Carcass records of autumn-slaughtered reindeer as indicator of long-term changes in animal condition

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Abstract: This study investigates the possibility of using carcass records from the commercial slaughter of reindeer as indicator of long-term changes in animal condition and, thus, the condition and use of their snow-free pasture. The aim was to assess the suitability of this indicator for use within adaptive management programmes for reindeer husbandry grazing resources. Data comprising measurements of carcass weight, conformation and fatness taken from commercial reindeer slaughter between 1994 and 2007, were analysed in relation to year, slaughter date, herding district, population density, and three categories of animals selected for slaughter. The carcass measures were significantly affected by year, and the effects were strongly correlated among the three animal categories. There were generally positive trends over the 14-year period studied. We identified several factors that should be considered when using carcass data to indicate long-term changes in animal body condition: (i) slaughter date had different effects depending on animal category; (ii) reindeer population density negatively affected female and calf carcasses, but not male carcasses. The effects of herding district were similar for carcasses of calves and females, but differed between females and males. Some of the differences between animal categories may be due to differing timing of slaughter (point i above), by different slaughter selection among districts, or have ecological explanations, e.g. sex differences in range use. Uncertainties in the classification of animals when using skeletal development to discriminate between calf and yearling carcasses, may also add to differences among districts. That population density effects on body condition were detectable together with the similarities in the effects of year and general long-term trends between animal categories support the suggestion that carcass measures can be used to indicate general changes in reindeer body condition and range use.

Key words: adaptive management; animal condition; carcass characteristics; pasture quality; *Rangifer tarandus tarandus*.

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Introduction

In the highly seasonal environment of northernmost Europe, reindeer husbandry is an important industry, for both economical and cultural reasons. In Sweden, the entire northern half of the country is used as grazing land for semi-domesticated reindeer (*Rangifer tarandus tarandus*). The production system is pastoral and practised by the indigenous Sami people, as a form of land use and a means of livelihood. The reindeer depend on natural forage in tundra and boreal forest (taiga) habitats on communal lands. The animals are collectively herded in a total of 51 herding districts. Thirty-three of these districts use the forested eastern parts during winter and the western mountain area during the snow-free season (April to October/November). The other 18 districts reside in the forested areas all year, but use different parts of the landscape at different seasons. Within its land, reindeer husbandry competes with other forms of land use, such as forestry, wind and hydroelectric power, tourism, mining, and nature preservation interests (e.g. Widmark, 2006; Lundqvist, 2007).

The number of reindeer in Sweden and the production of reindeer meat exhibit large fluctuations over time, with reindeer numbers varying between 150 000 and 300 000 during the last century (Statistics Sweden, 1999; Sami Parliament in Sweden, 2010). Fluctuating population numbers are also common in wild *Rangifer* populations, with changes in food availability generally being seen as the main driver (Skogland, 1983; Post & Klein, 1999; Kumpula *et al.,* 2002). The body condition, and thus the survival and reproduction of the animals, depends on pasture quality in a wide sense, including its accessibility, abundance, and the nutritive quality of vegetation at different times of the year (Fancy, 1986; Langvatn *et al.*, 1996; Tveraa *et al.*, 2007; Lundqvist *et al.*, 2009; Roturier & Roué, 2009).

Due to the presence of stochastic variations and uncertainties regarding system dynamics, it is difficult for herders to adapt population density and management actions to the resources available at any time. The implementation of desirable management actions can therefore be delayed, so causing fluctuations to grow in magnitude, which then become more difficult to counteract. The effects of disturbances from other human actions add to the uncertainty about management outcomes.

Adaptive management provides a framework to support decision-making that acknowledges uncertainty in the dynamic resource system (Walters, 1986; Walters & Holling, 1990). In adaptive management, regular monitoring of multiple indicators, together with models and a theoretical understanding of the resource system, are combined with observations and experiences of the resource users, in order to detect and evaluate ongoing changes in the system and predict future outcomes of adaptation measures and other management actions.

Several indicators for monitoring body condition and herd productivity have been proposed for ungulate systems (Huot, 1988; Langvatn *et al.*, 1996; Morellet *et al.,* 2007). In a previous paper (Olofsson *et al.,* 2008) we proposed the use of carcass records from commercial reindeer slaughter as indicator of changes in the general body condition in the reindeer herd, and, by inference, the condition and use of snow-free season pasture. Since the snow-free period (late spring, summer and early autumn) is regarded as being fundamental for growth and the rebuilding of body reserves (Klein, 1968; Skogland, 1983), carcass characteristics from the main reindeer slaughter, which takes place in autumn and early winter, are likely to indicate pasture quality during the preceding snow-free period.

There are several factors, apart from the stochastic effects of e.g. weather and disturbances, that can affect the average body condition of slaughtered reindeer, and which therefore need to be taken into consideration when using slaughter data to indicate changes in general body condition in the reindeer herd. Annual variation in the selection of animals for slaughter may introduce bias, since it affects the relative numbers of animals of different ages and reproductive states, and thus the average body size and composition of the slaughtered animals. Dividing the slaughter data into narrower classes of sex and age (as suggested by Olofsson *et al.*, 2008), would make it possible to account for any confounding effects of variations in sex or age ratios of the slaughtered animals. However, the information necessary to accomplish this is not available in the current slaughter records.

The date of slaughter within the season is also important, since reindeer may gain or lose body reserves with time. Fluctuations in population density can cause short-term variations, as well as long-term changes in body condition, because of competition for high-quality forage. Although the availability of forage is generally high during the summer, effects of animal density can be observed even at this time of year (Holand *et al.*, 2010).

The aim of the present study was to further elucidate the prospect of using data from commercial slaughter as indicator of long-term changes in the body condition of reindeer in the autumn, primarily reflecting changes in pasture quality and the appropriateness of the used stocking rate. Important questions to answer in this context were whether carcass measures might serve as consistent indicator variables of general changes of animal condition in a reindeer herd, that is, if they are consistent between different measures and between animal categories. We also wanted to find out if effects of variations in population densities are detectable and how the time of slaughter might affect the results, and hence whether this factor should be taken into account when analysing the data in an adaptive management application.

For this purpose we analysed data compiled from the commercial slaughter of reindeer in Sweden from 1994 to 2007. We used generalized equation estimation (GEE) models to assess how carcass weight and classifications for different animal categories were affected by year, time within year, herding district, population density and the selection of animals for slaughter; and correlation analyses to understand how these variables were related to each other.

Material and methods

Data

Two sets of data (slaughter records and reindeer numbers), both retrieved from the Sami Parliament of Sweden, were used in the study. The slaughter records were used to assess body condition of slaughtered reindeer and to calculate the proportion of calf slaughter. Reindeer numbers were used to calculate relative reindeer densities and proportion of females in the reindeer herd (a second measure of the selection of animal categories for slaughter).

For information on the body condition of slaughtered reindeer, we used carcass records from autumn slaughters in the years 1994-2007, including altogether 430 380 animals. The records hold information on the date of slaughter, reindeer ownership, herding district, carcass weight, conformation and fatness classifications, and animal category, for each slaughtered reindeer. The classifications of conformation and fatness, respectively, into 15 classes were done according to the EUROP system (Swedish Board of Agriculture, 2002), although for reindeer, the 5 highest classes of both are only rarely used. The carcasses were classified into four animal categories: calves, adult females, adult bulls, and steers; in our analyses the last two categories were both defined as ‘males’. The discrimination between calves and adults was based on maturation stage of the skeleton; in calves, the joint surface of the forelimb bones should have a bluish colour, (Swedish Board of Agriculture, 2002). According to herders, this criterion sometimes results in immature yearlings being classified as calves.

The carcass records included some registrations of weight that were obviously incorrect, so only calves with weights ranging from 8 kg to 40 kg, females from 12 kg to 80 kg, and males from 12 kg to 100 kg were included in the analyses. We chose to use these fairly wide ranges, since quite a small portion of the observations were affected and tighter limits were difficult to determine.

In order to be able to treat conformation and fatness classifications as continuous variables in the statistical analyses, they were transformed into quasi-normal distributions. Using

Table 1. Number of reindeer carcasses, means and standard deviations (SD) of carcass weights, and normal scores for conformation and fatness classifications of calves, females and males during the selected slaughter periods, divided on months. The figures are based on data from commercial reindeer slaughter in Sweden from 1994 to 2007, representing all the 51 herding districts in Sweden.

	Carcass weight (kg)		Conformation		Fatness	
	N	Mean ±SD	N	Mean ±SD	N	Mean ±SD
Calves						
October	59837	20.5 ± 3.4	59439	0.24[1] ± 0.95	59837	0.01[1] ± 1.08
November	124522	20.5 ± 3.4	124522	-0.09[1] ± 0.88	124522	-0.10[1] ± 0.90
December	91099	20.9 ± 3.8	91022	-0.12[1] ± 0.87	91099	-0.05[1] ± 0.89
Females						
October	21946	31.4 ± 4.7	21830	-0.19[1] ± 0.95	21946	-0.24[1] ± 1.03
November	45507	31.5 ± 4.6	45506	-0.23[1] ± 0.88	45507	-0.25[1] ± 0.90
December	36205	32.2 ± 4.8	36183	0.00[1] ± 0.87	36205	0.01[1] ± 0.95
Males						
September	51264	48.4 ± 13.0	51141	0.64[2] ± 0.83	51264	0.62[2] ± 0.90

[1] For calves and females the mean scores for conformation corresponds to a grading close to O in the EUROP classification. Mean scores for fatness corresponds to 1+ for calves, and between 1+ and 2- for females.

[2] For males, the mean score for conformation corresponds to a grading close to R-, and the mean for fatness to a grading close to 2+ in the EUROP classification.

the full slaughter dataset, the expected values of each class on a conceptual underlying normally distributed variable (normal score) were calculated using a threshold model applied to calves, females, males and steers, respectively. The normal score (s_i) for each class (i) was calculated as $s_i = \frac{\phi_{i-1} - \phi_i}{\Phi_i - \Phi_{i-1}}$, where ϕ is the normal density function, and Φ is the cumulative normal distribution function, evaluated with i equal to the upper threshold value of the class.

Since the focus of the present study was on animal body condition during the main slaughter season, and since we wanted to exclude data that were confounded with winter conditions, we used carcass records of males from September (the bull slaughter) and calf and female records from October to December (the main reindeer slaughter). The number of carcasses and the mean values of carcass measures (weight, conformation and fatness) during these months are shown in Table 1.

In order to consider variation resulting from the date of slaughter in the statistical analyses, we divided each calendar month into four 7- or 8-day periods (slaughter time). Later, the first and second halves of October, and the second half of December, were each merged into 15- or 16-day periods because of a low number of observations.

The data on reindeer numbers include the number of calves, females and males belonging to each reindeer owner after the main slaughter, i.e. the winter stock. A relative reindeer population density index (hereafter termed 'reindeer density') was calculated for each herding district and year, by dividing the registered number of animals each year by the maximum number of animals in the herding district during the whole period 1994-2007. The minimum reindeer density in a single herding district varied from 45 to 85 per cent of the maximum for the same district.

Two variables were used to account for possible effects of variations in selection of animal categories for slaughter (including effects of misclassifying yearlings as calves). These were the proportion of calves in the slaughter (calf slaughter ratio), and the proportion of females in the winter herd (female ratio), both of which were calculated for each herding district and year. For calculation of calf slaughter radio we used the slaughter data from October to December. This ratio varied from 0.01 (nearly no slaughter of calves) to 0.96 (almost only calves in the slaughter) for single herding districts and years, and showed a general increasing trend during the studied period. When calculating the female ratio in the herd, we excluded data from individual reindeer owners for whom there was incomplete information for that particular year. The female ratio varied from 0.47 to 0.87 for single herding districts and years.

Statistical analyses

To elucidate the relationships among the three carcass measures, Pearson correlations of carcass weight, conformation and fatness within animal for the three animal categories were estimated with Proc Corr in the SAS software (SAS Institute Inc, 2006). In order to indicate how the variables were related to each other at herding district and year level, we also calculated Pearson correlations between reindeer density, female ratio, calf slaughter ratio and the within herding district and year means of the carcass measures of each animal category.

GEE models with a normal distribution and an identity link function were fitted to the data for each animal category and carcass measure, with the carcass measures as dependent variables, and herding district, year, slaughter time, calf slaughter ratio, female ratio, and reindeer density as independent variables. Year and slaughter time were treated as class variables. For each animal category, 1-year lagged means of the carcass measures were also included in the models as independent variables. In addition, the lagged means of measures relating to slaughtered females were included in the calf models. Due to the inclusion of lagged means, the observations from the first year could not be used in these analyses. Longer time lags than one year were not used, based on the results of preliminary autocorrelation and cross-correlation analyses, and the need of model parsimony.

Autoregressive structures, AR(1), of the error term co-variances were used to account for possible non-normally distributed error terms of the regression models. Two-way interactions between the dependent variables were initially included but the models did not converge, and thus these were removed. The GEE models were analysed with Proc Genmod in the SAS software (SAS Institute Inc, 2006). By backward selection, excluding variables with a P-value > 0.2, the best model for each animal category and carcass measure was selected using the Quasi-likelihood Information Criterion (QIC) (Pan, 2001; SAS Institute Inc, 2006). Afterwards, Pearson correlations were calculated (as described above) for the estimates of year and herding district of the three animal categories, to measure the congruence of effects over animal categories.

To illustrate temporal trends in the data, we assessed the three carcass measures for each animal category by using the same GEE models as above, but with year as a continuous independent variable. Trends within seasons were estimated in an equivalent manner, with slaughter time as the continuous independent variable.

Results

The three carcass measures were all correlated within animals (with the correlation coefficients r ranging from 0.31 to 0.64; $P < 0.001$). The mean values of the three carcass measures for calves within year and herding district were all positively correlated with the means for females (r = 0.21 - 0.52; $P < 0.001$), with the exception that the fatness of calves was not significantly correlated with the conformation of females. Positive correlations were also found between fatness and conformation for males and the corresponding measures for calves (r

Table 2. Estimated effects (ranges for class variables), standard errors (SE) and significances of the independent effects on carcass weight (CW), conformations (Conf) and fatness (Fat) for calves, female and male reindeer.

	Carcass weight			Conformation score			Fatness score		
	Estimate	±SE	Sign.	Estimate	±SE	Sign.	Estimate	±SE	Sign.
Calves									
Intercept	20.4			0.58			-1.28		
Herding district	-2.83 – 1.78		****	-0.48 – 0.91		****	-0.14 – 1.70		****
Year[1]	-2.41 – 0.56		****	-0.21 – 0.25		****	-0.16 – 0.56		****
Slaughter time[2]	-0.15 – 0.48		***	0.00 – 0.59		****	-0.09 – 0.34		*
Reindeer density	-1.62	±0.39	****	-0.33	±0.15	*	-0.39	±0.20	*
Female ratio	-3.45	±1.23	**	-1.13	±0.38	**	1.09	±0.55	*
Calf slaughter ratio				0.37	±0.16	*			
1-year lagged means:									
Calf CW	0.11	±0.04	**						
Calf Conf				0.15	±0.06	**	-0.14	±0.07	
Calf Fat	-0.35	±0.10	***	-0.13	±0.05	**			
Female CW	0.07	±0.04	*						
Female Conf				0.18	±0.06	**			
Female Fat							0.16	±0.06	**
Females									
Intercept	28.1			0.69			1.44		
Herding district	-2.62 – 2.01		****	-0.74 – 0.44		****	- .67 – 0.83		****
Year[1]	-2.11 – 0.01		****	-0.33 – 0.03		****	-0.43 – 0.34		****
Slaughter time[2]	-1.33 – 0.00		****	-0.28 – 0.00		****	-0.48 – 0.00		****
Reindeer density	-1.19	±0.55	*				-0.31	±0.17	
Female ratio	2.73	±1.17	*				0.88	±0.38	*
Calf slaughter ratio	-1.20	±0.45	**	-0.46	±0.13	***	-0.65	±0.14	****
1-year lagged means:									
Female CW	0.20	±0.04	****				-0.04	±0.02	*
Female Conf				0.17	±0.05	**			
Female Fat				-0.08	±0.04		0.17	±0.06	**
Males									
Intercept	29.7			0.57			-0.86		
Herding district	0.0 – 29.7		****	-0.61 – 0.47		****	0.00 – 2.40		****
Year[1]	-12.1 – 0.00		****	-0.34 – 0.19		****	-0.35 – 0.32		****
Slaughter time[2]				0.00 – 0.36		****	0.00 – 0.28		****
Reindeer density									
Female ratio				-0.65	±0.38				
Calf slaughter ratio	-4.23	±1.72	*	-0.22	±0.16		-0.30	±0.20	
Bull/Steer	9.34	±0.84	****						
1-year lagged means:									
Male CW	0.12	±0.06	*	0.01	±0.01		-0.01	±0.01	
Male Conf	2.27	±0.76	**	0.32	±0.07	****			
Male Fat	-0.85	±0.61		-0.31	±0.08	***	0.16	±0.06	*

Significances of the Type III test, **** $P<0.0001$, *** $P<0.001$, ** $P<0.01$ and, * $P<0.05$

[1]For individual estimates see Fig. 1.

[2]For individual estimates see Fig. 2.

= 0.09 and 0.26, respectively; P < 0.05), and between the carcass weight of males and the fatness of calves (r = 0.23; P < 0.0001). Female conformation and fatness was positively correlated with the same measures for males (r = 0.09 and r = 0.14, respectively; P < 0.05). We found, however, negative correlations between female conformation and male carcass weight and fatness (r = -0.21 and -0.16, respectively; P < 0.001).

Effects of herding district

As expected, herding district significantly (P < 0.001) affected the carcass measures for all animal categories (Table 2). The effects of herding district were positively correlated between the three carcass measures within animal category (Table 3). These effects were generally positively correlated between calves and females. Some positive correlations were found between calves and males, whilst no significant correlations in the effects of herding district were found between females and males. It should be noted, however, that only about half of the herding districts had a bull slaughter every year. The rest of the herding districts had a bull slaughter only occasionally, or slaughtered only very few (1-10) bulls per year.

Table 3. Pearson correlations of the estimated effects (from the GEE models) of reindeer herding district and year, respectively, on carcass weight (CW), conformation (Conf) and fatness (Fat) for calves, females and males.

	Calf			**Female**			**Male**		
	CW	Conf	Fat	CW	Conf	Fat	CW	Conf	Fat
Effect of herding district									
Calf CW	1.000								
Calf Conf	0.564 ****	1.000							
Calf Fat	0.487 ***	0.726 ****	1.000						
Female CW	0.491 ***	0.404 **	0.196	1.000					
Female Conf	0.419 **	0.355 *	0.004	0.812 ****	1.000				
Female Fat	0.496 ***	0.398 **	0.349 *	0.844 ****	0.826 ****	1.000			
Male CW	0.123	0.506 ***	0.634 ****	-0.062	-0.181	-0.060	1.000		
Male Conf	0.021	0.332 *	0.245	0.171	0.242	0.254	0.468 **	1.000	
Male Fat	-0.171	0.224	0.409 **	-0.138	-0.281	-0.168	0.833 ****	0.489 ***	1.000
Effect of year									
Calf CW	1.000								
Calf Conf	0.353	1.000							
Calf Fat	0.740 **	0.372	1.000						
Female CW	0.708 **	0.546	0.480	1.000					
Female Conf	0.035	0.594 *	-0.026	0.653 *	1.000				
Female Fat	0.697 **	0.360	0.884 ****	0.675 *	0.288	1.000			
Male CW	0.897 ****	0.112	0.517	0.581 *	0.019	0.566 *	1.000		
Male Conf	0.558 *	0.579 *	0.251	0.706 **	0.557 *	0.424	0.476	1.000	
Male Fat	0.736 **	0.429	0.725 **	0.539	0.191	0.732 **	0.699 **	0.361	1.000

Significances of the Type III test, **** P<0.0001, *** P<0.001, ** P<0.01 and, * P<0.05

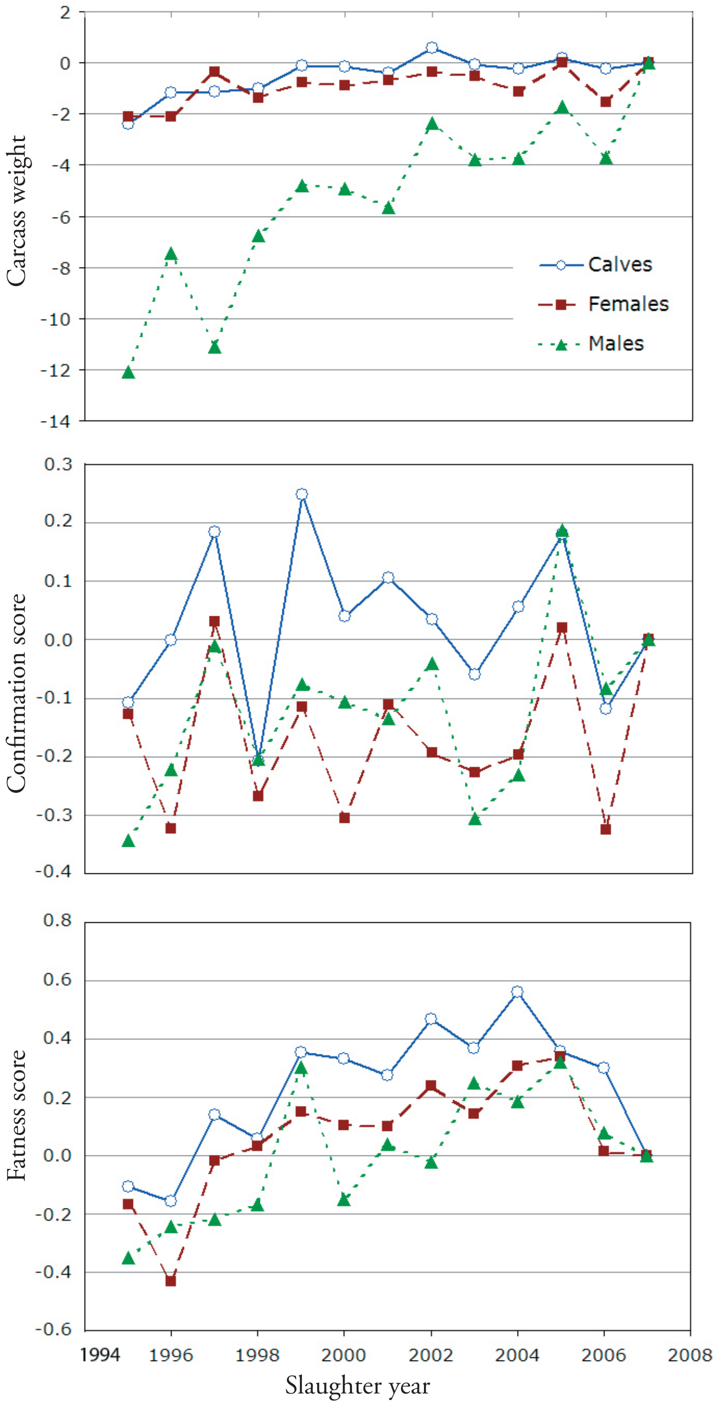

Fig. 1. Estimated effects of slaughter year on carcass weight, conformation and fatness from the GEE models. The estimates were obtained with the last year, 2007, as the reference year (estimate set to 0). Intercepts for the different carcass measures and animal categories are found in Table 2.

Effects of year

When treated as a class variable, year of slaughter had a significant effect ($P < 0.001$) on carcass measures in all animal categories (Table 2). In contrast to the effects of herding district, the effects of year were all positively correlated within each carcass measure and across animal categories (Table 3). The effects of year were less correlated between the three carcass measures with no significant correlations between the year effects on conformation and the corresponding effects on fatness. Thus, even though the carcass measures were generally correlated with each other within animal, the effects of year were similar across all animal categories, but not across all carcass measures.

Some general long-term trends were observed over the whole 14-year period studied (Fig. 1). There were significant positive trends over time for the carcass weights of all animal categories, with mean weights increasing by 0.111 ± 0.015, 0.114 ± 0.019 and 0.755 ± 0.076 kg year^{-1}, for calves, females and males respectively; $P < 0.001$. There was also a positive trend in the conformation of males (0.021 ± 0.007 year^{-1}; $P = 0.0016$), but not of calves or females, during the same period. For fatness, we found positive trends in all animal categories (0.019 ± 0.007, 0.025 ± 0.006 and 0.040 ± 0.007 year^{-1}, for calves, females and males respectively; $P < 0.005$).

Effects of date of slaughter

Date of slaughter (slaughter time) significantly affected all carcass measures except the carcass weight of males (Table 2), although in different ways. The carcass weights and conformation of calves showed declining trends from the second half of October until late December (-0.053 ± 0. 014 kg week^{-1} and -0.038 ± 0.005 week^{-1}, respectively; P < 0.001, Fig. 2), whilst for females, all carcass measures increased during the same period (0.125 ± 0. 025 kg week^{-1}, 0.024 ± 0.005 week^{-1} and 0.042 ± 0.006 week^{-1}, for weight, conformation and fatness respectively; P < 0.0001). For males, no significant trends were found within the slaughter period (September). There was, however, a significant difference in carcass weight depending on whether the carcasses were classified as steers or bulls. For conformation and fatness no such differences were found, probably because the normal score calculations were done separately for bulls and steers.

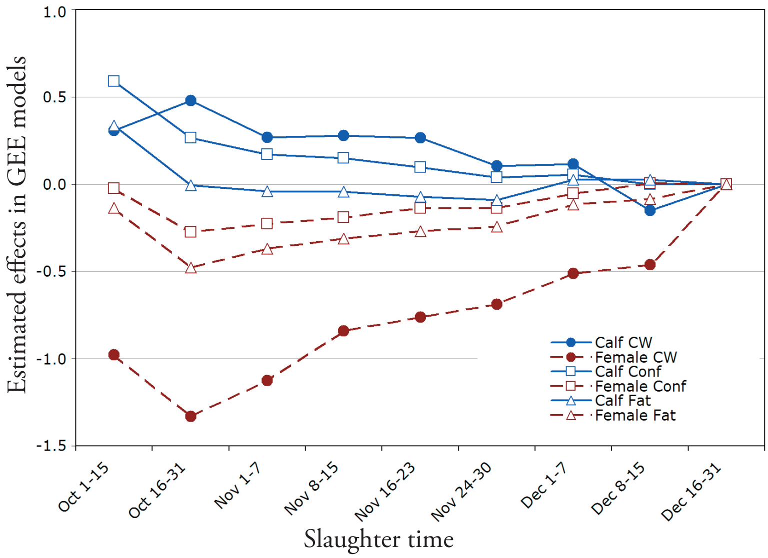

Fig. 2. Estimated effects of slaughter time on carcass weight (CW), conformation score (Conf) and fatness score (Fat) for calves and females according to GEE models. Note that the estimates were obtained with the period December 16-31 as the reference point (estimate set to 0). Intercepts for the different carcass measures and animal categories are found in Table 2.

Effects of reindeer population density and slaughter selection

The GEE analyses showed that reindeer density negatively affected all carcass measures in females and calves (Table 2), but not in males, where this effect was excluded from further analyses due to high P-values (P > 0.2). A negative correlation between female ratio and reindeer density (r = -0.15; P = 0.004) showed that the variations in population size were not generally caused by changes in the number of females, but rather by the numbers of males or calves.

The two variables describing the selection of animals for slaughter (female ratio and calf slaughter ratio) were, as expected, positively correlated with each other (r = 0.32; P < 0.001). We found a negative effect of female ratio on carcass weight and conformation of calves, but a positive effect on fatness (Table 2). A positive effect was also found on female weight and fatness. Calf slaughter ratio had a positive effect on calf conformation, but a negative effect on all carcass measures for females and also on the carcass weight of males.

Lagged effects

All carcass measures, except calf fatness, were positively affected by the mean for the same measure lagged from the previous year (Table 2). In addition, the carcass measures of calves were positively affected by the lagged means of the same measures for females in the previous year. The conformation of calves and males was negatively affected by the mean fatness for the same animal category in the previous year.

Discussion

Our analyses of commercial slaughter records were performed in order to assess the possibility of using carcass measures as indicator of the body condition within the living reindeer herd related to pasture quality and stocking rate on snow-free season pastures for use in future adaptive management systems. The indicator is primarily intended as proxy for monitoring changes in the condition of snow-free pasture and as an incentive for the regulation of reindeer numbers and other adjustments of management strategies on the herding district level. In the following discussion we consider how the slaughter records may be influenced by various stochastic and systematic factors and how they thus should be interpreted as indicator variables.

The consistent correlations found between the three studied carcass measures (weight, conformation and fatness) is in accordance with the results of our previous study (Olofsson *et al.*, 2008) and strengthen the assumption that the body condition of an individual animal is reflected in all these measures. Similar long-term trends and year-to-year variations show that changes in the carcass measures are consistent across animal categories and therefore probably indicative of individuals in these categories responding in a similar manner to common circumstances. A small dataset on body mass of live adult females and carcass measures of slaughtered reindeer from the same herd (results not shown) support our hypothesis that variations in carcass parameters reflect corresponding variations in the living herd.

There may be several reasons for the differing patterns observed in the data relating to males, compared to females and calves, especially in the effect of herding district. One possible reason is discrepancies between herding districts with regard to the selection of animals for slaughter. This is more pertaining to males, because of larger disparity in the age at which males are slaughtered, combined with a significant increase in male's body mass up to five years of age (Timisjärvi *et al.,* 1982). Selection among adult males of different age was not accounted for by the variables aimed to capture effects of slaughter selection (calf slaughter ratio and female ratio). Moreover, males differ from females and calves in their use of habitats within the grazing range, especially during the first part of the snow-free season (Loe *et al.*, 2006). In addition, the females and calves were slaughtered later during the season than the males, and it is likely that late autumn pastures, used after the bull slaughter, differ in many respects from summer pastures and thereby affect the condition of the animals differently.

A notable finding was that the effect of year was incoherent with respect to the different carcass measures, but nevertheless similar within carcass measures across all animal categories. In some years, the animals seemed to put on more weight and fat; in other years they were lighter, but still had high conformation scores (muscle mass). The positive trend over years, found in both carcass weight and fatness, suggests that these variables may be more affected by slow-changing factors, whilst conformation is more sensitive to factors that vary from one year to the next. It is also possible that the scale on which conformation was judged was inconsistent between slaughter occasions and years. Unlike fatness, which is related to the percentage of fat on the carcass, conformation cannot be easily linked to any objective measure and is therefore a more subjective assessment.

The large long-term increase in carcass weight of males (0.76 kg per year) is too big to be explained only by a general increase in animal condition. As mentioned above, male body mass may increase up to five years of age. A general increase in the age of slaughtered males might thus be an explanation to the increase in male carcass weights over the observed years.

Animal density is a key variable to control in adaptive management of grazing resources. We used a relative measure, calculated for each individual herding district, when analysing the effects of reindeer density. This was done since the size of the area actually utilized by reindeer, and hence the absolute population density, was not known. We found that the relative density had negative effects on female and calf carcass measures, but failed to find any significant effects in males. Negative effects of population density have been observed in earlier studies on reindeer (e.g. Lundqvist *et al.*, 2009; Holand *et al.*, 2010; Rødven, 2010). Based on previous knowledge of reindeer herding systems (e.g. Helle & Kojola, 1994; Weladji & Holand, 2003), it is likely that some of the density effects we found were due to competition for food during the preceding winter. In reindeer husbandry, there is generally a surplus of forage during summer and early autumn, although the quality of the forage varies (Larter *et al.*, 2002). High reindeer densities may, however, negatively affect the reindeer's ability to select forage of optimal quality. This can have dramatic effects on the energy available for growth and the possibility to rebuild body reserves (White, 1983). Long-lasting reductions in the productivity and nutritional quality of tundra vegetation have been found at very high reindeer densities in Finnmark, Norway (Bråthen *et al.*, 2007). However, these reindeer densities are among the highest in the world, and similar effects have not been observed in the Swedish mountain area (Olofsson *et al.*, 2001). Any actual degradation of vegetation because of reindeer grazing is thought to occur only rarely within the Swedish reindeer summer ranges (Moen & Danell, 2003), but is not an argument for lack of density effects. Regarding density dependence, it is obvious that short-term effects may occur, depending on variations in reindeer numbers and land use from year to year, as well as long-term effects over years due to general trends in population size. For management purposes it is important that both of these aspects are taken into consideration.

The reindeer slaughter statistics in Sweden do not allocate animals older than one year to separate age classes, nor does it distinguish between male and female calves. The age and sex distribution of the slaughtered reindeer may thus have large influence on the average carcass weights, and also influence conformation and fatness records. A more serious limitation of these data was the classification of poorly developed yearlings as calves, which may result in false conclusions being drawn about any apparently ongoing trend. If the general condition of animals declines, more yearlings may be classified as calves, and the average values of carcass weights of both the calf and the adult male classes may actually rise, and so distort any apparent effect of animal density. In such circumstances, data from slaughtered calves, which constitutes the main group at slaughter, may be of limited informative value for an adaptive management application.

An obvious factor to take into consideration, when using slaughter data as an indicator, is the time of slaughter within a season. Calves and females were both affected by slaughter time, but the general pattern differed so that the measures relating to female carcasses improved over the season, while they declined for calves. The reason for this difference may be that the quality of pasture in the late autumn, in addition to the pasture used earlier, affects animal condition at the late slaughter. Pasture quality, especially its digestibility, is generally considerably lower in the autumn than during the summer (Larter *et al.*, 2002). Since body size is known to affect digestive capacity in other ruminants (Illius & Gordon, 1992) it is likely that reindeer also experience the same effect. Thus, the difference observed between females and calves may result from females, because of their larger size, being more able than calves to digest forage of lower quality (i.e. forage with a higher fibre content). However, it should be noted that the trends over season were estimated based on data from all districts and that other patterns thus may be found in individual districts.

Lagged effects of animal condition during the previous year seemed to be present in our study system. Such lagged effects may have different signs depending on whether the animal density is in a build-up or a reduction phase. This was however not possible to show in the present data. Lagged effects can delay the detection of ongoing changes in the system, but at the same time smooth out any non-systematic variation between successive years and so make the progression of a trend more evident. The latter is obviously of benefit in adaptive management where long-term trends are sought.

The present reindeer slaughter records are compiled primarily for uses other than as indicator of body condition. They are, however, already routinely collected and hence available without the need to incur any additional costs. Taken together, the results of the present study imply a promising potential of using carcass measures from commercial slaughter to indicate changes in reindeer body condition. In practical applications a set of indicator variables seems advisable, as was implied in the previous work by Olofsson *et al.* (2008). This is also in line with the proposals by Morellet *et al.* (2007) for management of large herbivore populations. This set of variables would include the easily acquired routine carcass measures (weight, conformation and fatness) for certain animal categories, preferably calves and females. Special caution is needed if using slaughter data for adult males, due to the possible large biases caused by age at slaughter. Among animal categories, the male calves appear to have the largest potential, as they constitute the most numerous and least selected group at slaughter. A disadvantage with calf records is the potential confusion of calves with yearlings when classified as carcasses, which however can be avoided by classification by age on live reindeer, before the slaughter.

According to the results by Olofsson *et al.* (2008), the quality of the information from slaughter measures could be enhanced by also including body size measures, either by adjusting carcass weights for the structural size of the animal or combining weight, scores and size measures using multivariate techniques.

Notwithstanding the fact that body condition trends within individual reindeer herding districts are more difficult to identify since they are based on fewer data, the development of a trend within a single herding district might be easier to interpret because of better understanding of local dynamics. Even so, as much as possible of available data should be used and combined in an optimal way in an index in order to facilitate inferences. Apart from using multivariate techniques as suggested by Olofsson *et al.*, an alternative could be to combine the information in a linear index with coefficients derived with best linear prediction (BLP) or best linear unbiased prediction (BLUP) techniques, well known from genetic evaluation applications (e.g. Henderson, 1973). All these alternatives have particular advantages in their abilities to account for the variance structure within the set of indicator variables, and the latter two also the benefit of taking into consideration different numbers of observations behind each indicator.

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Abstract in Swedish / Sammandrag: I denna studie undersöks möjligheten att använda slaktkroppsinformation från kommersiell renslakt som indikator på långsiktiga förändringar i renhjordens kondition och därmed konditionen på barmarksbetet. Syftet var att bedöma om slaktkroppsinformation skulle kunna vara en lämplig indikator inom ett adaptivt förvaltningsprogram av renskötselns betesresurser. I undersökningen användes data från kommersiell renslakt under åren 1994 till 2007, bestående av slaktvikt, form- och fettklassning, indelade på tre djurkategorier. Slaktkroppsmåtten analyserades med hänsyn till år, slakttidpunkt inom år, sameby, populationstäthet, och två variabler som speglar variationer i slakturval. Samtliga slaktmått påverkades av slaktår, och effekterna var starkt korrelerade mellan de tre djurkategorierna. Det fanns också generellt positiva trender i slaktmåtten över den studerade 14-årsperioden. Vi identifierade flera faktorer som bör tas hänsyn till då slaktkroppsdata används för att indikera långsiktiga förändringar i djurens kondition: (i) slakttidpunkt hade olika effekt beroende på djurkategori; (ii) populationstätheten hade negativ effekt på slaktkroppar från vajor och kalvar, men inte på dem från handjur. Sameby hade likartad effekt på slaktkroppar från kalvar och vajor, medan effekten skiljde mellan vajor och handjur. De skillnader som observerades mellan djurkategorierna kan bero på olika slakttidpunkter (punkt i ovan), olika slakturval mellan samebyar, eller ha ekologiska förklaringar, t.ex. könsskillnader i användningen av betesmarkerna. Det finns även osäkerheter i kategoriseringen av djur, då skelettutveckling används för att skilja mellan kalv och fjolåringar, och detta kan ha påverkat skillnaderna mellan samebyar. Att effekter av betesbeläggning gick att upptäcka hos åtminstone kalvar och vajor, att effekten av år påverkar de tre djurkategorierna på snarlikt sätt, samt att likartade generella trender över år går att påvisa stödjer hypotesen att information från renslakten kan användas för att upptäcka generella förändringar i renars kondition relaterade till betesförhållanden.