b and 3c. The proposed average weights at 7 months ranged from 40 to 45 kg, and the average weight gain between weighing occasions was set at 20 kg. Other parameters needed were the same as those used above. The frequency of "failed" selections increased as the need for replacement females rose in combination with an increase in the diffe-

Table 6. Proportion of female calves that would have to be selected at 2 or 7 months of age to obtain a desired proportion of replacement females above a given threshold weight at 19 months of age. Average weights and S.D. at 2 and 7 months were 22.9 (2.8) and 42.30 (4.3) respectively. Since weight gains between 2 and 19 months and 7 and 19 months were approximated to 39.4 and 20.0 kg respectively inaccordance with Fig. 2, the average weight at 19 months of age was estimated to be 62.3 kg for both occasions. S.D. at 19 months of age was 5.04 kg (Tab. 2).

Desired propor- tion of replace- ment	Intensity of selec- tion	Threshold weight at 19 months of age																	
		57 kg		58 kg		59 kg		60 kg		61 kg		62 kg		63 kg		64 kg		65 kg	
	i	2*	7**	2	7	2	7	2	7	2	7	2	7	2	7	2	7	2	7
30	1.159	33.8	31.8	35.5	32.6	37.8	33.9	41.0	35.7	45.3	38.1	51.1	41.2	58.7	45.5	69.9	51.5	85.2	59.6
35	1.058	39.6	37.3	41.6	38.4	44.3	40.1	48.0	42.1	53.1	45.1	60.0	49.2	69.6	54.7	83.1	62.2		72.8
40	0.966	45.4	42.8	47.7	44.3	51.0	46.2	55.4	48.9	61.1	52.6	69.1	57.3	80.5	64.0	95.9	73.1		86.0
45	0.880	51.1	48.4	53.8	50.2	57.5	52.5	62.6	55.8	69.4	60.2	78.3	66.0	91.3	73.8		84.8		
50	0.798	57.0	54.2	60.0	56.2	64.2	58.9	70.0	62.8	77.6	67.7	88.2	74.6		84.2		97.3		
55	0.720	62.8	60.0	66.2	62.4	70.9	65.4	77.3	69.8	85.9	75.9	97.9	84.0		95.0				
60	0.644	68.7	65.7	72.5	68.5	77.6	72.3	84.8	77.3	94.3	84.3		93.2						
65	0.569	74.7	71.7	78.7	74.9	84.4	79.2	92.2	84.8		92.6								
70	0.497	80.7	77.7	85.1	81.2	91.3	86.1	99.7	92.8										
75	0.424	86.6	83.9	91.4	87.7	98.2	93.2												
80	0.350	92.6	90.1	97.8	94.6														

*) proportion to be selected at 2 months of age.
**) proportion to be selceted at 7 months of age.

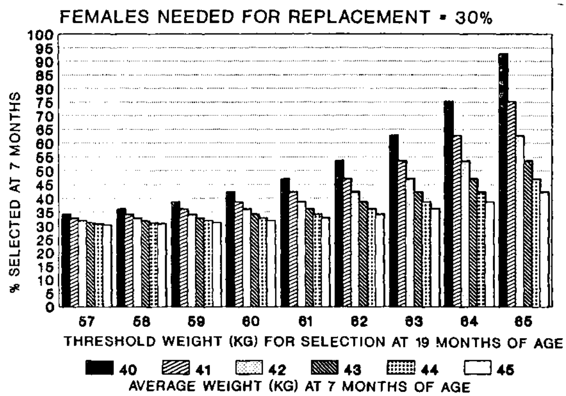

Fig. 3a.

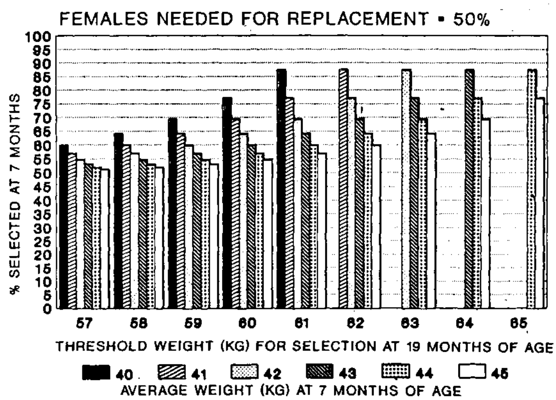

Fig. 3b.

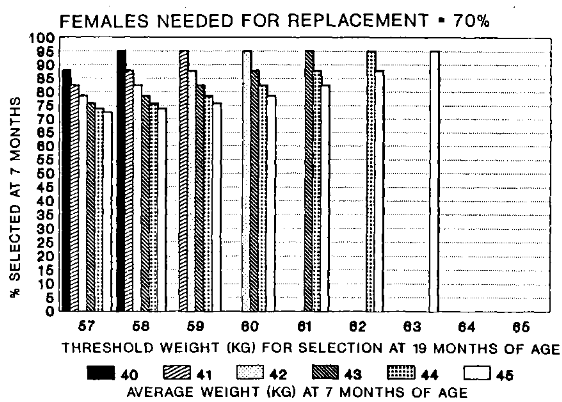

Fig. 3c.

Fig. 3. a–c. Required proportion of breeding female reindeer selected at seven months of age in order to reach a given proportion (a = 30 %, b = 50 % and c = 70 %) above a targeted weight one year later. Proportions are given for nine different targeted weights in populations with six different mean weights at 7 months of age.

rence between the 7-month weight and the threshold weight at 19 months.

Discussion

The distribution of the selected females was expected to be heavily skewed to the left because the heaviest calves were selected. In contrast, the selection of 7-month old female calves for breeding purposes, gave a normally distributed group of animals (Fig 2). The normal distribution obtained can be ascribed to selection method (Petersson *et al.*, 1990). Each reindeer owner gave individual figures for the culling percentage he was aiming at, which generally ranged between 35 and 65 percent. During the culling period, the threshold weight varied significantly owing to the differences in selection intensity. Consequently, the selected calves represented a wide range of weights. According to Petersson *et al.* (1990), the difference in weight between selected calves at two intensities of culling, e.g. 35 and 65 percent, can be about 6 kg for female calves at 7 months of age. However, weight variance in the selected group was lower than that in the unselected group, as expected.

The repeatabilities were moderately high (0.316 to 0.609), indicating that the ranking of some of the animals changed between weighings. Values obtained in the male calf group between 2 and 7 months of age (Table 3) deserve comment: In Petersson & Danell (1993) it was shown that weight gain among calves from 2 to 4 months of age was greater in males than in females. However, the corresponding difference in weight gain between 4 and 7 months of age was much less pronounced. It was assumed that the heaviest male calves actively participated in rutting and thereby lost weight, whereas male calves of "normal" weight and female calves gained weight during the rutting period. Thus, considerable changes can be expected in the rank order of males of "heavy" and "normal" weights during the course of the autumn. It therefore seems likely that the repeatability of weight measurements would be even higher if the heaviest calves were excluded from the analysis.

The repeatability values are expected to decrease over time, i.e. long-term estimates are more sensitive to environmental changes than are short-term estimates. This was also shown in the present study for the estimates, i.e. 0.316 vs. 0.548, between 2 to 19 and 7 to 19 months respectively, in the selected female group.

In at least one previous study dealing with reindeer, a positive correlation between early and later weights was reported. Varo (1972) reported positive phenotypic correlations for both sexes between birth - and 7-month weights (0.46), birth - and 19-month weights (0.57) and 7 - and 19-month weights (0.57).

Coefficients of determination for female weight at 19 months based on "normal" ($\approx$ 40 kg) 7-month weights and 2-month weights were 0.50 and 0.20, respectively in a study by Lenvik (1988b). For heavy calves ($\approx$ 50 kg) at 7 months of age the corresponding figure was around 0.10.

In the present study the weights of the selected female calves were regarded as "normal". One explanation for the extremely low weights of some 19-month-old animals (Table 2; Fig. 2), relative to the average weight, in the selected groups could be that some of these animals became pregnant. They raised a calf the following summer which considerably lowered their weights. Another reason could be that the owner of a particular animal decided, for some reason, to keep it for breeding purposes regardless of the threshold weight used in the truncation selection at 7 months of age.

The computed selection differences in Table 5 show that selection based on 2-month weights was inefficient. The average weight of calves in the slaughtered group increased and decreased in the selected group in comparison with observed data. Selection based on 7-month weight was almost twice as efficient. Thus, selection based on 7-month weight should be preferred when one of the goals is to increase the weight of replacement females.

Comments on the selection model

One purpose of the selection model is to improve the productivity of the primiparous group. The immediate result should be an improvement in calf production in the primiparous group. If the results of Lenvik (1982, 1988, 1990) are valid, then the offspring of selected females should be born earlier, be heavier and should show higher survival rates compared with offspring from unselected females. However, it should be emphasized that the present model only makes short-term effects on flock productivity of selection aiming at increasing the live weight of young females. Replacement of primiparous dams with high expected production potential can adversely influence productivity in later stages. Differences in lifetime performance between highly productive primiparous dams and "normal" primiparous individual with respect to growth, pregnancy rates, pregnancy "resting years", etc., need to be estimated. Thus lifetime productivity rather than first-year production should be the selection objective.

One shortcoming with selecting the heaviest female calves is the risk of pregnancy occurring the first autumn. Lenvik (1988b) used the body weight of female reindeer calves at 6 months of age to predict their weight at 18 months of age. Following his study, the weight of calves with a "normal weight" explained about 50% of the variation in body weight at 18 months of age. For heavy calves at 6 months of age, i.e. female calves that had been subject to selection, the corresponding figure was only 10%. This lower value was explained by the fact that heavy calves are more likely to breed. Carrying a calf the first winter results in a dramatic change in growth. The weight gain during the following grazing period is moderate, and mortality among calves is high (Ropstad *et al.,* 1990). In areas with good natural conditions there is a considerable probability that heavy, calves will become pregnant. (Skjenneberg & Slagsvold, 1968; Skuncke, 1969; Reimers, 1983; Ropstad *et al.,* 1990). Under such conditions the probability of female calves being mated can be reduced significantly by regulating the age structure of the males used in the herd (Lenvik, 1981). In the present study there were only a few yearling females with calves at the roundups in July. In cases where these females could be distinguished, they were excluded from the analysis.

In some production strategies the proportion of replacement animals should be minimized, i.e. where the meat production is based mainly on meat of slaughtered calves (e.g. the herd in the present study; Lenvik, 1988a). Also, in many districts, the amount of winter pasture is the limiting factor in the production system. Keeping more animals than necessary in those areas during the winter period can therefore negatively influence both the overall growth and survival rates of the herd. The costs of keeping more female calves than are necessary for replacement needs over the winter must be subtracted from the benefit of getting heavier female yearlings. These costs include losses during the winter, lowered value of the carcass and adverse effects in the rest of the herd.

It should also be emphasized that there is a risk for a considerable "over-selection" in situations where a high threshold weight is combined with a low average weight at either 2 or 7 months of age. As a consequence, there will be a significant decrease in weight of the selected females which affects the average weight at 19 months of age. This will tend to decrease the robustnes of the selection model.

Therefore, caution is justified in cases where differences between selection- and threshold weights are large.

Concluding remarks

Until recently, improvement in reindeer production has mainly been achieved by introducing new techniques and management policies directed mainly at controlling flock structure. In contrast to the modern husbandry of domestic animals (sheep, pigs, cattle) efforts to make improvements at the individual level in reindeer production have been minimal. One shortcoming, in particular, has been the lack of knowledge of individual performance. However, in intensive systems, with recordings made at the individual level, genetic improvements through selection can be achieved. This requires that the heritabilities of the most important production factors, such as vitality, fertility, mothering ability and growth rate be known. The estimation of such parameters, however, would require large-scale registration projects lasting over a whole life-cycle of a reindeer flock. Therefore, little information on such parameters is available. In addition, selection aimed at improving productivity in reindeer is probably not as straightforward as in animal husbandry, where the environmental conditions are fairly controlled. For example, over the long term, selection for rapid growth could decrease the ability to withstand severe environmental conditions, especially if there is a negative genetic correlation between growth rate and the ability to build up fat stores needed to survive the winter.

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