Associations between annual and seasonal variations in body mass and reproductive success and blood biochemical parameters in semi-domesticated reindeer

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Abstract: The main objective of the study was to follow reproductive performance and blood biochemical parameters associated with fat and carbohydrate metabolism in a herd of free-ranging, semi-domesticated reindeer (*Rangifer tarandus tarandus*) over a two-year period, with extreme between-year variation in forage availability. The effects of climatic factors on reindeer reproductive performance were investigated by analysing whether time of onset of luteal function in autumn and calf survival were associated with changes in body mass and weather conditions, such as snow depth, precipitation, and temperature. Considerable between-year variation in the onset of luteal activity was found. In 1997, 4.2% of the female reindeer were either cycling or pregnant in the second week of October, whilst in 1998, in the same week, 100% were cycling or pregnant. Although energy balance was important for timing of the onset of luteal activity, delayed conception had no apparent effect on calf survival. The results indicated that maternal body mass (BM) in spring was of primary importance for calf survival, and the productivity of the herd. Since climatic factors influence the availability of forage, and hence female BM, it also has an indirect impact on calf survival. Females with low BM demonstrated greater seasonal variation in BM than heavier females. Plasma concentrations of free fatty acids and β-hydroxy butyric acid responded to changes in forage availability, but the initial condition of the reindeer and their fat reserves also seemed to have a major influence on these parameters.

Key words: body condition, calf survival, luteal function, nutritional status, pasture condition, *Rangifer tarandus*.

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Abbreviations:
body mass (BM)
free fatty acids (FFA)
β-hydroxy butyric acid (B-OHB)
glucose (GLU)

Introduction

In recent years, overgrazing of the winter range has been regarded as a major challenge in Finnmark, Norway (Ims, 2006). The decline in winter pasture conditions and subsequent reduction in reindeer herd productivity represents a considerable economic loss for the herders. Despite increasing winter pasture degradation

(Tømmervik *et al.*, 2009), supplementary feeding of reindeer in order to limit production losses is unusual in Norway. Forage shortages have been associated with both metabolic disturbances and weight loss in reindeer. Winter and early spring are the most challenging periods for reindeer survival (Skogland, 1985), and the accessibility of forage could be limited due to particular snow conditions (Skogland, 1978; Reimers 1982). Semi-domesticated reindeer (*Rangifer tarandus tarandus*) in Norway usually rely on natural pastures as their sole food resource. Consequently, the productivity of reindeer herds is vulnerable to environmental fluctuations. Both summer and winter weather affect the potential carrying capacity of the range by influencing the 'absolute' (summer) and 'relative' (winter) forage availabilities (Callahan *et al.*, 2004). Predicting weather conditions in the northernmost areas from year to year is notoriously difficult (Caughley & Gunn, 1993), and therefore density-independent factors may interact with population density to a greater extent than in temperate regions (Grenfell *et al.*, 1998; Aanes *et al.*, 2000). Reindeer are seasonally polyoestrous (Ropstad *et al.*, 1995), and mating coincides with decreasing photoperiod in autumn, followed by parturition the following spring. Females usually have a high fecundity, and pregnancy rates are generally regarded as satisfactory, although considerable between-year variation has been reported for various populations (Ropstad, 2000; Milner *et al.*, 2003). Lower reproductive success, in terms of lower pregnancy and birth rates, and lower calf survival, may be expected when winter and early spring forage availability is restricted or of poor quality (Skogland, 1983, 1985; Kojola *et al.*, 1995).

While body mass (BM) may provide a reflection of an animal's nutritional status over the preceding weeks and months, blood biochemistry parameters may alter in response to an animal's physiological status within minutes. Several studies have been performed on blood constituents related to protein metabolism and the nutritional condition of reindeer (Hyvarinen *et al.*, 1975; Bjarghov *et al.*, 1976; Säkkinen *et al.*, 1999, 2001, 2005). Some studies have also investigated metabolites of fat and carbohydrate metabolism, under experimental conditions (Nilsson *et al.*, 2000; Soppela *et al.*, 2000) and under field conditions (Larsen *et al.*, 1985a, b; Milner *et al.*, 2003). Measurements of the blood biochemical parameters such as plasma concentrations of glucose (GLU), free fatty acids (FFA), and β-hydroxy butyric acid (B-OHB) could be an alternative way to assess reindeer nutritional status. It would be expected that animals in a catabolic state would have high plasma levels of FFA and B-OHB, indicating consumption of their lipid body reserves as an energy source (Larsen *et al.*, 1985a; Kaneko *et al.*, 1997). GLU concentration in blood is strongly-regulated by homeostatic mechanisms, so concentrations within the normal reference interval would be expected unless the animals are subject to extreme nutritional stress (low values) or handling stress (high values) due to activation of the hypothalamo-pituitary-adrenal axis (Sire *et al.*, 1995; Säkkinen *et al.*, 2004).

The main objective of this study was to follow reproductive performance and blood biochemical parameters associated with fat and carbohydrate metabolism in a herd of free-ranging, semi-domesticated reindeer over a two-year period, with extreme between-year variation in forage availability. The effects of climatic factors on reindeer reproductive performance were investigated by analysing how the between-year variation in onset of luteal activity in autumn and calf survival could be explained by changes in BM and weather conditions, such as snow depth, precipitation, and temperature. Secondly, we investigated whether climatic factors and the decline in pasture conditions were associated with alterations in

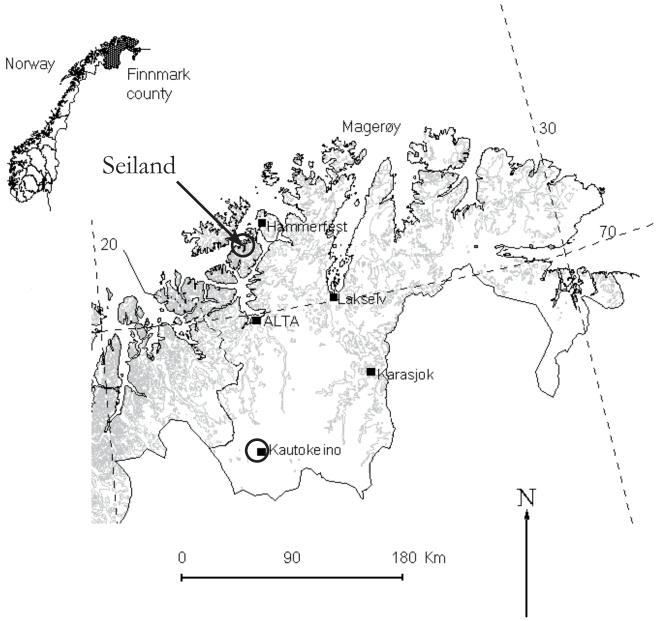

Fig. 1. Sampling locations at coast and inland areas. The summer range was at Seiland island in Altafjord (70.25°N, 23.15°E) and the winter range around Kautokeino (68.60°N, 23.00°E).

blood chemical parameters related to fat and carbohydrate metabolism.

Material and methods

The Seiland herd

Female reindeer of the Seiland herd in Finnmark County, Norway, named after the herd's summer pasture on the western part of Seiland island in Altafjorden (70.25°N, 23.15°E), were monitored for two consecutive years, 1997 and 1998. The continental winter pasture is located near Kautokeino (68.60°N, 23.00°E) (Fig. 1). Mating in the herd was not controlled. The lichen biomass on the winter pasture in the interior of Finnmark was generally low, whereas the pasture on the island of Seiland was regarded as limited in spring and early summer (Säkkinen *et al.*, 2005), but improved considerably by late summer.

Animal handling and sampling procedures

Blood was sampled from mature female animals in March 1997 (n=145), May 1997 (n=89), June 1997 (n=17), October 1997 (n=98), November 1997 (n=97), March 1998 (n=99), May 1998 (n=62), July 1998 (n=33), and October 1998 (n=100).

Sampling was conducted when the free-ranging animals were corralled for slaughtering or counting. Groups of approximately 20 animals were randomly moved from the large herd into smaller corrals and the individual animals were physically restrained for sampling of blood from the jugular vein using heparinized vacutainers (Venoject®, Leuven, Belgium). From October 1997 and each sampling occasion thereafter, the BM of each animal (n=489) was recorded at blood sampling using a portable livestock weighing scale with an accuracy to 1 kg (Farmer Tronics, Give, Denmark).

Blood biochemistry analyses

Blood plasma was separated by centrifugation (3000 g, 15 min) within 2-8 h of collection and stored at -20 °C prior to analysis at the Central Laboratory, Norwegian School of Veterinary Science, Oslo.

Plasma was analysed for concentrations of plasma FFA (FFA reagent, Wako Chemicals GmbH, Germany), B-OHB (B-OHB reagent, Sigma Diagnostics, USA), and GLU (method by Slein *et al.*, 1950) by employing a Technicon Axon auto-analyser (Bayer Health Care LCC, Tarrytown, N.Y., USA).

Hormone analyses

Progesterone (P4)

Plasma levels of total progesterone were determined by a solid–phase radio immunoassay kit (Spectria® Progesterone 125I Coated tube RIA, Orion Diagnostica, Espoo, Finland).

The assay was validated for use with reindeer plasma by demonstrating parallelism between dilutions of reindeer plasma samples and the standard curve, and by recovery of unlabelled ligand. Modifications to the standard procedures were unnecessary. The detection limit of the Spectria kit assay was 0.3 nmol/L, the intra-assay coefficient of variation was less than 5%, and the inter-assay coefficients of variation were 8.8% at 1.25 nmol/L, 7.6% at 19.1 nmol/L, and 5.9% at 44.1 nmol/L (Säkkinen *et al.*, 2005). Based on the frequency distribution of plasma progesterone concentrations, a cut-off value of 7 nmol/L was used to indicate pregnancy (Ropstad *et al.*, 1999). Comparatively high P4 concentrations have been reported in reindeer in the luteal stage of their oestrous cycle (Ropstad *et al.*, 1995), so P4 levels can be unreliable as a diagnostic tool for use in early pregnancy detection (Ropstad *et al.*, 1999).

Climate data

Meteorological data from two weather stations, one close to the winter pasture and one close to the summer pastures, were obtained from the database of Commercial climatological services, http://eklima.met.no, The Norwegian Meteorological Institute. One weather station is located by the coast (Loppa: 70.33°N, 21.47°E), and provided data on the summer conditions, and the other is based in-land (Kautokeino: 68.99°N, 23.03°E), and provided data on winter conditions. Climatic variables comprised monthly averages for temperature, precipitation, and snow depth from 1996 to 1998 (Table 1).

Productivity data

Total reindeer count and number of calves marked in the autumn in the region of West-Finnmark, and specifically in Seiland West herding area, during 1996, 1997, and 1998, were obtained from The Norwegian Reindeer Husbandry Administration. Productivity data, measured as meat production per kg live animal, for the whole region were also obtained (Table 2).

Statistical analyses

The results are given as mean ± SE. Dependent variables were assessed for normality by the Shapiro-Wilks' W test. All parameters investigated gave a satisfactory fit to the normal distribution. Analysis of variance (ANOVA) was used to compare continuous variables, such as mean BM, and mean plasma concentrations of blood biochemical parameters. Categorical data, such as pregnancy status, were analyzed with Chi-square tests. Significance level was defined at $P<0.05$.

Results

Body mass

The mean BM of the reindeer varied significantly between months. The lowest mean (SE) BM of 60.2 (1.4) kg was in May 1998, and the highest in July 1998, 67.6 (1.1) kg. The animals were, on average, 4.3 kg heavier in October 1998 than in October 1997, 67.3 (0.6) kg and 63.1 (0.8) kg respectively. There was a significant effect of month on the variation of BM within the body mass quartiles, except for the quartile with the heaviest animals (quartile 4; Fig. 2). The largest variations were in quartiles 1 and 2 (Fig. 2; Table 3).

Reproductive parameters

Based on the frequency distribution of plasma P4 concentrations measured in mid-October 1997 and 1998, and mid-November 1997, it appeared that the onset of luteal activity occurred at a later date in 1997 than in 1998. In 1997, only 4.2% of the animals were classified as pregnant or in the luteal phase of the oestrous cycle in mid-October, whereas measurements taken in the same week, but one year later, demonstrated that all the animals were pregnant or had an established oestrous cycle (Fig. 3).

Table 1. Climate variables showing mean values in selected time period at Kautokeino (68.99ºN, 23.03ºE) weather station, reflecting winter and spring conditions, and Loppa (70.33ºN, 21.47ºE) weather station, reflecting summer conditions.

	Winter Kautokeino Dec-Feb		Spring Kautokeino Mar-Apr		Early summer Loppa May-Jun		Summer Loppa Jul-Oct	
Year	1996/97	1997/98	1997	1998	1997	1998	1997	1998
Precipitation (mm)	22.7	29.1	14.1	10.7	29.5	71.2	89.0	54.4
Snow depth (cm)	40.6	33.3	58.7	41.8	11.5	1.0	1.1	0.0
Temperature (°C)	-13.9	-15.4	-8.2	-9.9	6.5	6.6	9.4	9.5

Table 2. Number of reindeer (*Rangifer t. tarandus*), percentage of calves marked and productivity for West-Finnmark herding region (WF) and Seiland West herding area (SW) in 1996, 1997, and 1998.

	1996		1997		1998	
	WF	SW	WF	SW	WF	SW
Reindeer count	88 313	1933	77 509	1311	75 906	895
Calves marked	58%	46%	44%	12%	65%	75%
Productivity (kg/live reindeer)	9.1	-	1.3	-	5.2	-

Data from the Norwegian Reindeer Husbandry Administration.

Table 3. Percentage change in mean body mass of the Seiland reindeer herd over the winter from October 1997 to May 1998, and over the summer from May 1998 to October 1998.

Body Mass	All	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Loss Oct 97 – May 98	4.5%	12.0%	6.3%	0.8%	-0.2%
Gain May 98- Oct 98	11.8%	29.6%	14.2%	6.5%	2.6%

Table 4. Pregnancy status of female reindeer of the Seiland herd, divided into body mass quartiles in March and May 1998. Pregnancy status determined by plasma progesterone concentrations (barren: < 7 nmo/l; pregnant: ≥ 7 nmo/l, Ropstad *et al.*, 1999).

	Pregnancy status (%)			
Body mass	March 98		May 98	
Quartiles	Barren	Pregnant	Barren	Pregnant
1	65.2	34.8	71.4	28.6
2	4.0	96.0	21.4	78.6
3	0.0	100.0	0.0	100.0
4	0.0	100.0	9.1	90.9

BM was significantly associated with being classified as pregnant, both in March and May 1998. Females in the two heaviest BM quartiles had the highest pregnancy rates, whereas those with BM in quartile 1 had the lowest pregnancy rate (Table 4).

In females classified as pregnant in 1997, there was a significant drop in mean (SE) P4 concentration from March to May, 28.50 (1.06) nmol/L and 17.97 (0.98) nmol/L, respectively. However, in 1998 pregnant females showed no significant drop in mean P4 concentration be-

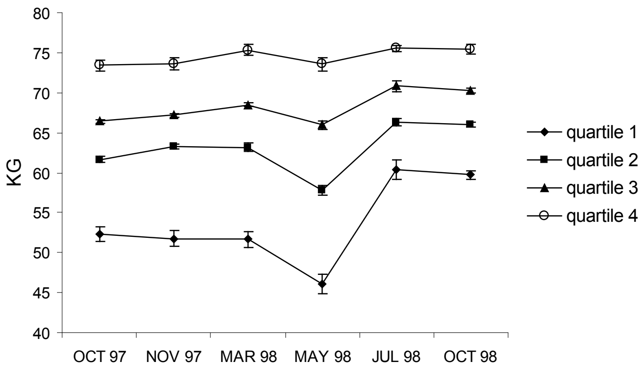

Fig. 2. Mean (SE) body mass within month and quartile of the Seiland reindeer herd (*Rangifer t. tarandus*). The data were divided into quartiles, according to the body mass distribution within each month, each year.

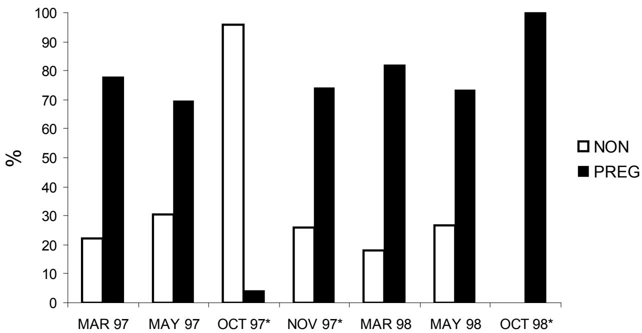

Fig. 3. Pregnancy rates in the Seiland reindeer herd as determined by plasma progesterone concentrations (barren: < 7 nmo/l; pregnant: ≥ 7 nmo/l, Ropstad *et al.*, 1999) in 1997 and 1998. Months marked with * could also contain individuals in the luteal phase of the oestrous cycle.

tween March and May, 34.8 (1.24) nmol/L and 32.7 (2.03) nmol/L, respectively. Between-year comparison showed that the mean P4 concentrations were significantly lower in March and May 1997 than in the same months in 1998.

Blood biochemical parameters

Both month and year had a significant effect on variations in both plasma FFA and B-OHB concentrations (Fig. 4). Significantly higher concentrations of FFA and B-OHB were found in May 1998 than in May 1997, (FFA: 2.47 (0.10) mmol/L in 1998 and 0.62 (0.05) mmol/L in 1997; B-OHB: 0.89 (0.05) inmmol/L in May 1998 and 0.56 (0.02) mmol/L in May 1997) (Fig. 4).

The mean GLU concentration in blood varied significantly within both years. The concentration was lowest after winter, before the start of the growing season, and highest in summer and autumn (Fig. 5). The mean (SE) GLU concentration was significantly lower in May 1997 (3.77 (0.12)) than in May 1998 (5.82 (0.21)).

Climate

According to the climate data, 1997 was characterized by a greater snow depth in winter and spring, and a higher summer precipitation than in 1998 (Table 1). Based on the snow cover in May and June we suggest that the start of growing season in 1997 was substantially later than in 1998.

Productivity

Data obtained from the Norwegian Reindeer Husbandry Administration showed there were decreasing numbers of reindeer in the period from 1996 to 1999, both in the herding region of West-Finnmark, and in the Seiland West herding area, and that the productivity dropped in the whole region. A lower percentage of marked calves were found in 1997 for both areas. The number of marked calves in the Seiland West herding area was particularly low, with only 12% of the females having a calf at foot in the autumn (Table 2).

Discussion

Body mass

Voluntary regulation of reindeer winter stocks has been unsuccessful in large parts of Finnmark (Ims, 2006), despite the fact that many areas have experienced severe overgrazing (Tømmervik *et al.*, 2009). The poor pasture conditions in 1997 were reflected as a lower mean BM in October 1997 compared with October 1998. Variation in BM is mainly a result of variability in the quantity and quality of available forage (Reimers, 1983; Skogland, 1983). However, it is difficult to distinguish climate effects on reindeer BM from density-dependent factors (Aanes *et al.*, 2000). The consequences of the difficult weather conditions of 1997 were a reduced reindeer count, less marked calves, and a low productivity for the whole region. Our data demonstrate that heavy females had a relatively constant BM throughout the year, whereas light weight females had substantial seasonal variation in BM, suggesting that lighter females are more likely to suffer from the effects of reduced forage availability than heavier females. An increase in BM as a response to feeding and a larger BM increase among light females compared with the heavy ones were found in a feeding experiment by Fauchald *et al.,* (2004), supporting our finding of greater seasonal variation in BM in light animals.

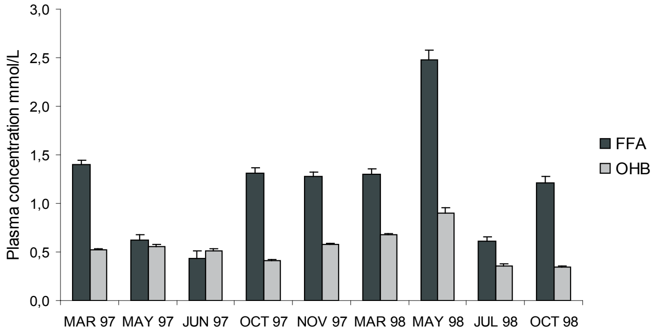

Fig. 4. Mean (SE) plasma concentrations of FFA and B-OHB of the Seiland reindeer herd in 1997 and 1998.

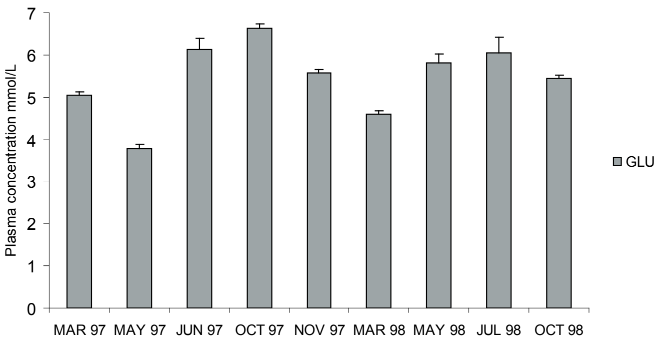

Fig. 5. Mean (SE) plasma concentration of GLU of the Seiland reindeer herd in 1997 and 1998.

Reproductive parameters

The one month delay in onset of luteal activity in 1997, compared with 1998, could be related to the harsh winter followed by a sub-optimal spring and summer weather that occurred that year. It is known from other ruminant species that energy balance and body condition are essential for the onset of cyclic ovarian activity during pubertal development, as well as in the *post partum* period of adult females (Mitchell & Brown, 1974; Putman *et al.*, 1996; Gillund *et al.*, 2001; Reksen *et al.*, 2001). The lack of necessary energy resources to invest in pregnancy results in a delay in maturity or a reproductive pause (Skogland, 1984). The delayed onset of luteal activity observed in our study does not contradict the findings of Ropstad *et al.*, (1995) that showed that cyclic ovarian activity occurs from September until February in unmated females. As a consequence, the potential duration of the reproductive season is considerably longer, than what is indicated by the rut period, which is normally confined to 2-3 weeks in September/October (Lenvik, 1988). In addition, Reimers (2002) reported a delay in conception dates in yearlings (by 1-31 days) and calves (by 22-51 days) compared with adult individuals.

A relevant question arising from the present data is how time of conception affects the reproductive success and the productivity of a herd. Calving early in the season provides calves with a long growing season (Reimers *et al.*, 1983; Skogland, 1983), thereby resulting in higher productivity. It also gives the female more time to recover from the loss of BM during the winter and the burden of lactation, and thus prepares her better for the next reproductive season (Reimers *et al.*, 1983; Skogland, 1983). The number of marked calves in the Seiland West herding area was particularly low in 1997. The fact that only 12% of the females had a calf at foot in the autumn could be a consequence of low female BM, low calf BM, or predation, or a combination of any of these. Previous data suggest that maternal BM is a strong predictor for calf survival, even in predator-free locations (Lenvik & Aune, 1988). Additionally, Tveraa *et al.* (2003) found that calves from low BM females had a higher probability of being predated than calves of heavier females. Despite the late onset of luteal activity in 1997, the number of marked calves in autumn 1998 was 75%, so time of conception seemed to have little, if any, effect on calf survival.

A significant positive relationship was observed between female reindeer BM and the probability of pregnan**cy** in March and May 1998. It is well-established that pregnancy within a population is positively related to BM and/or fat depth in several reindeer subspecies (*R. t. pearyi, R. t. tarandus,* and *R. t. plathyrhyncus*) (Thomas, 1982; Tyler, 1987a,b; Milner *et al.*, 2003). Due to the lack of sequential data on individual animals in our study, we were unable to draw any conclusions on the reason for the observed relationship between BM and the probability of pregnancy.

Females classified as pregnant had a significant drop in mean P4 concentrations from March to May 1997, and this was not found in 1998. It has previously been shown that plasma P4 peaks twice during pregnancy; first at around 24 weeks prior to calving, and then at around 3 weeks before calving (Ropstad *et al.*, 2005). After the second peak, P4 concentrations decrease towards calving. The observed difference in May P4 concentrations between 1997 and 1998 could reflect an asynchronous gestational stage at the time of sampling as a consequence of the late onset of the rut in 1997. It is unlikely that the lower P4 concentrations in spring 1997 were a direct result of the generally poor condition of the animals that year, as no such association has previously been demonstrated in reindeer (Ropstad, unpubl. data). The uncertainty concerning when the rut occurred in 1996 complicates interpretation of the reduced progesterone concentrations.

Blood biochemical parameters

FFA and B-OHB are indicators of increased fat breakdown (Sjaastad *et al.*, 2003), and are thought to reflect the extent of adipose tissue lipolysis (Larsen *et al.*, 1985a). Therefore, one would expect that animals in a catabolic state to have high plasma concentrations of FFA and B-OHB. The slightly lower values of FFA and B-OHB in October 1998 than in October 1997 could indicate a larger negative energy balance in 1997 that affected the onset of luteal function (Gillund *et al.*, 2001; Reksen *et al.*, 2001).

The differences in FFA and B-OHB concentrations between May 1998 and May 1997, with considerably higher concentrations in 1998, were unexpected, considering that 1997 was a poorer year. It could be that sampling took place at a stage of the year (May) when the fat reserves were at a minimum, due to the very meagre situation in 1997, and therefore mobilisation in FFA and B-OHB was less than expected. It is likely, that the seasonal variations in FFA concentrations mainly reflect the availability of forage, as the quality of the pastures was considerably better in summer and autumn than in winter and early spring. Values from 0.35-1.39 mmol/L have been reported previously in captive reindeer fed *ad libitum*, whilst values from 0.69-1.31 mmol/L were found during restricted feeding (Soppela *et al.*, 2000).

Blood GLU concentration depends on a variety of factors and, at any time, reflects the net equilibrium between the rates of entry and removal of glucose from the circulation (Kaneko *et al.*, 1997). Previous studies have shown that blood cortisol concentration is an important predictor for the GLU concentration in reindeer blood (Rehbinder & Edqvist, 1981; Rehbinder, 1990). Cortisol is released in response to stress, and it is probable that the stressful conditions associated with sampling procedures, would affect the blood GLU concentration as a consequence of elevated cortisol levels (Sire *et al.*, 1995). This association confuses the interpretation of GLU used as a marker for nutritional status, as plasma cortisol concentrations were not measured in our study. Nevertheless, the lower GLU levels measured in May 1997, compared with those in May 1998, could be associated with a later start in the growing season due to snow-covered ground in 1997 (Table 1). Of the animals sampled in May 1997, 17% had glucose concentrations below the lower reference limit for sheep (2.76 - 4.44 mmol/L; Kaneko *et al.*, 1997). In reindeer, values from 2.5 to 3.9 mmol/L have been previously reported (Säkkinen *et al.*, 1999). Considering that sampling occurred under stressful conditions, the true prevalence of hypoglycaemia was probably higher in this study than suggested by the values obtained. In contrast, only 1.6% of the animals were similarly hypoglycaemic in May 1998.

In summary, maternal BM was found to be an important factor for reindeer calf survival, and the productivity of the herd, but time of conception had no apparent impact on calf survival. Since climatic factors influence the availability of forage, and hence female BM, it also has an indirect influence on calf survival. Low BM females had more seasonal variation in BM than heavier ones. Maintaining a positive energy balance was of importance for onset of luteal activity, and BM was significantly associated with the probability of pregnancy.

The metabolic parameters FFA and B-OHB responded to changes in forage availability, but also seemed to be influenced by the initial condition of the animals and their fat reserves.

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Sammenheng mellom års- og sesongvariasjon i kroppsvekt og henholdsvis reproduksjonssuksess og biokjemiske blodparametre hos tamrein

Abstract in Norwegian / Sammendrag: Hovedformålet med studien var å følge reproduksjonen og blodparametre knyttet til fett og karbohydratmetabolismen hos en tamreinflokk (*Rangifer tarandus tarandus*) gjennom en toårs periode med stor årlig variasjon i næringstilgang. Effekten av klima på reinens reproduksjonssuksess ble undersøkt ved å analysere om værdata som snødybde, nedbørsmengde og temperatur og forandringer i vekt hadde innvirkning på igangsetting av lutealfunksjonen hos simlene og på kalvenes overlevingsevne gjennom sommeren. Det ble funnet en betydelig forskjell mellom år når det gjaldt igangsetting av lutealfunksjon. I oktober 1997, var kun 4,2% av simlene drektige eller i lutealfasen av brunstsyklusen mens i den samme uken i 1998 var alle dyrene drektige eller i brunstens lutealfase. Selv om energibalanse var viktig for igangsetting av lutealfunksjonen, hadde forsinkelse i drektighetene ingen innflytelse på kalveoverlevelsen. Resultatene våre indikerte at simlenes vårvekt var av størst betydning for kalveoverlevelsen, og dermed også for produktiviteten til flokken. Siden de til enhver tid gjeldene værforhold påvirket tilgangen av fôr, påvirket dette også simlenes vekt med en indirekte effekt på kalveoverlevelsen. Simler med lav levendevekt viste større sesongvariasjon i vekt enn tyngre simler. Plasmakonsentrasjonen av frie fettsyrer, β-hydroxy-smørsyre forandret seg i takt med beitegrunnlaget, men den initiale kondisjonen og fettreservene hos simlene syntes også å påvirke disse parametrene.