Approaches to estimate body condition from slaughter records in reindeer

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Abstract: Long-term fluctuations in population densities of reindeer and caribou are common, where pasture is the limiting resource. Pasture quality affects the nutritional status and production of the animals. Therefore, continuous information about changes in the grazing resources is important when making management decisions. The objective of this study was to investigate different possibilities of using routine and additional slaughter records as body condition indicators, and thereby indicators of pasture resources in the summer ranges of reindeer husbandry. Records from 696 reindeer slaughtered in the winter 2002/2003 were included in the study. We developed a model with carcass weight as body condition indicator and two different models combining fatness, conformation, carcass weight, and body size as body condition indicators. The results showed age and sex dependent differences between the variables, and differentiation of animal age and sex improved the precision of models. Adjusting weight for body size also improved weight as a body condition indicator in adults. Conformation and fatness had good resemblance to weight and body size adjusted weight and should preferably be included, together with carcass weight and body size measures, when estimating body condition from carcasses. Our analysis showed that using non-invasive slaughter records is a good and non-expensive method of estimating body condition in reindeer.

Key words: body size, carcass weight, conformation, EUROP classifications, fatness, nutritional status, pasture condition, *Rangifer tarandus tarandus*.

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Introduction

Both wild and domesticated reindeer (*Rangifer tarandus*) population densities are known to fluctuate in cyclic patterns (Skogland, 1985; Klein, 1991; Helle & Kojola, 2006). Pasture quality is generally seen as an important factor for variation in herd productivity and thus population density (Klein, 1968; 1982; 1991; Reimers, 1983; Skogland, 1983; Post & Klein, 1999; Kumpula *et al.*, 2002). Moreover, pasture quality is affected by reindeer grazing as well as e.g. climate, weather and soil properties (Georgiadis *et al.*, 1989; Hobbs, 1996; Post & Klein, 1996; Lenart *et al.*, 2002).

In reindeer husbandry it is desirable to maximize herd productivity and economic gain, and reduce the fluctuations in population densities. Knowledge about ongoing changes in pasture quality is therefore essential for optimizing animal density and herd structure and making other appropriate management decisions. To detect changes in pasture quality, continuous monitoring is essential and there is a need to find indicators of pasture quality that are simple and inexpensive to measure.

During the snow-free season the reindeer use wide pasture ranges while eating mainly herbs and grasses. Monitoring changes in vegetation over such areas would be difficult, time-consuming and expensive. The amount and nutritional quality of available food during the snow-free season (summer and autumn) strongly affect the calf growth and the energy invested in body reserves (fat and muscles) of all categories of reindeer (Klein, 1964; 1968; 1991; Reimers, 1983; Reimers *et al.*, 1983; Kumpula *et al.*, 2002). Thus, change in the average body condition (muscle and fat reserves) of the herd could be a useful indicator of change in the grazing resource during this period.

Several ways to estimate body composition and body condition in reindeer and other large ungulates have previously been suggested. Body condition score (BCS), bioelectrical impendence analysis and reproductive status among females are examples of *in vivo* body composition estimation (Gerhart *et al.*, 1996; Cook *et al.*, 2001; Kumpula, 2001). BCS and bioelectrical impendence require expertise and advanced equipment. In addition, data registration could be stressful for the animals. On the other hand, body condition estimation from carcasses after slaughter does not require extra handling of live animals. Previously used indicator measures on carcasses include carcass weight, body size, depth of back fat, abdominal fat, bone marrow fat and kidney fat (Dauphiné, 1971; Adamczewski *et al.*, 1987; Helle *et al.*, 1987; Huot, 1988; Chan-Mcleod *et al.*, 1995; Kofinas *et al.*, 2003). Whereas depth of back fat, abdominal fat and kidney fat are measures that require expertise and special equipment, body size measures can be easily recorded either before or after slaughter and without any advanced equipment. Carcass weight together with classifications of conformation and fatness are routine records at reindeer slaughter in Sweden. Carcass weight as a body condition indicator is however biased by the body size of the animal. One solution to this problem would be to adjust the weight for differences in body size. Conformation and fatness are used to value the carcass for the meat industry. These are subjective measures and have not been validated as body condition indicators; yet they are at least in theory size independent and more direct measures of body reserves (muscle and fat) than carcass weight. The body condition of adult females is influenced by whether they have had a calf or not during the preceding year (Rönnegård *et al.*, 2002) and should thus be considered.

Here routine records from slaughtered reindeer were used and supplemented with body size records and information about sex, age and reproductive status of the animals. The objective of the study was to investigate different possibilities of using routine and additional slaughter records as body condition indicators, with intended use as pasture quality indicators in reindeer husbandry. Specifically this addressed the questions: How can routine slaughter records be used individually or combined to estimate body condition? Can additional records improve the estimation?

Material and methods

Data collection

Records from 696 carcasses of slaughtered reindeer from 14 herding districts were included in this study (Table 1). The animals were distributed among five age and sex categories as follows: 103 female calves, 313 male calves, 44 female yearlings, 77 male yearlings and 159 female adults. The recorded carcasses were a random sample of animals slaughtered on 11 occasions at three slaughterhouses during the winter 2002/2003. Age and sex of the animals were determined by visual examination and, when doubtful, age was determined by examination of teeth according to Nieminen (1994).

Weight and EUROP classifications of the carcasses together with information about herding district and slaughter date were obtained from the slaughterhouses. The EUROP system for classification of carcasses is a standard system of the European Union including two subjective 15-degree scales for carcass conformation and carcass fat, respectively (Swedish Board of Agriculture, 2002). Prior to the statistical analyses, the conformation and fatness classifications were transformed to quasi-normally distributed variables using a threshold model for calculation of the expected value of the underlying variable in each class. The normal score (s) for each class (i) was obtained as

$$s_i = \frac{\phi_{i-1} - \phi_i}{\Phi_i - \Phi_{i-1}}$$

within each animal category, where ϕ is the normal density function evaluated at thresholds i-1 and i, and Φ the cumulative normal distribution function evaluated at the same thresholds.

Table 1. Distribution of recorded carcasses in herding districts and slaughter houses.

	Slaughterhouse		
Herding District	Harads	Hedenäset	Rensjön
Ängeså	-	61	-
Gabna	-	-	31
Gällivare	27	49	-
Jåhkågasska	80	-	-
Sirges	137	-	5
Sörkaitum	60	-	-
Udtja	93	-	-
Northern concession area		99	
Korju	-	27	-
Muonio	-	59	-
Pirttijärvi	-	4	-
Sattajärvi	-	7	-
Tärendö	-	2	–
Southern concession area		63	
Kalix	-	49	-
Liehittäjä	-	14	-
Total	**397**	**272**	**36**

In addition, three body size measures (back, radius and jaw length) were recorded on each carcass and the reproductive status of adult females was judged. Back length was measured from the front of the second spinious process of the thoractic vertebræ to the base of the tail (the dorsal side of sancrum). The length of radius (also including the ulna bone) was measured from olecranon tuber to the lower gliding joint in carpus. The radius and back lengths were measured on hanging carcasses in the refrigerator room on the day of slaughter or the day after. Jaw (*Mandibula*) length was measured from the most oral, medial point at the socket of the first incisor to the most posterior point of processus angularis (*Angulus mandibulae*), as described by Langvatn (1977). The jaw and radius lengths were measured on the animals left side. Jaw length was missing for some of the animals (in total 39) due to lost identification of the head. Back length was missing for one animal. The reproductive status of adult females, i.e. if they had had a calf during the last summer, was judged in three classes (calf, no calf or indefinite) by examining the udder for traces of recent milk production (Gerhart *et al.*, 1997). In total 78 fe-

Table 2. Overview of data distribution in the five animal categories.

	Calves		Yearlings		Adults
	Female	Male	Female	Male	Female
*Conformation classification**					
n	103	313	44	77	159
Median	5	5	5	4	5
Q1-Q3	4-6	4-5	4-6	4-5	4-7
*Fatness classification**					
n	103	313	44	77	159
Median	2	2	3.5	2	4
Q1-Q3	2-3	2-3	2-5	2-2	3-7
Carcass weight (kg)					
n	103	313	44	77	159
Mean	20.46	22.71	28.1	30.65	33.63
SD	2.84	2.85	3.61	3.3	3.96
Back length (dm)					
n	103	312	44	77	159
Mean	5.57	5.75	6.12	6.27	6.54
SD	0.231	0.268	0.29	0.284	0.326
Jaw length (dm)					
n	100	296	40	72	149
Mean	2.11	2.13	2.35	2.41	2.48
SD	0.097	0.086	0.064	0.081	0.095
Radius length (dm)					
n	103	313	44	77	159
Mean	2.79	2.88	3.09	3.18	3.16
SD	0.116	0.107	0.089	0.107	0.105

*Classes are numbered from 1 to 15, where 1 is the lowest classification and 15 the highest.

males were judged as indefinite and 10 females had a missing value for reproductive status.

The records of weight, conformation and fatness obtained (Table 2) closely resembled the overall slaughter statistics of County of Norrbotten for the season 2002/2003 (Swedish Board of Agriculture, 2003) although in these statistics animals are only categorized into calves, and female and male adults.

Data were unbalanced in relation to herding districts and slaughter dates. Districts with few records (all in the concession area) and similar characteristics were grouped into two areas (Table 1) based on geographical locations and results of preliminary analyses of weight records with herding district as independent variable (results not shown). Slaughter dates were grouped into two seasons, early winter season (before 31 December, 2002) and late winter season (after 31 December, 2002) based on preliminary analyses of weights, fatness scores and conformation scores with herding districts and slaughter occasions as independent variables (results not shown).

Descriptive statistics and Pearson correlations for weight, body size indicators and carcass classifications were calculated for all animals as well as each animal category to obtain a general view of the data. The significance levels of differences between categories were calculated by par-wise two-tailed *t*-test.

Statistical analyses

Linear regression models fitted with SAS procedure GLM (SAS Institute Inc, 2006) were used to investigate improvements of precision of weight records when adjusting for body size, reproductive status, sex of calves and age group (yearling or adult) of females. Linear models were also used to adjust the variables for fixed effects that were not in focus of this study i.e. herding district and slaughter season.

To explore possible ways to combine the indicator variables for estimating body condition, the common underlying dimensions of the variables were identified by principal component analyses (PCA) with the Simca-P software (Umetrics, 2003). Structural equation modeling (SEM) with the SAS procedure Calis (SAS Institute Inc, 2006) was then used to combine the indicator variables in a single model for prediction of body condition. By SEM, confirmatory testing of theories about explanatory relationships between the indicator variables and the unobservable (latent) body condition and body size was possible (Raykov & Marcoulides, 2000). Scores for the observed variables in prediction equations for body condition could also be derived (Lawley & Maxwell, 1971). Furthermore SEM, unlike conventional regression models took uncertainty in the independent variables into account, when estimating relationships (Grace, 2003). This uncertainty, i.e. measurement errors, can cause overestimation of error terms of the dependent variables and bias in parameter estimation of the model if unattended.

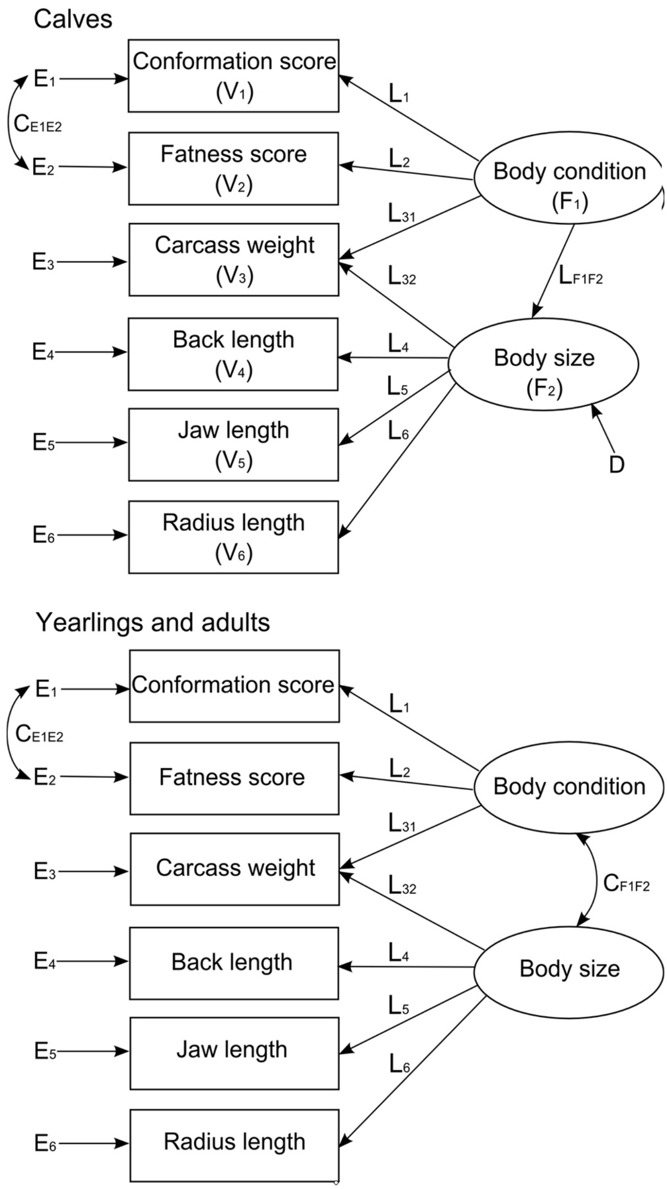

Fig. 1. The initial SEM model structure of the first SEM analyses (SEM-I). The F variables are latent variables and Vs are manifest variables. Ls are the loadings of the paths between the variables respectively, Cs are correlation terms, Es are error terms for the manifest variables and the D is a disturbance term for the latent variable body size.

In the linear regression analyses, models with herding district and slaughter season and specific category information (sex for calves and age for older females) were fitted to carcass weight of calves and to the older females to investigate effects of discrimination between different groups of animals. To estimate the improvement of the model by adjusting weight for body size, separate models were analyzed for each animal category. Body size measures were included one at a time, both as simple and cubic variables in the models. Variables with *P*-value >0.2 were excluded and variables with *P*<0. 05 in Type III tests were considered significant. The improvements in precision were evaluated with respect to reduction of residual standard deviations (SD). The effects of reproductive status of adult females on weight and classification scores were also tested.

PCAs were done individually for each animal category. In the first analysis (PCA-I), carcass weight, body size measures and carcass classification scores were included. In the second (PCA-II), the three body size adjusted carcass weights were added. The stopping rules in the PCA when extracting principal components were the latent root criterion (i.e. components with eigenvalues of the correlation matrix below one were excluded) and the scree plot criterion (McGarigal *et al.*, 2000).

In the SEM analyses an initial model was constructed for calves and older animals, respectively (Fig. 1). The initial models were based on knowledge about reindeer biology and information gained from analysis with linear models and PCA. Latent variables were body condition and body size. The manifest variables fatness score, conformation score and carcass weight were assigned to body condition. Carcass weight, back length, radius length and jaw length were assigned to body size. In the calf models, a causal connection from body condition to body size was assumed. This causal path aimed to capture that calves had gained their body size as well as their body reserves during the preceding snow-free season. In contrast, a causal relationship between body condition and body size did not seem realistic for the older animals since the main part of their body size gain had occurred during earlier years and a covariance relationship was used instead.

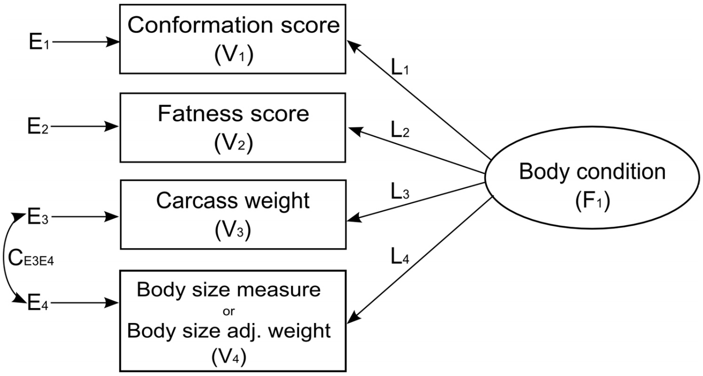

Fig. 2. Structure of the simplified models (SEM-II). Body condition (F_1) is the only latent variable, V_1-V_4 are manifest variables. The Ls are the loadings of the paths between the variables, Cs are correlation between variables, and Es are error terms for the respective manifest variables.

Measurement models corresponding to the initial models were constructed. The measurement models were tested and modified based on Wald test, which indicates the loss of model fit (increased χ^2) when excluding a particular parameter (Raykov & Marcoulides, 2000; SAS Institute Inc, 2006). The corresponding structural models for the calves were also tested and modified.

A simplified model (SEM-II) with only body condition as latent variable was constructed for each animal category. Although we collected three body measures for our analyses, it is likely that only one body measure will be recorded at slaughter for practical reasons. Manifest variables attached to body condition were fatness score, conformation score, carcass weight and either one body size measure or carcass weight adjusted for a body size measure (Fig. 2). The effect of the latent variable body size was captured through a covariance between carcass weight and the used body size measure or body size adjusted carcass weight. The model was tested and modified for each animal category.

Factor score regression coefficients (Lawley

& Maxwell, 1971; SAS Institute Inc, 2006) were retrieved for all models. The regression coefficients could be used to calculate the actual scores of the latent factors for each observation (Lawley & Maxwell, 1971) when estimating body condition.

Maximum likelihood estimation was used in all SEM analyses. Criteria for a good fit of the SEM were a non-significant *P*-value for χ^2, and comparative fit index (CFI) and non-normed fit index (NNFI) both larger than 0.9 (Bentler & Bonett, 1980; Raykov & Marcoulides, 2000; Pugesek *et al.*, 2003; SAS Institute Inc, 2006). Furthermore, the standardized residuals of the covariance matrixes were assured to be symmetrically distributed around zero and that none or only a few residuals were larger than 2.

Results

Carcass weight and the three body measures (back, radius and jaw length) were closely correlated (0.56 – 0.71) for the calves and male yearlings and less (but not significantly lower) correlated for the female yearlings and female adults (0.34 – 0.45). Correlation of weight with conformation and fat classifications was highest for female yearlings (0.62 and 0.63) and female adults (0.54 and 0.56) and slightly lower for female calves (0.45 and 0.44) and male calves (0.41 and 0.31) although the differences were not significant. In the male yearling group the corresponding correlations were non-significant. Body size measures were uncorrelated with conformation and fatness classifications for the female adults and yearlings, whereas for calves, generally small positive correlations were found. However, among male yearlings conformation was negatively correlated with back and radius length. A scatter plot matrix of all animals combined is shown in Appendix A.

Carcass weight as body condition indicator

Discriminating between female and male calves as well as between female yearlings and adults had significant effects. Residual SD of weight was reduced by 36% when discriminating between female and male calves. Discriminating between female yearlings and adults reduced residual SD with 15%.

All body size measures significantly affected weight and explained the variation of the data similarly, except for female yearlings where jaw length was not significant (Table 3). Adjusting weight for body size, by including the body size measures in the model, reduced the residual SD of weight by up to 33%.

Herding district had a significant effect on carcass weight in all animal categories except female yearlings (Type III statistics were for female calves P=0.011, male calves P=0.0017, male yearlings P=0.0028 and female adults P<0.0001). Neither the slaughter period nor

Table 3. Effect in reduced standard deviation (SD) by adjusting weight for body size measurements.

	n	Mean carcass weight (Kg)	SD before adjustment (Kg)	Remaining SD after adjustment		
				Back	Jaw	Radius
Female Calf	103	20.46	2.69	1.9 (71%)***	2.11 (78%)[1]***	1.8 (67%)***
Male Calf	313	22.7	2.77	1.96(71%)[2]***	1.98 (71%)[3]***	2.06 (74%)***
Female Yearling	44	28.09	3.6	3.34 (93%)**	3.55 (99%)[4]	3.35 (93%)*
Male Yearling	77	30.65	2.99	2.34 (78%)***	2.19 (73%)[5]***	2.12 (71%)***
Female Adult	159	33.63	3.6	3.27 (91%)***	3.31 (92%)[6]***	3.31 (92%)***

[1] *n*=100. [2] *n*=312. [3] *n*=296. [4] *n*=40. [5] *n*=72 [6] *n*=149. * is P < 0.05, ** is P < 0.01 and *** is P < 0.001.

Table 4. Comparison of loadings in PCA-I and standardized loadings of SEM-I analyses.

	PCA-I PC 1	**SEM-I** Body Size	**PCA-I** PC 2	**SEM-I** Body Condition
Female calves				
Fatness score	0.34	-	0.56	0.65
Conformation score	0.30	-	0.64	0.81
Weight	0.50	0.74	-0.04	0.36
Back length	0.44	0.75	-0.15	-
Radius length	0.43	0.83	-0.37	-
Jaw length	0.40	0.68	-0.34	-
Body Size				0.50
Male calves				
Fatness score	0.17	-	0.68	0.68
Conformation score	0.25	-	0.61	0.80
Weight	0.52	0.75	0.06	0.34
Back length	0.45	0.78	-0.16	-
Radius length	0.46	0.93	-0.34	-0.22
Jaw length	0.47	0.80	-0.17	-
Body Size				0.41
Female yearlings				
Fatness score	0.52	-	-0.28	0.85
Conformation score	0.49	-	-0.39	0.86
Weight	0.59	0.50	0.10	0.76
Back length	0.28	0.46	0.27	-
Radius length	0.16	0.89	0.62	-
Jaw length	0.19	0.85	0.55	-
Male yearlings				
Fatness score	-0.03	-	0.71	0.37
Conformation score	-0.19	-	0.60	0.99
Weight	0.48	0.93	0.34	0.33
Back length	0.48	0.69	0.10	-
Radius length	0.50	0.84	-0.03	-
Jaw length	0.50	0.80	-0.11	-
Female adults				
Fatness score	0.45	-	-0.45	0.82
Conformation score	0.44	-	-0.46	0.89
Weight	0.56	0.63	0.00	0.64
Back length	0.31	0.62	0.39	-
Radius length	0.32	0.71	0.45	-
Jaw length	0.30	0.68	0.48	-

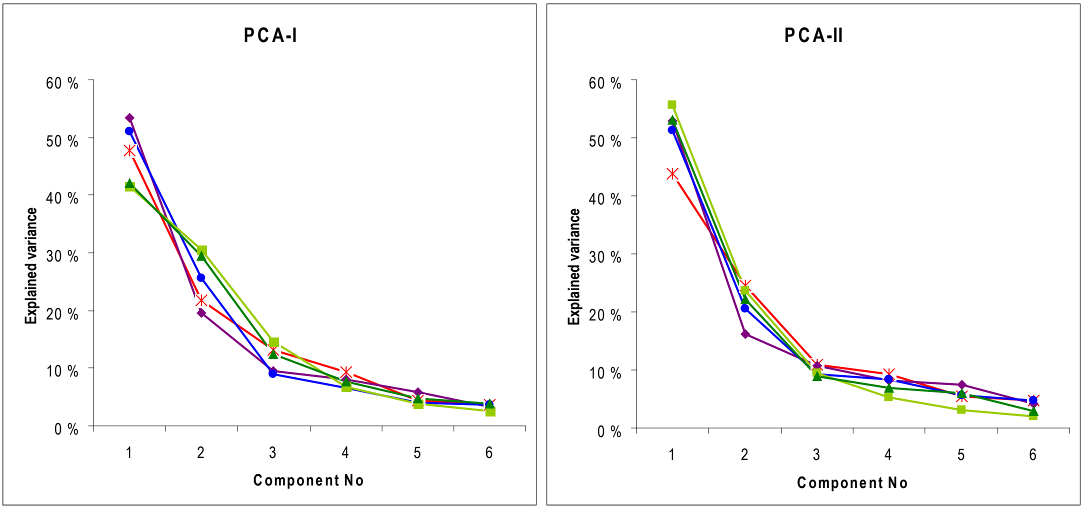

Fig. 3. Screeplot of explained variance in the PCAs. Diamond represent female calves, circle is male calves, square is female yearlings, star is male yearlings and triangle represent female adults.

the reproductive status of the adult females significantly affected weight in this data set.

Underlying dimensions of the variables

The PCAs resulted in two extracted principal components in all analyses, explaining 73% of the total variation in female calves, 77% in male calves, 72% in female yearlings, 69% male yearlings and 71% in female adults (Fig. 3). In PCA-I, similar patterns in both the first and second components were found for all animal categories except male yearlings (Table 4). In the first component, all loadings were strongly positive, suggesting an underlying overall size-related linear component in which all variables are indicators of different features that are size and mass related. However, for female yearlings and adults, the body size measures obtained smaller loadings than the weight and classification scores, implying that body size measures explain less of the variation in these categories. This difference was most apparent for the female yearlings, where the largest body size loading was only 57% of the conformation score loading. In contrast, weight and body size measures differed from the classification scores in the first component of the male yearlings, suggesting a more skeleton size related variable. The loadings of the second component of the male yearlings were high for the classification scores and weight and small for the body size measures, distinguishing body resources from body size. The second component of calves, female yearlings and female adults showed difference between the loadings for body size measures and those of classification scores, which can be interpreted as a component capturing variation in body condition relative to body size.

PCA-II, where body size adjusted weight was added, gave similar loadings as PCA-I of the classification scores in both the first and second component. For calves, the body size adjusted weights obtained similar loadings as fatness score and conformation score in both the first and second component. For female yearlings and adults the difference between body size measure loadings and classification score loadings were larger than in PCA-I.

Table 5. Fit statistics, χ^2, Bentler's Comparative Fit Index (CFI) and Bentler & Bonett's Non-normed Index (NNFI) of SEM-I and SEM-II models presented in tables 4 and 7.

Good-ness of fit index	Calves		Yearlings		Adults
	Female	Male	Female	Male	Female
SEM-I					
χ^2	8.57	9.63	7.27	6.79	7.98
df	7	6	8	7	8
$P > \chi^2$	0.29	0.14	0.51	0.45	0.44
CFI	0.99	0.99	1.00	1.00	1.00
NNFI	0.99	0.99	1.01	1.00	1.00
SEM-II					
χ^2	0.22	0.20	0.84	0.08	0.12
df	1	1	1	1	1
$P > \chi^2$	0.64	0.65	0.36	0.78	0.73
CFI	1.00	1.00	1.00	1.00	1.00
NNFI	1.04	1.01	1.01	1.01	1.01

Indicators of body condition

The initial models of SEM-I (Fig. 1) showed good fit to the data and few modifications were done. For female calves no model adjustments were needed. For male calves an extra path between body condition and radius was added (Table 4). In female yearlings and adults no significant covariance was found between body condition and body size and the covariance was therefore constrained to 0. The χ^2, CFI and NNFI of the resulting models are presented in Table 5. All paths were significantly differed from zero at the 5% level.

Body condition was found to positively affect body size in the SEM-I calf models (Table 4). On the other hand, for male yearlings there was a negative covariance of -0.3 ± 0.1 ($P<0.05$) between body condition and body size. Conformation score had the highest loading on body condition of the manifest variables. The models explained 65% of the variance in conformation score of the calves (Table 6), and 75-99% of the variance was explained in the yearling and adult models. Fatness score had the second highest loading although the size of the loading varied considerably among animal categories (Table 4). In male yearlings only 13% of the variance in fatness score was explained, whereas 72% of the variance was explained in the female yearling model (Table 6). Carcass weight had the lowest standardized loading on body condition in all animal categories except male calves, where radius length had a lower loading (Table 4). Among the manifest variables connected to body size, no general grading pattern was found highest although radius length had the highest degree of explained variance in all models (Table 6). Factor score regression coefficients are presented in Appendix B.

The fit of SEM-II models were good according to the fit indices (Table 5), but few paths had significant loadings (Table 7). Male yearling models with back and radius length fitted poorly with one

Table 6. Degree of explained variance of dependent variables in SEM-I.

	Calves		Yearlings		Adults
	Female	Male	Female	Male	Female
Fat score	43%	46%	72%	13%	67%
Conformation score	65%	65%	75%	99%	79%
Weight	94%	89%	83%	78%	80%
Back length	57%	61%	22%	47%	38%
Radius length	69%	74%	80%	71%	50%
Jaw length	46%	64%	72%	64%	46%
Body size (F2)	25%	17%	-	-	-

or more not positive definite eigenvalues in the covariance-variance matrix of the exogenous variables. The female calf model with radius length also fitted poorly with a high χ^2 and corresponding P=0.03, and large standardized residuals (>2).

The fit differed slightly between the models with different body measures. No body measure had good fit for all animal categories independently of using plain body sizes or body size adjusted weights. The loadings were similar regardless of kind of body measure. Back length gave best fit for male calves and female yearlings, jaw length best results for female calves and male yearlings, and radius length best for adult females. Rank order of standardized loadings within the models was the same regardless of animal category. Conformation score was the manifest variable with largest loading in all models. Body condition score regression coefficients are presented in Appendix C.

Table 7. Standardized loadings and latent covariances of best models for each animal category in the SEM-II analyses.

	Calves		Yearlings		Adults
Loading no.	Female[1]	Male[2]	Female[3]	Male[4]	Female[5]
L_1	0,70$^{\#}$	0,64$^{\#}$	0,86$^{\#}$	0,55^{x}	0,85$^{\#}$
L_2	0,76$^{\#}$	0,86*	0,86$^{\#}$	0,66^{x}	0,85$^{\#}$
L_3	0,74$^{\#}$	0,63$^{\#}$	0,73^{x}	0,09	0,62$^{\#}$
L_4	0,29	0,31^{x}	0,09	0,42	0,71$^{\#}$
$Corr_{E3E4}$	0,62224	0,45146	0,45146	0,75624	0,86923

V_4 used in the model is [1]jaw length, [2]back length, [3]back length [4]jaw adj. weight and [5]radius adj. weight. *is $P < 0.05$, # is $P < 0.1$, x is $P < 0.2$.

Discussion

The purpose of this study was to explore the opportunities of using routine and additional slaughter records as indicators of body condition reindeer. Such indicators may serve as a tool for monitoring changes of reindeer body condition as a consequence of changes in pasture condition. In the long run, estimates of body condition have potential of being an essential part of adaptive management of the resource base system.

In the study we showed how to combine weight, conformation and fatness classification of carcasses to estimate body condition among slaughtered reindeer. We also showed that precision of carcass weight alone as body condition indicator can be improved by differentiation of animals into specific age and sex classes and by adjusting weight for body size among yearlings. We found sex and age dependent differences, important to consider when estimating body condition.

The differences between the observed animal categories can be explained as consequences of age and sex related biological and social factors. Female yearling and adults differed in size and female yearlings were a more homogenous group than female adults. The larger variation among adults might be due to that all animals in this group are not fully grown (Skogland, 1983; Gerhart *et al.*, 1997), or that they have experienced different pasture conditions during their different first years. Another reason for inconsistency among the adults may be differences between females with and without calf the last season. Although females with and without calf did not differ in this study, females clearly spend a large amount of body resources on the calf (Gerhart *et al.*, 1997; Rönnegård *et al.*, 2002). On the other hand, the difference between lactating and barren females might be undetectable this late in season. If present, it is possible that the effect could have been detected by more definite information on whether females have had calf or not.

Male yearlings differed markedly from the other categories and also varied considerably within the group. One reason for the variation was probably a consequence of differences in activity during the preceding rut period, when males generally lose body resources. Males are hence no reliable indicators of the status of the snow-free pasture if slaughtered after the rut.

Among calves, female calves were more similar to the older females than the male calves were. However, the differences between female and male calves mainly concerned body size. The calves are all in an intensive growth phase during their first snow-free season, and body size growth as well as gain of body resources is both strongly affected by the nutritional status of the animals during this period. However, their condition is also clearly affected by the condition of their mothers (Langvatn, 1977; Skogland, 1983; Rönnegård *et al.*, 2002).

We here showed that keeping separate records of female and male calves and of yearlings and adults improves carcass weight as a body condition indicator. A way to further improve body condition estimates, besides separating animal categories, is to adjust weight for body size to avoid confounding effects of body size with body condition in yearlings and adults. To adjust calf carcass weight records for size seems not advisable, considering that the body size of calves also is gained during the snow-free season and therefore closely correlated with body condition (Langvatn, 1977; Skogland, 1983; Huot, 1988). Here we used three different body size measures to improve the estimations of body condition. Our results showed no clear advantage for any of the three body size measures. Choice of body size measure can therefore be based on other, e.g. practical, reasons.

Although it is possible to use only carcass weight as body condition indicator, the results of this study imply that conformation and fatness are useful complements. The high percentage of the explained variance of these variables in the SEM analyses, and the similarity in loadings of the size-adjusted carcass weights and the carcass classification scores for calves in the PCA supports this. Conformation and fatness give indications of energy not invested into body size increase but in body resources. Conformation appeared to be a better indicator of body condition than fatness as indicated by the higher loadings of conformation in the SEM analyses. The difference is however small. Both scores are recorded as a routine in Sweden and they can easily be used in combination.

Out of the two SEM models, SEM-I was found to be a better model for this data set, judged from the significant path loadings and good fit indices. Although the fit indices were good, many path loadings were non-significant in SEM-II. On the other hand, SEM-II may be more convenient for future use whereas fewer complement records are needed and the model structure is the same for all animal categories. The regression coefficients presented in Appendix B and C can be used to calculate factor scores of body condition and body size (Lawley & Maxwell, 1971). However, it is important to remember that these factor scores are based on a small data set restricted to one year and that some of the slaughter occasions where quite late in season (January and February). Future improvements of factor scores can be made using data from an earlier part of the slaughter season. For estimating change of latent variables in long-term data one can also use either latent growth models or multigroup analyses based on the model presented here (Lawrence & Hancock, 1998; Raykov & Marcoulides, 2000; Pugesek *et al.*, 2003; Arhonditsis *et al.*, 2006).

The use of slaughter records for detecting changes in body condition and pasture quality involves potential biases that have to be considered. There is a time-lag effect in the condition of the animals, i.e. the nutritional conditions of previous years as well as during the preceding winter may affect the body condition at the time of slaughter (Reimers, 1983; Skogland, 1983; Helle & Kojola, 1994; Lundqvist, 2007). Depending on the time of slaughter, grazing conditions during autumn and early winter may influence the observed body condition. Other variables than pasture condition, mainly weather conditions and insect harassment stress, might affect the nutritional status of the animals in the autumn (Reimers, 1983; Helle & Kojola, 1994; Lundqvist, 2007). Age and sex dependent differences have to be considered since the sensitivity of individuals to changes in pasture quality may differ between categories (Adamczewski *et al.*, 1987; Weladji & Holand, 2003). The selection of animals to be slaughtered affects slaughter records both directly and indirectly by affecting the live reindeer population (Lenvik, 1988; Rönnegård & Danell, 2003). Slaughter strategies may change over years and selection effects can easily cause bias in data in a long-term perspective although, as proposed here, preventive measures such as registration of age and sex data and a body size indicator can minimize bias. Selection will clearly be less in animal categories where a large part of the animals are slaughtered, as for male calves in Sweden. The calf proportion of total reindeer slaughter has increased during the last 15 years and is at present 63% (Sami Parliament in Sweden, 2007).

The natural resource in reindeer herding is the pasture, and it is important to adapt management actions to changes in the pasture. The management actions have to be adapted to specific changes in each herding district. Slaughter records are a time and cost effective way of data collection and have potential to serve as a reliable indicator of changes in reindeer body condition and thereby changes in pasture quality. This study provided methods to estimate body condition, useful in future management planning.

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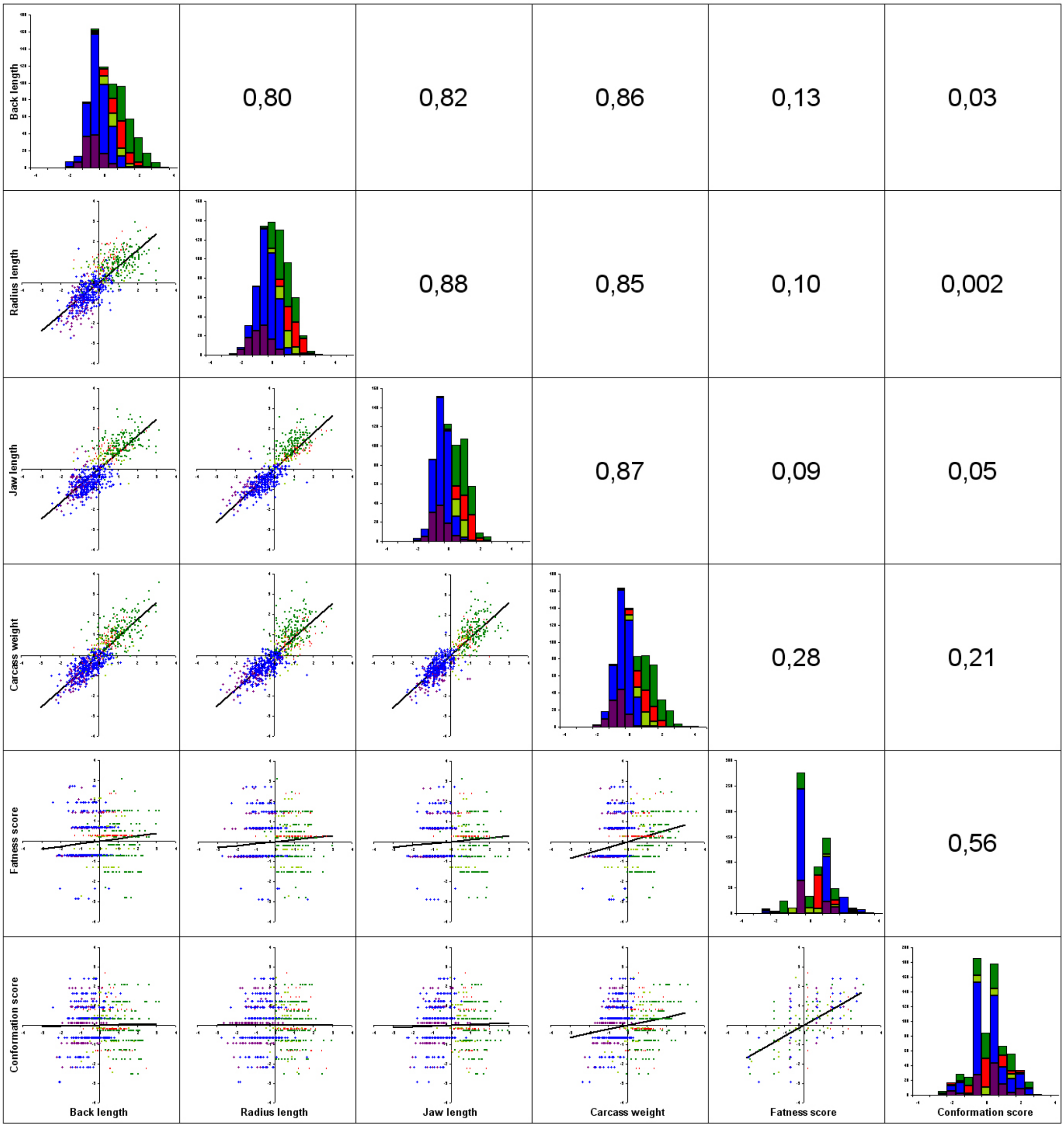
Tillvägagångssätt för skattning av kroppskondition hos ren från slaktregistreringar

Abstract in Swedish / Sammandrag: Fluktuationer i ren- och caribou-populationers täthet över tiden är vanliga då betet är en begränsad resurs och beteskvalitén påverkar djurens kondition och produktion. Kontinuerligt uppdaterad information om förändringar i betesresurserna är viktigt i samband med beslutsfattande om förvaltning av resurserna. Syftet med denna studie var att utvärdera olika möjliga sätt att använda rutinregistreringar och extra registreringar vid slakt som konditionsindikatorer och därmed indikatorer för betestillstånd i sommarland inom rennäringen. Registreringar från 696 renar, slaktade under säsongen 2003/2003 användes i studien. Vi utvecklade en modell där slaktvikt var den enda indikatorn på kroppskondition, samt två modeller som kombinerade fett- och formklassificeringen med slaktvikt och kroppsstorlek som indikatorer på kroppskondition. Resultaten visade att renarnas ålder och kön ger skillnader i de olika variablerna och att modellernas noggrannhet ökar om djuren grupperas med tanke på ålder och kön. Att korrigera slaktvikten för kroppsstorlek ökade precisionen för vikt som konditionsindikator för vuxna djur. Fett- och formklassificeringen överensstämde väl med storlekskorrigerad slaktvikt och skulle med fördel kunna inkluderas tillsammans med slaktvikt och storlek för skattning av kroppskondition från slaktkroppar. Våra analyser visar att användning av slaktregistreringar är en bra och billig metod för att skatta kroppskonditionen hos renhjorden.

Appendices

Appendix A. Scatterplot matrix of normalized variables. Purple represents female calves, blue is male calves, light green is female yearlings, red is male yearlings and dark green represents female adults.



Appendix B. Factor score regression coefficients of the SEM-I models.

	Fatness score	Conformation score	Weight	Back length	Radius length	Jaw length
Female calves						
Body Condition	0.186141	0.360053	0.145031	-0.275281	-0.889477	-0.437936
Body Size	-0.006212	-0.012017	0.023148	0.052998	0.171245	0.084313
Male calves						
Body Condition	0.223974	0.363393	0.128469	-0.080920	-1.627330	-0.288132
Body Size	-0.002111	-0.003425	0.015872	0.056138	0.274513	0.199890
Female yearlings						
Body Condition	0.355781	0.366231	0.106641	-0.063555	-1.233985	-1.492567
Body Size	-0.087595	-0.090167	0.058629	0.279743	5.431493	6.569661
Male yearlings						
Body Condition	0.008582	1.370071	0.002702	-0.008136	-0.045055	-0.051422
Body Size	-0.001443	-0.230342	0.144559	0.480014	2.658109	3.033723
Female adults						
Body Condition	0.349888	0.613841	0.070134	-0.147381	-0.656204	-0.640123
Body Size	-0.128789	-0.225947	0.135673	0.658412	2.931531	2.859690

Appendix C. Body condition factor score regression coefficients for the SEM-II models.									
	V1	**V2**	**V3**	**V4**					
	Confor-mation score	Fatness score	Weight	Back lenght	Jaw length	Radius length	Back adj weight	Jaw adj weight	Radius adj weight
Female calves									
	0,505331	0,359019	0,151984	-0,267036					
	0,445484	0,354286	0,181401		-1,442487				
	0,584891	0,276160	0,180365			-1,782577			
	0,505338	0,359014	0,120412				0,031570		
	0,441068	0,353459	0,094366					0,091684	
	0,605679	0,253008	0,076048						0,107138
Male calves									
	0,690935	0,263980	0,101391	-0,374395					
	0,627407	0,313614	0,111319		-1,195069				
	0,557839	0,296618	0,154619			-2,255253			
	0,690929	0,263983	0,052904				0,048488		
	0,624229	0,317579	0,062763					0,047231	
	0,557010	0,300845	0,035496						0,117346
Female yearlings									
	0,423599	0,415015	0,064208	-0,254540					
	0,463332	0,331799	0,082655		-2,770549				
	0,418074	0,325610	0,088693			-1,840004			
	0,448101	0,377441	0,016117				0,053782		
	0,483970	0,332211	-0,036803					0,112650	
	0,418075	0,325609	-0,047122						0,135815
Male yearlings									
	0,759501	0,540703	0,079254		-3,789792				
	0,626897	0,628047	-0,080865					0,188143	
Female adults									
	0,683214	0,353430	0,050161	-0,236774					
	0,575883	0,420001	0,057389		-1,077166				
	0,516618	0,468751	0,062411			-1,172699			
	0,683215	0,353429	0,001045				0,049116		
	0,533622	0,457426	-0,014916					0,073218	
	0,516626	0,468744	-0,019507						0,081917