Abstracts

Session 1	Physiology I: nutrition and energetics

1

Comparison of nutrient absorption by red deer and reindeer calves in winter

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This comparison was made to evaluate by tests of digestive function the classification of red deer (*Cervus elaphus*) and reindeer (*Rangifer tarandus*) as 'adaptable mixed foragers' (*sensu* Hofmann, 1985). Nutrient and dry matter (DM) absorption and secretion patterns in the alimentary tract in red deer calves fed a winter diet of bilberry (*Vaccinum myrtilus*) stems, grain oats, hay and silage (Cv) were compared with published values for reindeer calves fed lichens (Rl) or commercial pellets RF-71 (Rrf) (Staaland *et al.*, 1984; 1986; White *et al.*, 1984). All animals were of similar body mass (BM, 43-50 kg); digestibility of diets exceeded 0.7 (0.72, 0.77, 0.78), but daily dry matter (DM) intake was lower for Cv (34g/kg$^{0.75}$) than Rl and Rrf (42, 53). Nitrogen (N) intake of Cv (8.3 g/d) was intermediate between Rrf (18.2) and Rl (4.7), and in only Rrf did intake approach that for N balance. N intakes expressed as fraction of the rumen pool (k_{Ni}, /h) were equivalent for Cv and Rrf (0.026) while that for Rl was low (0.006). Results show that total alimentary fill for Cv was low at 9% BM compared with Rl 17% and Rrf 16%, but the rumen-reticulum contribution to DM fill was similar between groups (74, 77, 78%). Ruminal fractional intake rate (k_i, /h) at 0.043 for Cv was intermediate between Rl, 0.033 and Rrf, 0.053. However, retention of DM in the rumen (k_o, /h) of Cv was less than Rl and Rrf (k_o = 0.061, 0.026, 0.022). Fractional digestion of DM in the stomachs was 0.50 in Cv, 1.0 in Rl and 0.61 in Rrf. For N, a gain (0.09 of intake) was noted in the rumen for Cv, whereas digestion (0.31) took place in Rl and Rrf. Fecal N excretion was less than the expected endogenous fecal N loss, indicating an efficient conservation in all three groups. The smaller rumen of these red deer was more typical of a 'concentrate selector', even though the diet was low in N and minerals: This does not support theory that the alimentary tract increases in size in response to low quality diets. The relatively rapid rumen turnover of the red deer was accompanied by a good ability for fermentation and overall DM and N digestion of browse. Differences in gut dimensions were not associated with major effects on digestive function.

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Effect of wind on Svalbard reindeer fur insulation (corrected)

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The heat transfer through Svalbard reindeer fur samples was studied with respect to wind velocity, season and animal age. A total of 33 dorsal fur sections were investigated using a wind tunnel. Insulation varied with season (calving, summer, autumn and winter). At zero wind velocity, fur insulation was significantly different between seasons for both calf and adult fur samples. At the same time, there was no significant difference between calf and adult insulation for the summer, autumn and winter seasons. Calf fur insulated as well as adult fur. Svalbard reindeer winter insulation was approximately 3 times that of summer. Increasing wind velocity increased heat loss, however, the increase was not dramatic. When wind coefficients (slope) of the heat transfer regression lines were compared, between season and between calf and adult, no significant differences were reported. All fur samples showed similar increases in heat transfer for wind velocities between 0 and 10m s^{-1}. The conductance of Svalbard reindeer winter fur was almost half of caribou fur. Also, it was not as greatly influenced by wind as caribou fur.

3

Mechanisms of winter metabolic acidosis compensation in reindeer in the reticulo-rumen

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In February and April acid-base parameters in reindeers fed lichen (n = 8) indicated metabolic acidosis in the organism. 40.3 mm Hg of pCO_2, 45.6 meq/L of Buffer Base, -4,8 meq/L of Base Excess, 20.9 meq/L of Bicarbonate, 20.8 mmol/L of Standard bicarbonate, 22.1 mmol/L of Total CO_2, 7.33 of Actual pH in blood and

19 mmol/L of anion gap ($cNa^+ + cK^+$) - ($cCl^- + cHCO_3^-$) in serum of the animals was observed in this period. The cause of this acidosis was gastrointestinal loss of K^+ with faces whereas very little of the element was consumed with food. It was shown that the acidosis had no respiratory and had poor buffering and renal compensation. It's well-defined excretory compensation appeared to be in the reticulo-rumen of the animals. It was demonstrated in reindeer using fistulas in the duodenum (n = 4) and ones using fistulas in a parotid duct (n = 3) that Na^+ and K^+ utilisation efficiencies in the complex stomach, as compared with the whole digestive tract, in winter months are approximately 70% and 80%. These ions in the animals were secreted with saliva nearly 700 and 30 times and were absorbed in the complex stomach nearly 600 and 25 times as much as were consumed with lichen. In reindeer with fistulas in the rumen (n = 2) the mechanisms of Na^+ and K^+ absorption were studied in in vivo experiments during intraruminal loads by artificial solution without (n = 5) and with load of organism by acetazolamide in jugular vein (n = 3). Acetazolamide administration suppressed the Na^+ and K^+ absorption up to 100%. The findings suggest Na^+ and K^+ per H^+ exchange process occurring in the reticulo-rumen epithelium of reindeer. H^+ secreted can be removed out of the organism in a chemical-bonded state. As a result, pH of reindeer faces is 6.3 in winter whereas 8.2 in summer. Regulation of acid-base balance in reindeer organism by means of the digestive tract may be considered as a mechanism of adaptation of the animals to the seasonal dynamic of nutrition.

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Lichen digestibility in muskoxen and reindeer

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While lichens are of primary importance for reindeer and caribou during winter, muskoxen in general use them little. However, a previous study has shown that on the Seward Peninsula in western Alaska muskoxen and reindeer use similar winter feeding areas with a high percent cover of lichens and that muskox faeces in that area contain on average 14% lichen fragments in late winter. Lichens are highly digestible in *Rangifer* but no data are available for muskoxen. Two rumen-fistulated muskoxen and two rumen-fistulated reindeer were fed diets containing lichens (15% and 30% for one muskox and reindeer, each), brome hay (60% for muskoxen, 20% for reindeer), and a high-protein pelleted ration for 15 days. *In vitro* dry matter digestibility of each forage component was estimated for each animal immediately before and after the trial using each animal's own rumen liquor. Rumen contents and faeces, to be analysed for occurrence of forage fragments, were collected from each animal at 3-day intervals during the trial. In order to determine disappearance rates of lichens in the rumen and faeces, rumen contents and faeces were sampled 7 times at 3-hour intervals beginning immediately after animals had consumed their last lichen meal. Analyses are currently in progress. Results will help interpret the degree to which muskoxen use lichens and may have important implications for determining the potential level of competition between muskoxen and *Rangifer*.

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Determination of the heat increment of feeding in muskoxen

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We evaluated a technique to determine the heat increment of feeding (HIF) based on feeding a single meal to a test animal. Muskoxen were starved for 24 h and then sealed in a respiration chamber. Gaseous exchange and calculated energy expenditure (EE), was determined during the first 2 h to establish resting, or baseline, metabolism. A meal was then offered and EE was monitored for the next 8 h. Following the meal, EE that differed from the baseline values was attributed to the energy cost of consuming the meal, i.e. the HIF. Animal activity in all trials was also examined as an additional explanatory variable of the HIF. On 100% brome hay (*Bromus inermis*) diets fed at 10 $g/kg^{0.75}$ body mass, HIF was 6.5 - 14.5 (9.7 + 1.35 sem) $kj/kg^{0.75}$ body mass per day in the winter and 6.2 - 15.8 (10.6 + 1.24 sem) $kj/kg^{0.75}$ body mass per day during the summer. We suggest this approach results in a repeatable estimate of HIF. The determination of EE following the consumption of a standardised single meal over an 8 h period has advantages over the alternative, i.e. multi-day experiments with animals continuously restrained. This methodology would be most useful in wildlife studies where logistical constraints limit the number of study organisms and their inability to withstand days of restraint and where the availability of harvested wild forage places a limit on the study period.

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Adaptation of digestive system in reindeer to annual winter feeding

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The annual winter feeding of reindeer (*Rangifer tarandus tarandus*) has become a common practice in Finland, especially in the southern and middle part of reindeer herding area. The most used feeds are dry hay and grass silage, which are more fibrous and less digestible than the natural winter diet of reindeer. The reindeer are adapted to different diets during the year and are classified as intermediate mixed feeders. In this study we investigated the effects of annual winter feeding on gastrointestinal tract of adult female reindeer. We also compared gastrointestinal tract of reindeer to adult female Finnish sheep (*Ovis aries*), which is classified as grass and roughage eater. The study included two groups of adult female reindeer, which were caught for slaughtering from natural pastures in early winter in Inari area. The test group (n = 10) had been in annual winter feeding several years prior the study. The control group (n = 10) had been grazing natural winter pastures every year. The sheep (n = 7) had been grazing summer and autumn grass pastures before the slaughter. The reindeer and sheep were weighed before the slaughter. After killing the animals the sections of gastrointestinal tract were separated and weighed with contents. After emptying and cleaning the organ tissues carefully the empty tissue weights were determined. The length of the intestines was measured. The teeth were also studied. The relative weight of rumen tissue was heavier (77% v 74%, sheep 65%) and the relative abomasum tissue was lighter (10% v 13%, sheep 18%) in the control group than in the test group. The control group had longer relative small intestine length than the test group (67% v 65%, sheep 77%). The relative reticulo-rumen content was heavier in the test group (19% v 14%, sheep 18%). The long term annual winter feeding had slight effects in the structure of digestive tract in adult female reindeer. The supplementary winter feeding wore down the teeth more than the natural winter forage of reindeer. Results from our study indicate that the digestion of reindeer is relatively well adapted to utilise different kinds of feeds. The anatomical gastrointestinal changes in reindeer given supplementary feed in winter indicate that these animals might be closer to the roughage eater, sheep, than the control reindeer without any experience of supplementary feeding.

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Comparative digestion in two sub-species of reindeer

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Digestive adaptations were investigated in high Arctic Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and Norwegian reindeer (*Rangifer tarandus tarandus*) on mainland Norway. The oral anatomy of both sub-species is characterised by large lips, narrow muzzles and small molar teeth adapted for a high degree of selection when the animals forage nutrient rich plants during the short Arctic summer. The wet weight of rumen contents was 13% of live body mass (LBM) in Svalbard reindeer in summer and as high as 20% of LBM in winter compared to 12 and 14% of LBM in Norwegian reindeer in summer and winter, respectively. Ruminal production of volatile fatty acids (VFA) was very high in Svalbard reindeer in summer but was almost not detectable in winter. Ruminal production of VFA did not differ significantly between summer and winter in reindeer in northern. Mean ruminal ammonia concentration was 310 mg/kg rumen wet weight contents in Svalbard reindeer in summer and only 100 mg/kg in winter, while in northern Norway ruminal ammonia concentration was 500 and 260 mg/kg summer and winter, respectively. Svalbard reindeer have several digestive adaptations typical of ruminants of the concentrate selector type with short intestines and a large distal fermentation chamber. In winter, however, when daily intake of digestible energy is very low, gastrointestinal fill is large in Svalbard reindeer and fermentation of fibrous materials is inefficient like that of grazing type ruminants. The digestive physiology of these two sub-species is thus highly seasonal, reflecting adaptation to widely differing seasonal diets in terms both of species composition and nutritional quality.

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Adaptation of reindeer calves to various diets

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Female reindeer (*Rangifer tarandus tarandus*) calves were studied in a situation imitating an adaptation from poor pasture to feeding. A control group was continuously fed a lichen diet (a mimicked winter diet with 80% lichens and 20% blueberry brushwood and willow leaves). After a restricted feeding period (50% of *ad lib* consumption plus one day of starvation) the other groups were fed either silage, reindeer feed (RF) and silage or RF and lichens. The reindeer responded to the restricted feed intake by changes in rumen metabolism (decreased amount of rumen content and DM, increased pH, lower concentration of total volatile fatty acids and decreased number of bacteria in rumen content), losses in empty live weight (ingesta excluded) and kidney fat. The reindeer fed the lichen diet after the feed restriction recovered immediately and showed similar consumption behaviour as the control group within four days. In contrast, severe health problems (malnutrition and so-called wet belly) and deaths occurred in the group fed mainly silage. This diet was reformulated into a RF diet (80% RF and 20% silage) and after two weeks of feeding the health status was stabilised. Diarrhoea occurred within the first week after resumed feeding in groups fed RF diets (80% RF and 20% silage or lichen) even though the feed rations were increased gradually. After five weeks of feeding the reindeer fed RF diets had increased empty live weight and kidney fat, whereas reindeer fed the lichen diet had lost empty live weight. The amount of rumen content was lower, dry matter content was higher, ruminal pH was about the same and total volatile fatty acid concentration was higher in reindeer fed the RF diets compared to reindeer fed the lichen diet. The conclusion so far is that the condition of the reindeer is critical at the start of feeding. After a period of limited nutrient intake health problems may occur when new diets are introduced. This does not happen when the reindeer are refed a lichen based diet. Further analyses involving rumen bacteria and protozoa, blood metabolites and animal behaviour are under evaluation and will provide a more complete picture of the response to the various diets.

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Ruminal fibre digestion in lichen-fed reindeer

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The effect of lichen (*Cladonia stellaris*) on rumen fibre digestion and bacterial population in reindeer (*Rangifer tarandus tarandus*) was investigated. Three male reindeer calves (age 5-6 months, body mass (BM) 45.3, *s* = 5.0, kg) were taken from a natural winter (October) pasture in northern Norway (68°N, 17°E), instrumented with permanent rumen fistulas and given *ad libitum* access to a pure lichen diet for 3.5 months. The lichen (*C. stellaris*) contained (on dry matter basis) 2.7% cellulose, 74% hemicellulose, 2.1% lignin, 2.4% crude protein and 1.2% water soluble carbohydrates. Daily food intake was stable throughout the experiment and ranged between 23.8 and 27.4 g dry matter / kg BM (calculated for day 92-97). Median (range) in vitro dry matter digestibility (IVDMD) of pure cellulose (Whatman filter paper no. 1) in rumen fluid from these animals was only 27.3% (22.8-33.0%) after a 48 hours incubation. Median (range) IVDMD of xylan (catalogue no. X-0627; Sigma) (48 hours incubation) on the other hand, was high (55.1% (55.0-57.2%)). Mean (*s*) ruminal pH was 6.36 (0.07), while total concentration of volatile fatty acids was 89.3 (5.7) mM, with acetate, propionate and butyrate contributing 71.8, 16.1 and 12.1 mol %, respectively. Median numbers of viable bacteria cultured on an anaerobic M8-medium (Olsen *et al.* 1994) containing 0.3% (wt/vol) xylan as sole carbohydrate, ranged between 4.0×10^7 and 10.6×10^7 per ml rumen fluid. Bacterial strains ($n = 67$) isolated from the rumen fluid were mainly strains resembling *Butyrivibrio* spp. (32.8%) and *Streptococcus* spp. (16.4%), but *Ruminococcus flavefaciens* (4.5%), *Eubacterium* spp. (7.5%), *Lactobacillus* spp. (9.0%), *Bacteroides* spp. (3.0%) and *Clostridium* spp. (6.0%) were also isolated. Ability to digest xylan was demonstrated in 9.1% of the strains, while 6.0% of the isolates were cellulolytic. Two of the cellulolytic strains resembling *R. flavefaciens*, were Gram positive, strictly anaerobic, non-sporulating coccoid bacteria in chains producing succinate and lactate as their main fermentation products. The other cellulolytic strain resembled *Eubacterium* spp. and was a Gram positive, strictly anaerobic, motile slim rod, producing succinate as the main fermentation product with trace amounts of iso-valerate and iso-butyrate. This is the first reported isolation of cellulolytic bacteria from the rumen of lichen-fed reindeer.

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Factors influencing the in vitro digestibility of lichens in reindeer

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Reindeer (*Rangifer tarandus tarandus*) eat a mixed diet of vascular plants and lichens in winter. Lichens are composed largely (> 70% DM) of hemicellulose and contain very little protein (< 4% DM) and cellulose (< 2% DM). Though generally highly digestible (> 75%) in reindeer, ruminal *in vitro* digestibility of lichens (e.g. *Cladonia stellaris*) appears to vary considerably between trials. We propose two alternative explanations for this: (i) adaptation of the rumen microbiota to the substrate prior to trials is critical owing to the unusual chemical composition of lichens and (ii) dried lichen is poorly wettable. Low digestibility of lichens in some trials might therefore reflect either the failure of micro-organisms to ferment a new substrate or inadequate mixing of the substrate with the digestion medium in the *in vitro* tubes. The *in vitro* dry matter digestibility (IVDMD) of lichen and grass was measured in a standard two-stage technique using fresh rumen fluid from two reindeer that had been fed a commercial pelleted reindeer feed (45% timothy) for several months. The substrates included (i) standard timothy (*Phleum pratense*), (ii) wet *C. stellaris* (26% water), (iii) dry *C. stellaris* and (iv) a mixture of *P. pratense* (70%) and dry *C. stellaris* (30%) to examine any synergistic effects. The 48 hour digestibility of *C. stellaris* was conspicuously low (9.4% IVDMD) compared to that of *P. pratense* (55.1% IVDMD). There was no difference in the digestibility of wet and dry lichen and no synergistic effect of combining the two substrates was found. Hence, the low digestibility of *C. stellaris* cannot be attributed to the physical characteristics of dried lichen and may thus reflect the fact that we used rumen fluid from reindeer which had been fed a diet containing no lichen. Substrate composition is known to have a major influence on the composition of the ruminal microflora in reindeer and the diet eaten by inoculum-donors influences the resulting IVDMD. An alternative explanation of the low IVDMD of *C. stellaris* might be a deficiency of nitrogen for microbial growth owing to the low nitrogen content of lichens. Effective urea recycling and a corresponding effective renal reabsorption of urea in reindeer probably ameliorates this effect in free-ranging reindeer eating a natural diet.

Session 2 Physiology II: growth and lactation

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The effects of wintertime undernutrition on serum lipids and the fatty acid composition in reindeer calves

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The effects of undernutrition on serum lipids and fatty acid composition were studied in male reindeer calves (< 1 y, *n* = 8) during mid-winter and spring, with a particular focus on the proportions of polyunsaturated fatty acids (PUFAs) in major serum lipids. The reindeer were fed mixed lichen (*Cladina* spp.) *ad libitum* for 5 weeks, followed by 40% restriction of energy for 8 weeks and re-feeding to normal with lichen and concentrated reindeer feed for 6 weeks. Significant decreases in body weight and increases in serum free fatty acid and glycerol concentrations were found during both the *ad libitum* and restriction periods. The concentrations of major serum lipids, cholesterol and phospholipids decreased sharply at the beginning of the *ad libitum* period and remained low throughout the restriction period. Similarly, the proportions of PUFAs in serum cholesteryl esters and phospholipids, especially those of linoleic acid and α-linolenic acid decreased sharply during the *ad libitum* period and further during the restriction period. The decreased proportions of PUFAs most probably reflect the low PUFA content of lichen although they may have been modified also by seasonal factors. The decreases in the major lipids and their PUFA proportions were quickly reversed during the re-feeding. The control group which was fed high-quality concentrates *ad libitum* gained weight most of the spring but showed similar although slower decreases in the major serum lipids and PUFAs than the lichen group. Our results show that feeding reindeer on lichen, whether *ad libitum* or restricted quantities, leads to the development of negative energy balance, retardation of growth and reductions in major serum lipids and their principal PUFA proportions. Despite the low supply of PUFAs from lichen, reindeer appear to tolerate deprivation of these lipids quite well and obviously have various physiological mechanisms to adapt to the development of negative energy and PUFA balance during winter.

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Antlerless females in Svalbard reindeer - nutrition or genetics?

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The frequency of antlerless, one-antlered and fully antlered females was recorded in the Reinsdyrflya reindeer herd, a sub-population of Svalbard reindeer. The antler status of female calves was related to their mothers' antler status. Group size and calf:cow ratios of females in the three antler categories was recorded. Dropped antlers and mandibles from carcasses were collected for comparison with earlier data. There has been no recorded change in the proportion of females in the three antler categories since 1974 ($P = 0.85$). No relationship was found between the antler status of a cow and her calf ($P = 1.0$). The calf:cow ratios were not significantly different among the three antler categories ($P = 0.21$). Antlerless females foraged in smaller groups than antlered ones ($P = 0.02$), but they did not seem to avoid one- and two antlered individuals. Population size in 1996 was probably only a fourth of the population size in 1974, but size of female antlers and mandibles recorded in 1974 and 1996 did not indicate any change in body condition.

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The effects of wintertime undernutrition on haematological and serum biochemical characteristics in reindeer calves

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The effects of long-term undernutrition on blood composition were studied in male reindeer calves (< 1 year) during midwinter and spring. The lichen group ($n = 8$) was fed mixed lichens (*Cladina* spp.) *ad libitum* for five weeks; followed by 40% restriction of energy for 8 weeks; and the re-feeding period with lichen and high quality reindeer feed for 6 weeks. The control group ($n = 8$) received high quality reindeer feed *ad libitum* throughout the experiment. Significant decreases were found in body weight and serum biochemical characteristics of the lichen group during both the *ad libitum* and restriction periods, reflecting the development of moderate undernutrition. Body weight of the lichen group decreased by 15% during the *ad libitum* and restriction periods and during the re-feeding period it increased by 23%. Body weight of the control group remained unchanged until the beginning of March, thereafter it increased by 31%. Serum total protein, urea and phosphorus concentrations of the lichen group decreased significantly already during the first weeks of the *ad libitum* period and remained low during the restriction period. The serum albumin concentration of the lichen group decreased slowly during the *ad libitum* and restriction periods. Serum creatinine concentration of the lichen group increased sharply in the beginning of the *ad libitum* period and remained high during the restriction period. The alkaline phosphatase concentration of the lichen group increased slowly after the beginning of March. During the first two weeks of the re-feeding period all serum values of the lichen group were reversed. Serum biochemical characteristics of the control group were relatively constant during the entire experiment, only serum alkaline phosphatase concentration increased after the beginning of March. Blood haematological values (leukocyte, erythrocyte and platelet counts, haemoglobin and haematocrit) fluctuated in both groups, but there were no major differences between the groups during the experiment. Our results indicate that reindeer can maintain in moderate body condition despite prolonged reduction in food and nutrient supply. The recycling of nitrogen and microbial protein synthesis in the rumen probably compensated the deprivation of protein in the lichen fed reindeer, because no indication of increase in degradation of tissue proteins was found.

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Antler development in reindeer in relation to age and sex

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Yearling male and adult female reindeer (*Rangifer tarandus tarandus*) are similar in size and shape. If sexual clues are hidden, it can be difficult to distinguish between them. Antlers can be a useful aid in classifying yearling males and adult females, depending on whether specific antler characteristics are identifiable for these two groups. Even though variation was large and there was overlap between the groups, significant differences were found. Using the 25 and 75 percent percentiles to separate between the groups, right antler height between

35 and 54 cm, width between 28 and 43 cm and circumference between 7 and 9 cm was classified to females. Corresponding measurements of 58-74 cm, 44-56 cm and 10-16 cm were classified as yearling males. Adult females had 3-8 tines and less than 2 tine split-offs, while yearling males had 10-12 tines and more than 2 tine split-offs. Antler width measured narrower than 21 cm in female calves and between 23-37 cm in male calves, allowing the most reliable antler characteristic for calf classification. Males 2.5 years old had antler height longer than 78 cm, antler width more than 60 cm and more than 13 antler tines. No difference was found in right antler circumference between yearling males and 2.5 year old males, both measuring 10-16 cm. This study shows that classification of reindeer sex and age by identifying antler characteristics is possible, but difficult.

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Overwinter changes in urea nitrogen:creatinine and cortisol:creatinine ratios in urine from Banks Island muskox

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Over 400 snow urine samples were collected from Banks Island muskox between March 1993 and May 1998. Most (n = 351) samples were collected during 3 time periods in 5 successive years: early winter (27 October-18 November), mid-winter (12-28 February) and late-winter (20 April-4 May). Samples were collected from areas of high (ca. 1 to 2 muskox/km^2) and low (ca. 0.3 muskox/km^2) muskox density. We determined the ratios of urea nitrogen:creatinine (U:C) and cortisol:creatinine (C:C) for each sample. U:C ratios had significant year, time and density effects. Ratios from animals in high density areas were higher than those from muskox in low density areas. Early and late-winter ratios were higher than mid-winter ratios. U:C ratios ranged from 0.10 to 18.66 mg/mg and were highest in 1997-98. U:C ratios for muskox were generally much lower than those of Banks Island Peary caribou, but higher than those of muskox sampled from SE Victoria Island. C:C ratios had significant time and year effects. Ratios were higher in early than mid- or late-winter and were higher in 1993-94 than 1995-96. Winter 1993-94 had severe icing conditions on southern Banks Island. C:C ratios of muskox were similar to those of Peary caribou. It is unlikely that the pattern of decreasing ratios U:C and C:C from early to mid-winter is indicative of inferior health and condition. Because muskox have a variety of physiological adaptations, similar to summer desert animals, they may have an unusual capacity to recycle and/or store nitrogen especially during the mid-winter period of almost total darkness and extreme cold. These adaptations to minimise energy requirements and expenditures during mid-winter may result in lowered U:C and C:C ratios during mid-winter. Physiological data from wild muskox populations during mid-winter are lacking therefore, one can only speculate on what the changes in U:C and C:C ratios we report represent in regard to animal condition.

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Effects of undernutrition on the muscle fibre area, fibre composition and proteolytic activity in reideer calves

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Metabolism of freely grazing reindeer shows seasonal adaptation due to changes in diet and climatic conditions. The mobilization of fat during winter is well established, but the changes in the protein and nitrogen metabolism are less well known. Earlier studies have shown decreases in plasma urea concentration during late winter/spring, which may reflect the low nitrogen content of lichen, and also indicate more efficient recycling of urea. Other studies suggest that in severe starvation or in extreme conditions, such as those of Svalbard reindeer, the use of proteins for energy production is accelerated. The present study was designed to investigate whether moderate undernutrition of reindeer calves causes any changes in muscle protein mass, as indicated by muscle fibre area and the activities of proteolytic enzymes. In the beginning of the experiment 8 reindeer calves were fed lichen *ad libitum* for 5 weeks. Thereafter the amount of lichen was within 2 weeks gradually decreased to 60% of their *ad libitum* intake, and the restricted nutrition was continued for 6 weeks. The control calves (n = 8) were fed reindeer feed *ad libitum* throughout the trial. Biopsy samples from the middle gluteal muscle were taken before and after *ad libitum* feeding and after the restricted feeding. Muscle fibre type composition and the crossectional area of the fibres and the activity of cathepsin B were analysed. During the restricted feeding the body weight decreased by 16%, and in the control group during the same pediod the weight increased by 11%. In both groups the fibre type composition did not change during the trial. Areas of type I and IIA fibres were increased in the control calves but showed no changes in the calves fed restricted amount of lichen. The activity

of cathepsin B decreased in both groups during the *ad libitum* period and remained low until the end of the experiment indicating that the rate of protein degradation was slower during late winter. It can be concluded that in the control calves the rate of protein synthesis was higher than the rate of protein degradation during the winter. In the undernourished group no signs of muscle growth were observed and thus the difference between the two groups must have been in the rate of protein synthesis. The results also indicate that during moderate undernutrition muscle tissue is not used for energy production.

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Rumen-protected methionine stimulations wool production, body weight gain and protein deposition in muskoxen

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Qiviut, the extremely fine, soft underwool of muskoxen, is considered to be one of the finest natural fibres in the world. Because of the high market value of qiviut, domestication efforts have focused on muskoxen as wool producing animals. Supplementing sheep and goat diets with rumen-protected methionine has been shown to cause rapid and dramatic increases in fibre growth and liveweight gains. We conducted two experimental trials and one field trial to evaluate the effects of supplementing muskox (*Ovibos moschatus*) diets with rumen protected sulphur-amino acids. In trial 1, sixteen muskoxen were blocked by age and sex and used to assess the palatability of four diets and their effects on Qiviut production. Animals were fed either no supplement (control diet); 68.3 mg rumen-protected methionine (Smartamine) x BW $(kg)^{0.75}$ x d^{-1}; 68.3 mg rumen-protected methionine (Mepron) X BW $(kg)^{0.75}$ x d^{-1}; or 1.92 g menhaden fishmeal x BW $(kg)^{0.75}$ x d^{-1} through the wool growth season (May 1 to Nov 1). Palatability of all four diets was high. Wool yields, measured by clipping known areas (mg/d), were greatest in the Smartamine group. In trial 2, we measured rates of wool production, body weight gain and hoof growth through the wool growth season for nine adult female muskoxen on a high plane (HP) or low plane (LP) nutritional regime. Rates of wool production, hoof growth and daily gain were greater in the HP animals ($P < 0.05$). Supplementation of both groups improved wool production (mg/d, mm/d) in the LP group from August to December and in the HP group from August to September ($P < 0.05$). Rates of body weight gain and overall hoof growth increased significantly in the LP group ($P < 0.05$). In trial 3, five adult males at the MODC commercial facility were given the Smartamine supplement with no modifications to the standard communal feeding regime. Results showed no effects either on combed qiviut yields or body weights for the supplemented animals when compared with those from a control group of five non-supplemented males. In spite of the negative results in trial 3, we advocate the efficacy of supplementing muskox diets with bypass sulphur-amino acids, especially for low plane diets. We suspect the lack of statistical effect in trial 3 reflects differences in basic feeding regimens practised during the pre-experimental and experimental nutritional periods. Differences were not limited to the pre-experimental period, since MODC animals received Purina pelleted ration and access to different grazing conditions through the experimental trial.

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Fatty acid binding to placental membranes of reindeer

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The developing foetus and the placenta require long-chain fatty acids to synthesise complex lipids necessary for structural membranes and molecules involved in cellular signalling and immune responses. Studies in several mammalian species have shown that the placenta is capable of preferential transportation of long-chain polyunsaturated fatty acids (LCPUFA) from the maternal circulation by a specific fatty acid binding protein system. In order to find out if such a fatty acid binding/transport system is present in reindeer, we studied the binding of various long-chain fatty acids to membranes of full-term (ca. 7 mo.) placenta of reindeer. Binding of radiolabelled oleic, linoleic, arachidonic and docosahexaenoic acids to reindeer placental membranes was determined using a radioligand binding assay. The results indicated that the fatty acid binding to reindeer placental membranes was time and temperature dependent. Equilibrium of [14]oleate binding was attained by 20 minutes, with an optimum binding temperature of 37 °C for all of the fatty acids in the study. The reversibility of binding for all of the fatty acids was demonstrated by a decrease in binding 85%, when a 20-fold excess of the corresponding unlabelled fatty acid was included in the incubations. Treating the membranes with trypsin resulted in inhibition of the fatty acid binding indicating that the binding sites are protein in nature. The degree

of inhibition after treating the membranes with trypsin appeared to be greater for linoleic, arachidonic and docosahexaneoic acid compared with oleic acid. The specific binding value for each of the fatty acids seemed to be similar. There also appeared to be little difference in the inhibition of oleic acid binding by different unlabelled fatty acids. These results are preliminary findings and further experiments need to be carried out with more specimens for definitive conclusions. However, this data indicates that the reindeer placenta may contain plasma membrane fatty acid-binding/transport proteins similar to those found in sheep and human placentas, with capability of preferential transportation of LCPUFAs from the maternal to foetal circulation. The existence of such a fatty acid transportation would be of particular importance for the development of foetal reindeer, as the major winter diet of reindeer, lichen, contains small amounts of lipids and polyunsaturated fatty acids.

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Leptin, insulin and body condition indices: their relationships in reindeer

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Leptin, a polypeptide hormone secreted by white adipose tissue, is thought to be a metabolic signal that regulates whole body energy homeostasis by influencing food intake and energy expenditure via central and peripheral mechanisms. If leptin plays a universal role in the modulation of energy balance, then it should be detectable in the circulation and its seasonal trends and relationships to feed intake and body fat reserves should be well expressed in highly seasonal animals. A study was designed to test the hypotheses that the ob gene product leptin is present in reindeer by determining levels of circulating serum leptin and that leptin level either alone, or in combination with insulin, will correlate with fat reserves. We evaluated the relationship between leptin, insulin and body condition indices in reindeer in winter during naturally changing voluntary food intake. Our results suggest that leptin concentration correlate with body mass but not with fat. We documented a highly significant inverse relation between serum leptin and serum insulin levels suggesting a state of relative leptin resistance with possibly decreased insulin sensitivity in reindeer during seasonal winter hypophagia.

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Photoperiod-associated changes in serum insulin levels in reindeer

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Seasonal hyperinsulinemia occurs during summer hyperphagia and maximum fat deposition in reindeer, which suggests a possible role for insulin as an appetite regulator with direct consequences for a regulatory role of seasonal fattening. We tested the hypothesis that the annual insulin cycle is driven by photoperiod and affects food intake in 4 non-pregnant female reindeer prior, during and after winter solstice. We measured body condition indices, voluntary food DM intake, meal-patterns, an index of alimentary fill, serum insulin, serum glucose and serum lactate. Our results support the hypothesis that insulin is photo-periodically-regulated. This gives credence to the possibility that insulin is a seasonal pacesetter for the observed seasonal appetite cycle, body growth and body composition changes in reindeer.

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Behavioural influence on duration of lactation in muskoxen may not be nutritional

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We provide evidence that nursing behaviour can influence the duration of lactation in muskoxen. Whereas muskox females generally nurse their calves for approximately 8-9 months, between 1988 and 1994, six muskox calves at the Large Animal Research Station were nursed for approximately 18 months and they entered a breeding pause. The results showed the relation between nursing behaviour and the duration of lactation, however factors such as calf body mass and milk intake were not investigated. We hypothesised that these calves were in need of increased nutrition, therefore they are likely underweight and make more frequent attempts to nurse in order to receive more milk. Undernourished calves of lighter body mass possibly received less milk than normal calves early in lactation. To test these predictions we examined behavioural, body mass and milk intake data for six pairs of 'sibling' calves. Each calf pair consisted of a calf exhibiting prolonged nursing and a calf weaned at the normal time from the same cow. We used three measures of nursing behaviour: total time spent nursing per day, mean number of nursing attempts per day and mean daily nursing bout duration. Body mass was recorded for each calf at regular intervals beginning at birth and continuing throughout the first three

to four years of life. We used the same prolonged-normal pairs as the behavioural analysis to compare calf body mass at birth, rut, the first possible weaning period and final weaning for the prolonged calves. Milk intake was measured three times in summer, once in early winter and opportunistically for those cows nursing past one year. Calves exhibiting prolonged nursing had significantly more nursing attempts than normal calves before rut ($P < 0.005$), however they were not of lower body mass. This does not support the prediction that the calves were in need of increased nutritional support. These calves also spent more time per day nursing than normal calves from 6 weeks of age until the end of the post-rut period ($P < 0.05$), however the behaviours were not associated with an unequivocal increase in milk intake. Thus, the hypothesis that the calf provides behavioural feedback to the dam that influences the duration of lactation is supported. However, we have neither evidence that the expressed nursing behaviour is a consequence of prior nutrition nor that the dam responds to the behaviour with an immediate increase in milk synthesis.

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Use of host-mimicking trap catches to obtain data for parasitic flies associated with reindeer

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Catches in baited insect traps and from models that mimic hosts in attracting parasitic flies accurately reflect the species composition of the attacking fly fauna and the relative seasonal/daily abundance of different species. Such trapping studies conducted 360 km north of the Arctic circle in Norway also provided data on comparative densities of flies in different habitats and the types of climatic factors that favoured the host-seeking activity of different species. Trap catches revealed that the largest numbers of blood sucking culicids and simuliids were trapped during climatic conditions that suppressed the host-seeking activity of *Hypoderma tarandi* L., *Cephenemyia trompe* (Modeer) and various species of blood sucking Tabanidae. Videotape analysis and catches from a baited model provided information on body sites attacked. In studies during three different years we obtained trap catch data for 7 species of Tabanidae, 4 species of Culicidae and several unidentified species of Simuliidae and Ceratopogonidae.

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Changes in bioavailability of radiocaesium from 1986 to 1998 in lichen contaminated by the Chernobyl accident

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The availability of ^{137}Cs and ^{134}Cs for absorption depends on the chemical form of the radionuclides in ingested material. Lichens, which intercept deposited radioactivity directly, will shortly after a contamination event be the most radioactive plants in the diet of reindeer. Intercepted radioactivity will be incorporated in lichen tissues, both in ionic and apparently also in particulate form. Ionic forms of Cs are highly available for absorption, while the radionuclides may be unavailable for extraction by the digestive processes of reindeer when present in particles formed in a reactor or during an atomic explosion. We have tested lichen, which has grown undisturbed during the period 1986 to 1998 in a high alpine area in S. Norway where deposition of radiocaesium from the Chernobyl reactor accident was 50-100 kBq m^{-2}. Lichen were picked by hand, and fed to 4-6 reindeer calves kept in metabolism cages for 6-7 weeks. In 1986 and 1988 30-40 % of the total radiocaesium in lichen was ^{134}Cs of Chernobyl origin, and no experiments with extra ^{134}Cs were done. However in 1995 and 1998, most of ^{134}Cs had decayed (physical halflife 2.2 years). It was therefore possible to compare the bioavailability of ^{137}Cs remaining in lichen from the accident with ^{134}Cs-chloride in aqueous solution. The latter was taken to be 100% bioavailable. Transfer to red blood cells (RBC) was calculated as Bq per liter RBC per Bq of radiocaesium ingested. The bioavailability of the ^{137}Cs in lichen was calculated relative to $^{134}CsCl$ from the concentration ratios of the two isotopes in red blood cells after 6-11 weeks of feeding. Average transfer in 1995 and 1998 was used to calculate availability in 1986 and 88.

Year	^{137}Cs from lichen		^{134}Cs from CsCl		RBC-ratio
	Intake (kBq d^{-1})	Transfer to RBC (L^{-1} *10^{2})	Intake (kBq d^{-1})	Transfer to RBC (L^{-1} *10^{2})	^{137}Cs/^{134}Cs
1986	9.5	3.45	-	-	0.31
1988	15.0	4.30	-	-	0.39
1995	8.4	3.25	6.7	9.57	0.34
1998	8.9	5.7	16.5	12.6	0.45

It is concluded that approximately 1/3 of the radiocaesium in lichen was in a bioavailable form in 1986. The transformation of radiocaesium from the Chernobyl accident from unavailable to more bioavailable species occurs very slowly, if at all, when deposition is trapped in living lichens. Contamination of reindeer would have been 2-3 times higher if all radiocaesium was available for absorption

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Early reindeer calf mortality

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To register the causes of death in reindeer calves from birth up to six months of age, 600 tagged female reindeer in a study group have been placed in a large fenced area during the calving period in May. The females were weighed at arrival, dewormed and continuously fed pelleted reindeer fodder and silage. The calving ground was supervised and all calves found dead were necropsied. In the beginning of June the animals were rounded up and calves were weighed, counted and ear tagged. About one third of the calves received a subcutaneous mortality telemetry transmitter implant along the vertebral column, between the scapulae. The reindeer were then released for free range grazing on the summer pastures. Regular helicopter surveillance located any activated calf transmitters and collected the carcasses for necropsy. At ordinary summer round-ups for calf marking, the study group was counted and calves were weighed. At the autumn round-up the study group was counted, weighed and dewormed. Blood samples were taken for pregnancy diagnostics and faecal samples for helminth examination. Expected positive effects in reindeer husbandry with a fenced calving area was better protection against predation, a better growth potential for calves born by supplementary fed females and a higher calf survival rate. Early calf marking in June is made possible and repeated gatherings of the reindeer during the anabolic period in hot July and August weather can be avoided. So far the preliminary results seem to be positive in terms of more surviving and heavier calves at the autumn gathering, compared to the control animals, a herd kept as free range grazing reindeer all year around. Diagnosed mortality causes have been starvation, predation, abortion, dystocia, disease, accidents and so far, one malformation, a cleft palate.

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Toxovars of *Clostridium perfringens* isolated from reindeer in Arctic Northern Europe and from sheep in tropical West-Africa

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This study is a contribution to evaluate the importance of enterotoxemia in ruminant production systems in different climatic regions of the world to improve the protection of livestock from outbreaks. *C. perfringens* is the causing agent of enterotoxemia of huge economic importance in ruminant production. Ingested together with fodder it reaches and colonises the small intestine. The presence alone of this bacteria does not cause disease. Sudden changes in climatic conditions and in nutrition and the infectious agent are important factors in causing enterotoxemia. Shifting of ruminants to fodder rich in carbohydrates (e.g. winter pasture of reindeer composed mainly of lichens or emergency concentrate supplementation feeding) and/or fodder rich in proteins (e.g. onset of the rainy season and oversupply of young fresh fodder in the tropics) makes undigested feeding stuff reach the small intestine as protozoa and bacteria in the rumen fluid are not yet adapted to deal adequately with the new fodder. This creates optimal growing and multiplication conditions for *C. perfringens* eventually producing large quantities of toxins leading to an outbreak of fatal enterotoxemia. It is of major concern as mainly the best fed animals are lost. Twenty-one isolates from faeces of reindeer from Kaamanen Research Station in Finland and one hundred and fifty isolates of *C. perfringens* from faeces of sheep in Benin were typed in the Free University of Berlin using the EIA method. Eighteen isolates of *C. perfringens* from reindeer were typed as

toxovar A, one as toxovar C and two as toxovar D. One hundred and forty one isolates of *C. perfringens* originating from sheep were typed as toxovar A and nine as toxovar C. Toxovars B and E were not found. Emphasis must be given on the isolation from reindeer of toxovar C known as causing 'Struck' in sheep and toxovar D the causative germ of the classic form of enterotoxemia in sheep the 'Pulpy Kidney Disease'. Finding of different toxovars in faeces of healthy reindeer and sheep does not prove but suggests an involvement of these strains in causing enterotoxemia and makes assume a world-wide epidemiological danger.

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Trace minerals in northern ruminants: copper and ceruloplasmin

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Trace mineral reserves may be crucial to maintenance of body tissues and the development of reproductive tissues in ungulates at high latitudes. Body reserves must be established when forage is available in spring and summer to sustain biochemical activities throughout winter. Copper, zinc and iron comprise the catalytic centers of numerous metalloenzymes for extra-cellular, cytoplasmic and nuclear functions in blood, skin and reproductive organs. Mineral reserves were measured in the digestive tract, liver, and kidney of six male *Rangifer tarandus* fed a complete pelleted ration during October and November. Dry matter content and absolute amounts of Cu, Zn and Fe were highest in the liver. Digesta contents of Cu and Zn were greatest in the rumen but dry matter concentrations were greatest in the cecum. This suggests hepatic storage of Cu and Zn with excretion into the hindgut via biliary secretion. Serum ceruloplasmin (an oxidase containing Cu) activity was related to liver copper in 14 captive *Rangifer* (r^2 = 0.837). Ceruloplasmin was assayed by oxidation of o-dianisidine (7.88-0.99 mM) which was degraded in a linear fashion from 15 to 30 min. Michaelis-Menten kinetics of ceruloplasmin were measured in sera from captive *Rangifer* (n = 3), *Ovibos moschatus* (n = 3), and *Alces alces* (n = 3). Maximum velocities (V_{MAX}) were 42, 20 and 9 ($IU.L^{-1}$); kM were 0.38, 0.55 and 0.62 (mM) for *Ovibos*, *Rangifer* and *Alces* respectively. Free-ranging *Rangifer* (n = 3) from the Teshekpuk herd and *Alces* (n = 3) from the Colville River had lower V_{MAX} (7 $IU.L^{-1}$) and higher kM (1.9mM) than the captive animals. Although V_{MAX} may decline with the amount of enzyme circulating in each species, increasing kM indicates decreasing affinity for the substrate. These kinetic parameters probably reflect differences in Cu transport between species as well as differences in tissue reserves within each species. Serum ceruloplasmin activity is a non-lethal method for monitoring hepatic Cu reserves in wild and captive populations within a species.

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Safety of *Brucella abortus* Strain RB51 Vaccine in Reindeer

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Control of brucellosis in Alaskan reindeer is currently done through a safe and effective vaccination program using a killed *Brucella suis* type 4 vaccine. Nevertheless, the development of *B. abortus* strain RB51 vaccine for use in American cattle may offer a beneficial alternative. RB51 is a rough mutant of virulent *B. abortus* strain 2308 that is deficient in O-side chains of lipopolysacharrides on the bacterial surface. RB51 is less expensive than the current vaccine but, more importantly, RB51 protects against abortion without producing antibodies that interfere with the interpretation of standard serologic tests. RB51 has proven safe and effective in cattle and, more recently, in bison and elk. The objective of this study was to evaluate the safety of RB51 in pregnant reindeer. We used pregnant adult reindeer housed in a 1-hectare, outdoor paddock at the Institute of Arctic Biology. Animals used in this study have a proven breeding history, were seronegative for *Brucella* (card and plate tests) and no abortions have occurred in this herd for over 12 years. To maximise sample size, we did not use a saline injected control group; instead, we utilised the herd's reproductive history. All animals were previously habituated to the handling procedures used in this experiment. Pregnant reindeer (n = 23) were vaccinated with 1 x 10^9 colony forming units of RB51 vaccine on January 22, 1999 by a subcutaneous injection in the left neck. On the day of vaccination and for 4 weeks thereafter, all animals were blood, urine and faecal sampled for serologic testing and culture. Subsequently, animals are being bled biweekly until calving. As of February 28, 1999 we have had four abortions occurring on day 32, 34 and two on day 37 post-inoculation. One vaccinated, pregnant cow was slaughtered 35 days post-vaccination because of a leg injury that occurred prior to this experiment. Marked endometritis and/or placentitis was grossly evident in all 4 abortion cases and, although slightly less severe, these lesions were present in the slaughtered, pregnant cow. Confirmation of an etiology awaits histopathology and cultivation. However, for a herd with no previous abortions, the 17% (4/22) abortion

rate and 22% (5/23) placentitis rate within 37 days of vaccination suggests that the vaccine may be responsible. Final results will not be available until calving is completed in April, 1999. At this time, we are unable to recommend use of RB51 vaccine in pregnant reindeer, however, it may still prove useful in a high incident herd.

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Heavy metals and trace elements in reindeer from Rybatsjij Ostrov, North Western Russia

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Previous studies have found highly increased levels of arsenic and nickel and increased levels of chromium, cobalt copper, selenium and zinc in Norwegian reindeer at Jarfjord and Pasvik near the Russian border. The increase of these elements resulted from atmospheric transport of industrial pollution from the Russian towns Nikel and Zapoljarnij. There is, to our knowledge, no data available from reindeer in Russian areas. In the present study, reindeer that had lived in Rybatsjij Ostrov, a peninsula in northwest Russia were analysed for heavy metals and trace elements. Rybatsjij Ostrov is a similar distance north east of Nikel and Zapoljarnij as Jarfjord and Pasvik are to the north and west. Samples of livers and mandibles from yearlings and adult reindeer of both sexes were collected at slaughtering in Varangerbotten, East-Finnmark, Norway, in March 1997 immediately after the animals were transported live from Russia. Liver tissues from 40 reindeer were analysed for the concentrations of arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, and zinc. The corresponding mandibles were used for age determination. The concentrations of arsenic and nickel in the Russian reindeer were similar to those found in Pasvik reindeer and were about one third of the levels found in reindeer from Jarfjord. The median levels of cobalt, copper, selenium, and zinc in the Russian reindeer were 30-80% higher than median levels in reindeer from western Finnmark. The levels of cadmium, mercury and lead were not significantly greater than in reindeer from western Finnmark. The concentrations of cadmium increased significantly with age in the Russian reindeer ($r^2 = 0.48$, $P < 0.001$) confirming the particular persistency of cadmium. The levels of nickel decreased significantly with age ($r^2 = 0.35$, $P < 0.001$). The elements that were most increased above a background level, nickel and arsenic, were far below levels of toxicological significance to the animals. None of the other elements analysed demand further assessment, and the measured heavy metal concentrations are harmless to human consumers of reindeer organs.

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Influence of the global pollution on lichens and reindeer on the Russian tundra

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In 1994-98 the study of global atmosphere pollution effect on the food chain lichen-reindeer was conducted in the 12 regions across the Russian Arctic (Kola Peninsula, Kanin Peninsula, Yamal Peninsula, Taymyr, Olenekskiy Bay, the Yana basin and the number of Arctic islands - Novaya Zemlya, Kolguev, Belyi, New Siberian Islands, Ayon, Wrangel). The accumulation of organochlorines (OCs) was determined in lichens (n = 36), muscles (n = 26), kidneys (n = 18) and livers (n = 24) of reindeers. OCs were detected in all the regions of the Russian Arctic. The main pollutants among OCs are pesticides (HCH, DDT) and industrial chemicals and byproducts refer to a group of chemicals called polychlorinade byphenyls (PCBs). OCs content in livers of reindeers (HCH 1.5 – 5.5 ng/g ww; DDT 1.5 – 7.5 ng/g ww; PCBs 2.5 – 14.5 ng/g ww) which 5-10 times more than in muscles and 2-5 times more than in lichens. Polynuclear aromatic hydrocarbons (PAHs) were determined in lichens (n = 36) and reindeer livers (n = 36). In all the regions 12-14 types of PAHs were detected in lichens - the main pollutants among them in food chains 'lichen-reindeer' are Anthracene, Pyrene, Phenantrene and Fluoranthene. The content of these PAHs in reindeers' livers (Phenantrene 8-40 hg/g ww; Anthracene 5-10 ng/g ww; Pyrene 15-30 ng/g ww; Fluorenthene 10-30 ng/g ww) are 2-3 times higher than in lichens. The conducted investigation showed that OCs and PAHs accumulations in the lichens-reindeers food chains of the Russian Arctic region are mainly the result of the global atmosphere pollution, transborder input of those pollutants from lower latitudes.

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Potential value of *in vitro* antigen-specific IFN-gamma assays for the diagnosis of Brucellosis, Tuberculosis, Paratuberculosis and Infectious Bovine Rhinotracheitis in wild ruminants

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In the different Member States of the European Union, eradication programs for bovine tuberculosis (*Mycobacterium bovis*) and bovine brucellosis (*Brucella abortus*) were initiated in the sixties, the vast majority of the cattle herds (> 99.5%) being nowadays declared officially free in Northern Europe. Paratuberculosis (*M. avium* subsp. *paratuberculosis*) and Infectious Bovine Rhinotracheitis (IBR) control programs are currently under progress. Reintroduction of these diseases from non conventional sources, i.e. free ranging wild ruminants, ruminants in zoological parks, farmed cervids (*Cervus elaphus*) or bisons (*Bison bison*) is a possibility that has to be taken in consideration. A practical cost-effective in vitro assessment of the specific cellular mediated immunity (CMI) should overcome, at least partially, the repeated immobilization problems of wild rumunants and other inherent limitations linked to the *in vivo* nature of the skin test for tuberculosis and paratuberculosis. It could also overcome some of the limitations of serological tests for IBR (maternal antibodies) and brucellosis (false positive serological results). We adapted a commercial IFN-gamma test developed in Australia in the context of tuberculosis for the diagnosis of IBR (Godfroid *et al.*, 1995) and brucellosis in cattle. The reactivity of IFN-gamma is species specific in the bovidae family and cross-reactivity for the red deer has also be evidenced. In a first stage we detected tuberculosis (confirmed by *M. bovis* isolation) in three skin test positive bisons (*B. bison*) in a zoo, using the IFN-gamma test kit. In a preliminary field study, we have used IFN-gamma assays in a bison herd, in parallel with the classical serological tests (IBR, brucellosis) or skin tests (tuberculosis, brucellosis) to certify the absence of these diseases. This test is currently under investigation in a paratuberculosis infected deer farm (*C. elaphus*). Our preliminary results suggest that the assessment of the CMI for different infections by the same *in vitro* cytokine release assay, should be further evaluated in the context of different infectious diseases in wild ruminants.

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Histopathological responses to radio-collars in caribou and muskoxen

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Caribou *Rangifer tarandus* and muskoxen *Ovibos moschatus* are frequently fitted with radio-collars and we assume that wearing those collars has relatively little effect on the animal. To investigate this assumption, we have described the appearance of the neck and have taken skin biopsies during removal of both conventional and satellite transmitters worn for up to 3 years. In caribou, hair breakage to a stubble is common for late winter pelage but not in summer pelage. Muskoxen had no hair loss, breakage and only some minor matting. Skin biopsies reveal that animals show some minor degree of skin thickening and inflammatory cells.

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Parasitic nematode larval densities and calving ecology of barren-ground caribou in the Northwest Territories, Canada

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In the NWT, barren-ground caribou *Rangifer tarandus groenlandicus* concentrate at high densities on annual calving grounds at a time when output of abomasal nematode larvae may increase. Calving grounds, it has been proposed by Folstad *et al.* 1991, '...may develop into transmission foci for parasites, where females and their susceptible calves would experience intense parasitic transmission'. We are investigating the significance of whether the high caribou densities on the calving grounds lead to build-up of parasites. Although calving distribution annually overlaps, we also have documented a directional shift in the annual overlap that leaves calving areas unoccupied for decades before the calving use returns. Our results on parasitic nematode faecal loads and overwinter larval survival on the Bathurst herd's calving grounds contribute to understanding the role of parasites in calving ground ecology.

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The population dynamics of parasitic nematodes of Svalbard reindeer (*Rangifer tarandus platyrhynchus*): species differences in age intensity and seasonality

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Abomasal parasitic nematode populations in Svalbard reindeer are dominated by two main species (*Ostertagia gruehneri* and *Marshallagia marshalli*) that are 100% prevalent in adult reindeer. Analysis of 268 abomasum from 217 known age females and 51 known age males from two different populations revealed similar species profile to that found by Bye & Halvorsen (1983). Here we demonstrate that the two species operate different life history strategies with respect to seasonality and intensity in relation to the age of the reindeer host. This suggests that the two species have different strategies for transmission. The seasonality and age intensity relationships were analysed using negative binomial distribution. In recognition of theoretical studies that have shown that the dispersion parameter k is positively related to abundance we demonstrate that allowing k to vary linearly improves the model. Age intensity relationships were investigated by including a gompertz function and seasonality by using a sine function. The nematode population of calves of both sexes was almost exclusively composed of *M.marshalli* (n = 51) and by the end of their first winter intensity was 6400 and similar to that found in yearlings and adults at that time of year (χ^2 = 0.008, df = 2, P = 0.93). In contrast, *O. gruehneri* abundances did not increase significantly over the reindeers' first winter (χ^2 = 0.95, df = 2, P = 0.62), but started to increase at the end of their second summer and showed little change with respect to reindeer age after 3 years of age. *O. gruehneri* showed little within year variation although there was some evidence for between year differences in abomasal intensity. Although *M. marshalli* intensity appears consistent across years in adults there was strong evidence for seasonal fluctuations Whilst *M. marshalli* populations were lower in one population, they both exhibited minima that occurred in October and a maxima in March/April. The amplitude of the wave as a proportion of the mean was the same in both populations. Evidence from faecal egg output of animals in the summer mirrors the species differences with *M. marshalli* eggs only appearing in winter and strongyle type eggs peaking during the summer months. Adult animals treated with an anthelmintic in April/May showed patent infections two months later indicating transmission does occur in the summer. However, increasing burdens of M.*marshalli* in adults over winter indicate the possibility that winter transmission takes place and is reinforced by data from calves where the nematode population is dominated by *M.marshalli*.

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Parasite biodiversity in Arctic ruminants and the influence of climate on transmission dynamics

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Little is known about parasite biodiversity and host-parasite systems in ruminants at high latitudes. Large ruminants are critical components of Arctic ecosystems, thus knowledge of these host-parasite systems is necessary to understand and predict potential impacts from anthropogenic and climatologically driven change. Recent discoveries highlight the paucity of baseline knowledge of parasite faunas in Arctic North America: 1) discovery of a large lungworm *Umingmakstrongylus pallikuukensis* in muskoxen; 2) description of a new species of *Teladorsagia* in muskoxen and caribou; 3) recognition of unidentified muscle-dwelling protostrongylids and trypanosome-like blood parasites in Dall's sheep; and 4) enigmatic reports of unidentified protostrongylid larvae in moose, caribou and muskoxen in Alaska and Canada. Although there is much information concerning parasite transmission, host-parasite interactions and parasite induced pathology in domestic ruminants, with the exception of *Elaphostrongylus rangiferi* in reindeer, little is known about these aspects of parasitism in wild Arctic ruminants. One key factor influencing parasite transmission is environmental temperature. Recent evidence indicating ongoing global climate change suggests that warming is most pronounced in the polar regions. Fifty-one year temperature records for the Mackenzie and Arctic tundra regions of northern Canada indicate a warming trend of 1.1 °C and 0.9 °C, respectively. They also show that 1998 was the warmest summer on record by 2.5 and 3 °C, respectively. These increased temperatures, particularly during the summers, could have significant effects on parasite transmission and, as a result, on parasite prevalence, intensity and geographic distribution in host populations. A system has been developed for monitoring the development of *U. pallikuukensis* in its gastropod intermediate hosts in the Arctic that has potential as a model for assessing the effects of temperature change on parasite dynamics in the Arctic environment. More research is critical to define the parasite fauna of Arctic ruminants and understand the potential effects of climate change on host-parasite systems and emerging disease.

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Studies of *Elaphostrongylus rangiferi* in caribou of Newfoundland

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Elaphostrongylus rangiferi was introduced onto the island of Newfoundland, Canada, with reindeer transported from Norway in 1908. The parasite has since spread throughout most of the major caribou herds on the island and has caused at least 2 epizootics of cerebrospinal-elaphostrongylosis (CSE). It remains absent from mainland Canada. Studies being initiated on the biology, pathogenesis and epizootiology of *E. rangiferi* are confounded by concurrent infections of *P. andersoni*, a related elaphostrongyline nematode. Adult *P. andersoni*, are located deep within skeletal muscles and are difficult to detect. They do not cause neurologic disease but their high larval output contributes to an extensive verminous pneumonia seen in young caribou. Progress in developing strategies to separate the effects of these two parasites and in identifying factors responsible for epizootics of CSE will be presented.

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Exposure rates of muskoxen on Banks Island, Northwest Territories to yersiniosis

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The Department of Resources, Wildlife and Economic Development, Inuvik Region documents the incidence of diseases and parasites in muskoxen harvested at commercial harvests conducted on Banks Island. The proportion of animals harvested that showed clinical signs of having been exposed to yersiniosis (calcareous deposits in lymph nodes and surface of liver) varied among years. In fall 1997, approximately 20% of the animals harvested showed clinical signs of having been exposed to yersiniosis at one time or another and had recovered. During the 1997 harvest, samples of intestine were collected from 350 muskoxen of all age and sex classes and tested for yersiniosis antibodies using ELISA. Seventy-five percent of those animals tested positive for yersiniosis antibodies, 20% were suspicious and 5% tested negative.

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Attempts to eradicate reindeer parasites (*Hypoderma tarandi*, *Cephenemyia trompe* and *Linguatula arctica*) on an island in northern Norway

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Ivermectin is now used extensively to reduce the abundance of parasites in many reindeer herds in northern Fennoscandia. In the autumn of 1995 and 1996 all reindeer were treated with ivermectin in an attempt to eradicate the warble fly (*Hypoderma tarandi*), the nose bot fly (*Cephenemyia trompe*) (Diptera: Oestridae) and the sinus worm (*Linguatula arctica*) (Pentastomida: Linguatulidae) from the island of Silda (42 square km). The island is situated 2-3 km off the mainland in Finnmark, northern Norway and harbours about 475 reindeer in the summer. Unexpectedly, one and two years after treatment the abundance and prevalence of the target parasites were at the same level or even higher compared with results at the start of the trial. We did not succeed in eradicating any of the three target parasite species even if all reindeer were treated two years in succession. Our main hypothesis is therefore: The warble and nose bot flies from untreated reindeer on the mainland had flown to the island the summer of 1997, possibly also in 1998 (both summers were exceptionally warm). Oestrids are known to be good flyers, even if it is somewhat surprising that they are willing to cross 2-3 km of Arctic waters. We have no good explanation why we did not succeed to eradicate *L. arctica*. With its known life cycle, this species should be easy to eradicate, but the results indicate that there may be elements in its life cycle that are unknown. The present results suggest that it will be very difficult or impossible to eradicate these parasites permanently, even locally such as on islands. Treatment seems only to have limited effects on the three parasite populations and it is tempting to suggest that parasite treatment in reindeer is quite unnecessary in many cases.

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Effect of ivermectin on reindeer dung fauna

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Ivermectin is used against parasites in semi-domesticated reindeer (*Rangifer tarandus* (L.)) in Scandinavia and Finland. Most of the injected drug is excreted unchanged in the faeces and several studies have shown that ivermectin in cattle dung disrupts survival of dung inhabiting insects. In this study, we investigated possible negative effects of ivermectin on the reindeer dung fauna. Four reindeer calves were injected subcutaneously with standard doses of ivermectin in early December. The daily produced faeces was collected until day 30 after treatment and the concentration of ivermectin was determined by high pressure liquid chromatography (HPLC) using fluorescence detection. The highest concentration measured was on day 4 after treatment. The concentration approached zero on day 30. Field studies showed that the most important coprophilous beetles and flies were not detected in dung from the winter season whether it contained ivermectin or not. Treatment against reindeer parasites (usually done in autumn/early winter) implies that summer dung, which is the dung that can be utilised by the important coprophilous species, will not contain ivermectin. The results indicate that the current treatment practice in autumn/early winter does not constitute a serious threat to the coprophilous fauna and their part in the decomposition process of reindeer dung.

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Calving and calf mortality at the Experimental Field Station in Kaamanen 1970-*97*

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At the Experimental Field Station of the Association of Reindeer Herding Co-operatives calving and calf mortality of semi-domesticated reindeer has been followed up for ca. 30 years. The data of this experimental herd has given long-term information, e.g. of the effect of maternal weights on calving, that would be very hard to collect in natural conditions. In this study we present the updated data on calving and calf mortality in the experimental herd during years 1970-97. During this time 1886 calves were born at the field station in Kaamanen. The average starting date of calving was 7 May and the date when 50% of the calves during the calving period had been born was reached in average on 19 May. The average calf-% of adult hinds (3-year-old and older females) was 83%. The calf-% has increased close to 90% after the 1980s as a consequence of antiparasitic treatment and increased supplementary feeding. The average birth weight of calves born was 5.4 kg and male calves were approx. 300 g heavier than female calves. Sex-ratio of calves was slightly male-dominated being 1.06 male against one female. In contrast, male calves suffered of higher mortality, thus equalising sex-ratio after first six months of life. The time of calving, maternal age and maternal weight had clear correlation to the birth weights and survival of calves. The average calf loss rate during 1970-97 was 22% (4 to 89%) and the large variation observed in annual mortality rates seemed to be in connection with the variation in annual natural conditions, e.g. in snow conditions. Most of the mortality during calving period (before10 June, 42% of total six months mortality) was observed already during the first post-calving days. Still, 58% of the total calf loss during first six months took place after calving period during summer and autumn. As causes for calf mortality during the calving period abortion (20%), weakness of calf (20%), pathophysiological causes (acute inflammations, diseases and parasites altogether 9%), predation (6%), accidents (5%) and maternal rejection (7%) were observed. In 33% of the cases during calving period the cause of death remained unknown. After calving period only few cases of deaths could be identified cause-specifically.

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Reindeer calf mortality in reindeer herding co-operatives of Hammastunturi and Muddusjärvi

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Reproduction, growth and survival of reindeer are the main ecological factors affecting the productivity of reindeer husbandry. As nowadays over 70% of all annually slaughtered reindeer in the Finnish reindeer husbandry area are calves the economical income of reindeer herders is increasingly dependent on calving and calf survival. To investigate the rate and causes of reindeer calf mortality a research project was started in summer 1994 in Hammastunturi and Muddusjärvi reindeer herding co-operatives situating in the municipality of

Inari, NE Finland. During 1995 an intense study was carried out in Hammastunturi to explore whether calves born in the fenced and frequently observed area had higher survival than calves born free at fells. Prior to calving period two groups of hinds, altogether 167 animals were marked with individually numbered visual collars. The survival of the calves of study hinds was followed by marking the calves with individually numbered ear tags and studying the weight, sex and colour of study calves. Simultaneously additional study calves were weighed and ear tagged in the neighbouring reindeer herding co-operative of Muddusjärvi. To get a picture of the rate of calf mortality in both of the study areas all the calves collected for slaughter round-ups during winter were intensively checked for ear tags. The results of the study in the reindeer herding co-operative of Hammastunturi show that almost 40% of all calves born in study groups disappeared during the summer and autumn 1995. The loss of calves during period from calving to the summer round-up (23-28 June) was in average 17% and between summer round-up and slaughter (in November) 23% in average, respectively. In the reindeer herding co-operative of Muddusjärvi the rate of calf loss varied between 9% and 28% during years 1994-97 being significantly lower than the rate observed in Hammastunturi. Maternal body size and age affected future survival of reindeer calves in this study. Also birth weight of calves affected significantly in their survival. Light-coloured calves seemed to have higher risk of mortality in Hammastunturi area. The cause for death was identified in 8 cases taking place in the fenced calving area of Hammastunturi. The causes were golden eagle predation (3), disappearing during first day of life (2), maternal rejection (1), accident (1) and weakness (1). There were not any significant differences in the rate of calf loss between different study groups.

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Cause-specific calf mortality in reindeer herd studied with radiotelemetry

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To figure out the reasons for reindeer calf mortality after the midsummer ear-marking round-ups, we followed up for 620 calves (303 and 317 calves during years 1997 and 1998, respectively) by using silent mortality transmitters in a reindeer herding co-operative locating in mid-Lapland. Before the closing up of slaughter season in the end of January, 7% of the marked calves died. In the majority of all deaths (n = 45) during this period, the likely cause in 53% of the cases was golden eagle (*Aguila chrysaetos*) predation. Out of these cases 71% were confirmed for cause with careful examination of the carcass. Ca. ten breeding golden eagle pairs inhabited our study area, but during the study it became evident that subadult (nonbreeding) birds corresponded more strongly on calf predation than expected. This idea was supported by feather samples collected from the carcasses and by the fact that no carcasses were found from the nests. Other predators in our study included brown bear (*Ursus arctos*), lynx (*Lynx lynx*), red fox (*Vulpes vulpes*), white-tailed eagle (*Haliaeetus albicilla*) and possibly wolverine (*Gulo gulo*), but they had a minor role (together 18% of the deaths) as compared to the golden eagle. In the rest of the cases calf died accidentally (for traffic collision 7%, for damages at round-ups 4%), for pathological causes (9%), for starvation (2%) or for unknown reason (7%). Out of the calves carrying the transmitter after the early winter round-ups during winter 1997/98 (n = 60), 37% died before the next summer round-ups. This data provided evidence about the major role of late winter foraging conditions. From the cases identifiable for the cause of death (n = 13), most were died from starvation (46%), 15% killed by bears, 15% by lynx and 23% by an unidentifiable predator.

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Health and pregnancy status of the Colville River, Alaska, moose during and following a population decline and poor recruitment in 1996-97

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In response to poor recruitment and declining numbers, moose of the Colville River, Alaska and associated drainages on the north slope of Alaska (near Umiat, Alaska) were serologically tested for bacterial and viral abortifacients, pregnancy status, presence of parasites (faecal examination) and whole blood evaluated (haematology) in 1996 and 1997. Eight (19%) cows had antibody titres $\geq$ 400 to *Brucella* spp. and 6 (13%) had antibody titres $\geq$ 100 to *Leptospira interrogans* serovar *pomona*. A significant effect on calf survival and location of capture was determined for moose with *L. pomona* serum antibody, however, this assessment should

be interpreted with caution due to the small sample size. Antibody to other agents were detected at lower prevalence rates. Faecal examination indicated the presence of dorsal spined larva in 13% of the moose tested and counts ranged from 0 to 4.8 larva/g faeces. Evidence of *Strongyles* and *Nematadirella* were present in 21% and 62% of the animals tested, respectively. *Monezia* spp. was present in 11% of the moose. Fluke eggs were detected in 6% of the moose. Forty (82%) of 49 moose were pregnant (based on pregnancy serum protein B or PSPB) and a minimum of 31 (78%) of the pregnant cows were observed with a calf. This is a minimum calving estimate as aerial surveys can easily miss a recently born calf or a calf may have died before being observed. No cows testing negative for pregnancy were seen with a calf. Oestradiol levels were 4.31, 8.25 and 3.00 pg/ml for males, pregnant females and non-pregnant females, respectively and progesterone levels were 1.45, 4.46 and 0.41 ng/ml for males, pregnant females and non-pregnant females, respectively based on PSPB results. Basic haematology values were at expected values. This report discusses the significance of the higher then expected seroprevalence of *Brucella* spp. and *L. i.* serovar *pomona* and detection of dorsal spined larva in faeces of moose; and the lack of demonstrable adverse health effects based on calf survival and haematologic status of this population to *Brucella* spp. but possible affect on pregnancy rates and possible affect due to *L. i.* serovar *pomona* on calf survival.

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Radionuclide levels in caribou of northern Alaska in 1995-1996

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Caribou (*Rangifer tarandus*) were sampled (1995-96) from a mortality event near the Project Chariot site (NW Alaska), the location of a radiotracer experiment in the 1960's and reference sites. Radionuclide levels in muscle and bone and the cause(s) of the mortality were determined due to concerns of local residents. Bone gross alpha mean activity (n = 65) was 130.0 Bq/kg and varied significantly ($P < 0.01$) from 73.3 to 168.0 Bq/kg among locations. Bone and muscle gross beta mean activity was 510.4 and 9.78 Bq/kg. Bone strontium-90 mean activity (n = 58) was 137.8 Bq/kg. Muscle potassium-40 mean activity (n = 65) was 183.0 Bq/kg and significantly varied from 76.0 to 104.4 Bq/kg by location. Muscle cesium-137 mean activity (n = 65) was 6.67 Bq/kg, ranged significantly from 0.74 to 15.6 Bq/kg by location and increased with increasing body condition score. Bone potassium-40 mean activity ranged from 18.9 to 47.4 Bq/kg and muscle strontium-90 ranged from 8.89 to 20.0 Bq/kg. Radionuclide concentrations were at expected levels and low in some cases as compared to Canadian caribou studies.

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Mineral and heavy metal status associated with and following a mortality event and poor recruitment in moose of the Colville River System, Alaska

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Moose (*Alces alces*) found dead and hunter-killed in 1995 from the north slope of Alaska (Colville River drainage) were evaluated for heavy metal and mineral status. Compared to previous reports for moose and domestic cattle and data presented here from Alaska moose outside the Colville River area and New Hampshire, levels of Cu were determined to be low in hoof, hair, liver, kidney, rumen contents and muscle for these north slope moose. Fe was low in muscle as well. These findings, in conjunction with evidence of poor calf survival and adult mortality prompted investigation of a mineral deficiency in moose (serum, blood and hair) captured in the spring of 1996 and 1997. Captured males had higher Ca, Zn and Cu levels in hair than females. Female moose hair samples were determined to be low (deficient) in Cu, Ca, K, Fe, P and Se with mean levels (ppm) of 2.77, 599.7, 674.0, 37.4, 62.9 and 0.30, respectively. Serum Cu levels were low and to a lesser degree K, Mg, Na, P and Zn were deficient as well. Whole blood (1997 only) was marginally deficient in Se and all animals were deficient in Cu. Based on whole blood, sera and hair, Cu levels were considered low for moose captured in spring 1996 and 1997 in the Colville River area as compared to published data and other populations evaluated in this study. Low levels of ceruloplasmin activity support this Cu deficiency theory. Evidence indicates that

these moose are deficient in Cu and other minerals, however, the remote location precluded sufficient examination of animals to associate this apparent deficiency with direct effects or lesions. Renal levels of Cd increased with age at expected levels.

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Ivermectin treatment of reindeer

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The Fennoscandian semi-domesticated reindeer harbour a variety of different parasites. Most of the important species belong to arthropods and nematodes and are easily killed with modern antiparasitics. Oestrid fly larvae, warbles (*Hypoderma tarandi*) and throat bots (*Cephenemyia trompe*), are the most evident parasites, but gastrointestinal nematodes are also highly prevalent. The high efficacy against oestrid larvae has made ivermectin very commonly used in the reindeer husbandry. In Finland, over 80% of the stock are treated once yearly, during autumn or winter. The pronounced seasonality of the reindeer and its parasites has helped the success of such treatment; the first possibility of reinfection is often during the next summer. The high efficacy of ivermectin against the most evident parasites has led to the herdsmen developing new treatment regimes. Instead of calling a veterinarian to inject ivermectin, some herders have started to use ivermectin paste developed for horses. Moreover, because this paste is relatively expensive, the most innovative reindeer herders have reduced the dose from the original 200 µg/kg down to about 50 µg/kg, still retaining high efficacy against oestrid larvae. To elucidate the potential problems, we started experimenting with ivermectin in the Kaamanen Experimental Reindeer Herd. We compared the antiparasitic efficacy of subcutaneously, orally and topically administered ivermectin. While all the treatments were highly effective against warbles and throat bots, gastrointestinal nematode egg production in the spring was retarded only after subcutaneous administration. The explanation is in plasma ivermectin concentrations; the low and short-lasting ivermectin concentrations in orally treated animals indicate that ivermectin is poorly absorbed from the gastrointestinal tract of reindeer. The probable reason is that ivermectin is adsorbed to ingesta, much of it going directly to the dung. We consider even the 200 µg/kg oral dose to lead to underdosage regarding gastrointestinal nematodes. Within reasonable limits, while nematodes are hypobiotic and before oestrid larvae start their rapid growth, timing of the treatment does not appear to be very critical. No difference was seen in the antiparasitic efficacy or production efficacy between hinds treated in September, December, or February, respectively. Based on the current knowledge, we recommend reindeer herders the use of ivermectin only subcutaneously to ensure the drug reaches its targets and at any time during the autumn or winter when the flock is collected. As the work continues, these recommendations will be subject to change.

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Histological analysis of small intestinal epithelium in reindeer

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This study presents data on the effects of different diets on the microanatomy of the wall of the small intestine reindeer (*Rangifer tarandus tarandus*). Diarrhoea induced diseases of the small intestines occur frequently when giving reindeer emergency supplements of commercially available pellets in winter. Replacement of new epithelial cells and maintenance of the numbers of lymphocytes in the intestinal cells are potentially important for protection against pathogenic bacteria, development of beneficial microbiota in the small intestinal and maintenance of the ability to absorb nutrients. Histological characteristics of the epithelium of the small intestinal and of the intestinal walls in relation to different diets were studied using light and electron microscopy. Tissue samples from duodenum, jejunum and ileum from reindeer feeding on natural winter pasture in Finnmark (n = 3), from reindeer fed a commercially available pelleted ration RF-80 (n = 3) and from reindeer fed a commercially available pelleted ration Poron Herku (n = 6) in winter were collected and fixed in McDowell's fixative.

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Immobilisation of captive reindeer (*Rangifer tarandus tarandus*) with medetomidine-ketamine: a comparison of clinical effects using different methods of drug administration and different doses for dart injection

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Clinical effects were studied in reindeer (*Rangifer tarandus tarandus*), using different methods of drug administration and two different darting doses of medetomidine (MED) - ketamine (KET). Ten male and two female reindeer, 8-9 months of age, were first kept in indoor stalls and immobilised by hand-injection, using the established individual optimal hand-syringe doses (OHD) and later darted outdoors in paddocks with the OHD and the established individual optimal darting doses (ODD). Time to first sign of sedation increased by 55% and induction time by 79% on changing from hand-syringe to dart injection, while respiratory rate, rectal temperature and heart rate were found to develop equally during immobilisation's. When increasing the darting dose from the OHD to the ODD, the mean time to first sign of sedation was reduced by 21% and induction time by 30%, while clinically insignificant differences were noted in respiratory rate, rectal temperature and heart rate between the dose levels. When comparing the accepted clinical effects produced by the OHD and those produced by the established ODD, no significant differences were found in time to first sign of sedation, induction time, relative arterial oxygen saturation, respiratory rate, rectal temperature or heart rate between the optimal dose levels. Reversal was achieved with i.m. injection of 5 mg atipamezole per mg MED 45 min after MED-KET administration. The head-up time seemed to be the same, regardless of method of drug administration, environmental factors, or dose levels. The study indicates that the post-head-up behaviour is more dependent on environmental factors, than the dose levels used. In conclusion, time to first sign of sedation and induction time varied, while the clinical effects during immobilisation were found to be similar between the different methods of drug administration and the different doses used in the present study.

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An ELISA for detection of antibodies against *Mycobacterium avium* subspecies *paratuberculosis* in wild ruminants in Norway

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Paratuberculosis is a chronic inflammation of the intestinal wall and mesenteric lymph nodes causing diarrhea and emaciation in most ruminant species. The disease is caused by *Mycobacterium avium paratuberculosis*. The bacteria are shed in milk and feces of infected animals, and may survive for up to one year on infected pastures. In Norway, paratuberculosis was first described in cattle (1908) and later (1934) in sheep and goats. Since 1979, no bovine cases were recorded until the disease again was diagnosed in imported beef cattle in 1994 and 1997, and in a few native milking cows in 1998. The infection in cattle is controlled by stamping out procedures. In contrast to cattle, paratuberculosis is widespread in goats, and the disease has been controlled by vaccination since 1967. Paratuberculosis has not been diagnosed in sheep for several decades. Cattle, sheep and goats often share pasture with wild ruminants like red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and moose (*Alces alces*). In Norway, no information exists on whether wild ruminant populations are exposed to mycobacteria and if such bacteria may be transferred to domestic livestock. We have established an ELISA (enzyme-linked immunosorbent assay) based on antigens from *M. a. paratuberculosis*. *M. a. paratuberculosis* is antigenically closely related to other mycobacteria present in wild fauna, and extensive serologic crossreactions are common. In order to remove such crossreacting antigens and achieve higher specificity, sonicated bacteria are run through a protein-G column loaded with rabbit hyperimmune serum against *M. a. avium*. Nunc 96-well plates are coated (1 (g/ml) and subsequently blocked with phosphate buffered saline (PBS) with 0,1% Tween 20 and 1% bovine serum albumin (BSA). Test sera are added in duplicate dilutions. After 1 hr incubation, protein-G conjugated with biotin (Sigma-Aldrich Norway) is added, which enable us to test sera from several species without the need for specific anti-species antibodies. Bound protein-G is subsequently detected by adding streptavidin-peroxidase (Böhringer), followed by orthophenylene-diamine (DAKO) as substrate for the peroxidase, giving rise to a yellow color in the wells. The reaction is stopped by adding 2M H_2SO_4. The optical density of the solution in each well is read at 492 nm wavelength in a spectrophotometer. Positive and negative sera from cattle and red deer are tested as controls. The ELISA is primarily designed to screen serum samples from red deer, roe deer, moose, wild and semi-domesticated reindeer (*Rangifer tarandus tarandus*), as well as musk ox (*Ovibos moschatus*) for the presence of antibodies specific for *M. a. paratuberculosis*.

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Inuit ecological knowledge of climatic influences on caribou and calving areas in the Kitikmeot region of Nunavut, Canada

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Inuit possess knowledge of caribou that is gained from an acute awareness of local lands and resources. This knowledge passes orally between generations, embodies adaptive self-management practices and is maintained through a relationship of respectful reciprocity with the environment. It is shared, compared and verified among community members on a daily basis. In referring to this insight as Inuit ecological knowledge, we recognise that aspects of this information cannot be obtained from other sources. During 1997 and 1998, thirty elders and hunters from the Kitikmeot region of Nunavut, Canada, were interviewed for the purpose of documenting Inuit ecological knowledge of caribou and calving areas of the Bathurst herd (*Rangifer tarandus groenlandicus*). Semi-directed interviews were conducted through a community-driven participatory action research endeavour known as the Tuktu (Caribou) and Nogak (Calf) Project. Results from interviews held within communities, out on the land and during an elder-youth camp indicate that recent changes in climate have affected the Bathurst herd in numerous ways. Since the 1950s, Inuit elders and hunters have observed both primary and secondary effects of a changing climate. A key primary effect is that regional vegetation has become more abundant and diverse. This has led to secondary effects such as altered caribou abundance, body condition, migration routes and calving ground location. Many interviewees stated that the observed change in vegetation has contributed to a healthier caribou population, with fatter and more numerous individuals. However, while interviewees said that the caribou population has generally increased, they have also observed more caribou fatalities. This contradiction points to the complex interconnectedness between various environmental factors. For example, interviewees observed that climatic changes have led to more incidents of caribou drowning and over-heating because of early melting and sea ice break-up. Caribou have become malnourished and have even starved to death when melted snow has later refrozen making vegetation unavailable for grazing. Inuit elders and hunters observed that spring and fall migrations and the location of the calving grounds have shifted, which they attribute to changes in climate and the related impacts on vegetation. This study suggests that Inuit ecological knowledge can provide interesting spatial and temporal insights regarding how climate effects the Bathurst caribou herd. In addition, results emphasise the importance of exploring the relationships between climate and caribou biology, vegetation, migration, calving areas and caribou abundance rather than focussing on these variables in isolation.

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Using historical Inuit knowledge for the delineation of habitat protection areas for Arctic tundra caribou

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In North America, calving grounds of major migratory caribou populations have been frequently suggested as important areas requiring protection from human developments and disturbance; in some cases such protection is already in place. Rationale for habitat protection for caribou populations permanently residing on Arctic tundra have been discussed largely with the assumption that calving areas are as equally important for this ecotype. On Baffin Island, calving occurs over relatively large areas and at low densities in many areas. As well, some calving areas can change from year to years and shift over longer periods. During 1983 to 1995, I interviewed 43 Inuit elders and active hunters on southern Baffin Island to learn if some habitats were especially important from a historical view of several decades. In the early 1900s, elders had been told by their elders that caribou would become very rare in coastal areas during coming decades. The elders were also told of special areas that would always have a few caribou when there was no caribou anywhere else. When the population reached a long-term low during the 1940s, the elders hunted in these special areas to obtain meat and skins for caribou clothing, although these were often adequate for their needs. The largest of these special areas occurred within an interior region with stable low Arctic conditions. Other special areas were located along deep north-south valleys or near large lakes among high mountains and plateaux. These special areas may have unique terrain and bioclimatic characteristics that produce stable, productive foraging habitats for caribou, even after

long-term population peaks. Historical indigenous knowledge of unique caribou habitats in other Arctic regions may suggest other rationale for long-term habitat protection for caribou as well as other wildlife. Such habitats may deserve protection even before their apparently distinctive ecological characteristics are fully understood.

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Identification of traditional knowledge of reindeer herding and comparisons with knowledge proceeded from scientific knowledge

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Among the reindeer herding Sami people there has developed a traditional knowledge about the possibilities of the landscape and the accessibility and the dynamics of the natural resources they depend on. This traditional knowledge has normally been transmitted verbally from one generation to another but today, in the new information society, traditional knowledge runs the risk of being superseded by scientific knowledge. The scientific knowledge about our mountain regions is built upon week empirical material collected during a relatively brief residence in the area. The two knowledge fields - the scientific and the traditional - are different in their nature, but it is possible that they have a closer correspondence between them than one would think at first. If this is the case, the traditional knowledge should be made more visible and contribute to the body of knowledge about the use of natural resources. The available documentation about traditional knowledge will be found in pure imaginative literature, in popular science literature and other scientific literature in which it can be hard to know sometimes if it is knowledge based on traditional or scientific knowledge. Scientifically based knowledge is accessible from both the Fennoscandian reindeer herding districts and from the caribou area of North America. New information about traditional knowledge is collected through interviews with reindeer herders in three mountain Sami villages (Gabna, Leavas and Girjas) and one forest Sámi village (Udtja) in Sweden. The informants were born 1950 or before and have lived their adult lives by reindeer husbandry and have not been involved in any previous similar research. The informant chooses the interview language, Swedish or Sámi and the interview is partly carried out outdoors, the reasons, among others things, being to to record important terminology and make possible visual contact with the topic under discussion, e.g. vegetation, plant communities/biotopes, landscape use and reindeer. The comparisons between these two types of knowledge covers the universal applicability of traditional knowledge and the degree of agreement between the traditional and the scientific knowledge. Traditional knowledge of reindeer herders regarding reindeer forage plants and habitat use is presented and compared with scientific data.

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Genetic data on the migration of ancient Eurasian hunters through Siberia and the circumpolar area

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We make the novel proposition that populations of North Mongoloids, Amerinds and some Caucasoids originated from a single ancestor population that inhabited South Siberia or the neighbouring regions. Our conclusion is based on data concerning protein and enzyme polymorphism of 11 human populations in Eurasia and America and the data of mt DNA polymorphisms of Asian, Sami and Amerinds. We calculated the matrix of genetic distances between 11 populations of Europeans, Asians, Americans, Finns, Germans, Russians, Sami, Nents, Nganasans, Evenks, Altaians, Yakuts, Mongols and American Indians. The evolutionary tree constructed on basis genetic distances showed that ancient populations in Asia were divided first into the ancestors of Amerinds and the cluster of other populations some 50 000 years ago. Sami migrated to northern Europe and separated after this. The Nenets, Evenks and Nganasans are related to the Sami, Altaians and Amerinds. The existence in mt DNA of Sami of haplotypes identical to haplotypes of Evenks and Amerinds (Lahermo *et al.*, 1996) supports this conclusion. Amerinds from Siberia migrated across Beringia to North America 13-30 000 years ago accompanied by ancestoral ungulate Bovinae from central Asia.

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Objective measures of qiviut fibre from wild muskoxen

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The downy underwool of the muskox, known as qiviut, is prized for its softness and rarity. In response to increasing commercial interest and the high market value of qiviut, we have employed the standards and measurements used in today's wool and cashmere industry to provide a description of qiviut fiber characteristics. Fleece samples (qiviut with guard hair) were shaved from the mid-shoulder of 299 wild muskox hides of known sex and age (1, 2, 3 years, and adult) during the Banks Island muskox harvest, November, 1997. Samples were analysed at the Wool and Mohair Research Laboratory, Texas A & M University, using an Optical Fibre Diameter Analyser (OFDA) for average fiber diameter (AFD), fiber diameter distribution (DD) and calculation of qiviut mechanical yield. The American Society for Testing and Materials (ASTM) guidelines were used to measure staple length (ASTM D1234) and scoured yield (ASTM D584). Staple strength was measured with an Agritest staple breaker. AFD was significantly finer in females than males (17.15 versus 17.45 µm, $P < 0.0001$) with the greatest differences occurring in the 4+ age class (17.51 versus 18.20 for females and males respectively) AFD also increased significantly with age, ranging from 16.61µm in 1-yr-olds to 17.86 µm in adults. DD decreased ($P < 0.0001$) with age and was greater ($P < 0.0001$) in males than females in age classes 2 to adult. Percent qiviut mechanical yield (mass of fibers $\leq$ 30 µm) increased ($P < 0.0001$) with age and adult females had higher yields than adult males ($P < 0.0004$). Scoured yield (washed mass/raw mass) did not vary between the sexes in any age class and averaged 93.3%. Qiviut staple length was longer in adult females compared to males and staple strength declined in both sexes with age ($P < 0.006$). This series of samples came from a robust population of free-ranging muskoxen and provides an excellent representation of qiviut characteristics. Up to the third fleece, differences between the sexes were small and not likely to be commercially significant. Changes with age were small but predictable and parallel what is seen in other fiber producing species e.g. Angora goats. Considering that AFD is the primary commercial criterion of values, AFD changes from 16.61 µm in yearlings to 17.86 µm in adults and from 17.51µm in adult females to 18.20 µm in adult males would be expected to result in significant differences in commercial value.

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Reindeer milking and the chemical composition of the reindeer milk

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Long duration reindeer milking was experimented in Reindeer Research Station for the first time in summer 1995. Milking was continued in next years. A project was started to research the variations in the composition of reindeer milk during the milk production period. Reindeer owners were asked if they are interested in and have possibilities to try reindeer milking. The tourists were found to be highly interested in reindeer milking as an exotic event and reindeer milk as a product. Personal information was wanted about earlier reindeer milking experiences and use of milk. People who were known to milk reindeer were interviewed. The interviewees lived in Inari, Enontekio and Ylitornio and they were between 60 and 91 years old. Two reindeer milking courses were organised in co-operation with Sami Educational Centre. Those who were interested had an opportunity to learn milking and they had also a chance to experience it in practice. Some of the participants were reindeer herders who act in tourist business and they were enthusiastic over reindeer milking and had an intention to try it in their own enterprises. Both females with calves and females without calves were milked for the experiment. Females with calves were separated from their calves in the morning about 8.30 a.m. and they were milked by hand at afternoon between 1 and 2.30 p.m. After milking the milk from each reindeer was weighted separately, quantities were recorded and the milk was frozen to -22 °C. The milking result was on average 39 to 62 grams. Reindeer were fed by concentrated reindeer feed (Poron-Herkku, Raisio Group). The mean intake of concentrates varied depending on season. The composition of reindeer milk varied during milk production period although the feeding was exactly the same during the entire season. Dry matter, fat and ash content increased during the first part of the season. The protein content increased and the lactose content was varying during the

season as well as the vitamin content. A milking machine (S.A. Christensen and Co., Denmark) was experimented in reindeer milking during summer 1998. The milking result was on average 83 grams. Milk yield was higher than in hand milking.

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A comparison of underwool (qiviut) from wild and captive muskoxen

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Qiviut, the soft underwool of the muskox, is considered to be one of the finest natural fibres in the world. At present, two captive facilities, MODC in Palmer and LARS in Fairbanks, provide the only regular supply of qiviut to the Alaskan market. We compared fibre characteristics of qiviut collected from a herd of wild muskoxen on Banks Island to samples from the captive herd at LARS. Additionally, we characterised the effects of supplemental methionine on fibre characteristics from LARS animals. Results indicated that wild muskoxen produced qiviut with a greater average fibre diameter and greater staple strength than captive animals. However, supplementation with rumen-protected methionine brought fibre characteristics more into line with those of free-ranging animals. Effects indicate that captive diets can play a significant role in determining fibre properties.

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Nutrient dependent composition of polyunsaturated fatty acids in *M. psoas minor* from reindeer

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The intramuscular fat content of reindeer meat is about 2% and reindeer meat is considered as a lean and healthy food. The present experiment was undertaken to provide information about the composition of polyunsaturated fatty acids (PUFAs) in intramuscular fat of reindeer meat from animals fed different diets. One group was fed a commercial diet, RF-80 and the second group had been fed an old meadow *ad libitum* and was slaughtered in the end of June. The third group was slaughtered in the winter and fed a natural winter pasture *ad libitum*. Muscle samples were collected from the *M. psoas minor* of slaughtered animals (*Rangifer tarandus tarandus*). The lipids from 200 mg muscle were extracted, methylated and analysed by gas chromatography. The diet influenced the composition of the PUFAs in the intramuscular fat. Intramuscular fat from reindeer fed an old meadow and RF-80 contained about 40% PUFAs. Reindeer fed old meadow had a characteristic content of α-linolenic acid (18:3n-3), where as samples from animals fed the commercial product, which contained fish by-products, contained docosahexaenoic acid (22:6n-3; DHA). Only traces of DHA were found in the other groups. In all three groups the muscle samples contained the long chained omega-3 fatty acids eicosapentaenoic acid (20:5n-3; EPA) and docosapentaenoic acid (22:5n-3; DPA). Muscle samples from reindeer fed old meadow and RF-80 contained 30% omega-6 fatty acids (linolenic acid and arachidonic acid) and 10% omega-3 fatty acids (α-linoleic acid, EPA, DPA and DHA). In intramuscular fat from reindeer taken from natural winter pasture the content of omega-6 and omega-3 fatty acids were 23% and 4%, respectively. The omega-6/omega-3 fatty acid ratio found in muscle tissues of reindeer fed old meadow and RF-80 was 3.0, where as in muscle from reindeer slaughtered in winter the omega-6/omega-3 ratio was 5.8. A recommended omega-6/omega-3 fatty acid ratio for human consumption is about 4-6.

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Reindeer blood, use and composition

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Reindeer blood has been earlier and is very good raw material for many uses. The aim of the project was to studied the operations of modern reindeer slaughter-houses and their blood collection systems. In Finland there are four reindeer slaughter-houses which collect blood for food production. These slaughter-houses collected ca. 56 000 litres of reindeer blood in the slaughter period 1998-99. The maximum blood volume could be 200 000 to 250 000 litres per slaughter period in whole reindeer herding area in Finland. At first was studied the use and the demand of reindeer blood in food production. The questionaires was sent to grocery shops, restaurants and a

few tourist operators who cook for their clients in North Finland. Because reindeer blood is new product in grocery shops and restaurants, there exists only minor demand. Some interviewees were interested in selling and serving reindeer blood products if material problems could be solved. For the product development purposes 77 food recipes of blood were collected. Most of the recipes were for the usage of pig and cow blood. Only in part of recipes reindeer blood was used. Reindeer blood recipes are transformed from mother to daughter by oral tradition. At the start of the reindeer blood-project 100 litres reindeer blood was collected from the reindeer slaughter-houses. The Technical Research Centre of Finland spray dried and freeze dried part of blood. The rest was stored in -20 °C. Different analyses were made from the spray dried, freeze dried and frozen reindeer blood. The Custom Laboratory made the mineral analyses and determined the heavy metals and mercurial contents. The Finnish Meat Research Centre determined the dry matter-, protein-, fat- and ash contents of blood. Results from these analyses were compared. The values of reindeer blood were also compared to the values of cow and pig blood. The fatty acid composition was determined from both freeze and spray dried blood. The most important nutritional values of the reindeer blood were: high protein (23.1g/100g) and iron content (0.24 g/100g) and low fat content (0.03 g/100 g of blood).

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Meat quality traits in reindeer (*Rangifer tarandus tarandus* L) fed various diets

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Reindeer are sometimes fed during parts of the winter to prevent starvation or to improve body weight and condition. In some areas feeding is used as a countermeasure to reduce radioactive caesium in the reindeer. Commercial feed mixtures are commonly used in combination with hay, grass silage or lichens. The present study was performed at the Zoological Gardens at University of Oulu, Finland and included 23 female reindeer calves. The reindeer came from five different herding area groups (Paliskunta). During an adaptation period all reindeer were offered free access to a mixed diet of lichens (*Cladina* spp.) (80%), blueberry brushwood (*Vaccinium myrtillus*) (10%) and willow leaves (*Salix* spp.) (10%). After adaptation, eight randomly allotted reindeer were slaughtered (group C_{Jan}) and the other were allotted into 3 groups with 5 reindeer per group. A control group was continuously offered free access to the lichen diet (group C_{Mar}) and the other two groups were given 50% of the amount offered to the control group of the lichen diet during 8 days and thereafter one day of total feed deprivation. Then one group was fed a diet of 80% commercial Reindeer Feed (RF) and 20% lichens (group RFandL) and the other group was fed a diet of 80% RF and 20% silage (group RFandS) during the feeding period (35 days). After the feeding period all animals were slaughtered. Ultimate pH was measured at 24 h *post mortem* in *M. longissimus* (at the last rib), *M. biceps femoris* and *M. triceps brachii*. Carcass parameters were registered at slaughter. The saddle from each of 18 reindeer was excised and packed in a plastic bag and frozen (-20 °C) at 2 days *post mortem*. The meat was prepared in a conventional oven at 150 °C to a core temperature of 68 °C. The sensory profile of the meat was assessed by 9 panel-members, selected, trained and monitored according to ISO standard. The measured attributes were tenderness, juiciness, reindeer flavour, liver flavour, bitter flavour, other off-flavours and sweet flavour. The lowest ultimate pH values were measured in the C_{Mar} group, though the highest carcass weights were recorded in the RFandL group. No significant difference was found in any of the sensory attributes of the meat. The present study suggests that a feeding period of 35 days might be to short to affect the sensory properties of reindeer meat.

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Climate, weather and caribou numbers: a question of scale

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Both recent views of ecology and understanding of temporal variability in weather and climate suggest it is time to modify conventional view of factors influencing caribou *Rangifer tarandus* numbers. Weather influencing caribou numbers is often only accepted for caribou on Arctic islands and for other caribou the balance of opinion vacillates between 'food limitation' and 'predator limitation'. Examples from herbivore-forage systems studied for decades - both small and large-bodied herbivores - suggests that those views are unnecessarily

restrictive. Conceptually, a hierarchical structure integrating temporal and spatial scales is more complex, but more realistic for mapping ecological influences on caribou numbers.

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Herd-specific predictive models that integrate effects of climate and development on caribou as a subsistence resource for Arctic communities

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Caribou and reindeer are the most important terrestrial subsistence resource for indigenous Arctic peoples. Industrial development may affect caribou distribution, their access to habitats and their survival, weight gain and population growth. However, predicted anthropogenic effects on caribou/reindeer have often been only qualitative in nature. The pervasive nature of northern development pressures demands that we construct and test, quantitative predictive models of human effects on caribou/reindeer populations. Trends in climate and variance among herds in: 1) the strength and direction of climate effects on habitats, 2) availability and use of habitats and forage and 3) body condition at arrival on calving grounds challenge our ability to quantify the relative value of calving grounds and their relative sensitivity to anthropogenic influences. We present a modelling framework that generates testable predictions of the effect of industrial development on caribou/reindeer calf survival and provide an example implementation based on two North American caribou herds. We then summarise available information on calving ground food habits of caribou/reindeer, resulting nutritional profiles and predation risk to identify research tasks that would allow construction of herd-specific predictive models of development effects on caribou as a subsistence resource for indigenous Arctic peoples.

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Overgrazing: signs and tendencies

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The West Siberian North is the main center of industrial development in Russia. The rates of industrial expansion have no analogies in Russia or probably in the World. Gas and oil fields are situated in territories utilised traditionally by indigenous population for reindeer breeding. Very sensitive taiga, forest-tundra and tundra ecosystems are involved in technological transformation. Nevertheless reindeer grazing is the main reason of plant cover transformation at regional scale. Prospects of development of a gas production connect to deposits, located at the Yamal peninsula. All areas suitable for grazing on the Yamal have been put to use. None of the farms has reserve areas. Pastures are used in summer and some of them twice a year - in early autumn and late spring. At present time the reindeer population exceed the carrying capacity of the pastures in 1.5 times. 70% of pastures currently belong to the low quality category. The impact of reindeer on the vegetation has two main components: grazing and trampling. Predominance of one of the two depends on many circumstances. Trampling stimulates substrate dynamics. Reindeer-breeding is one of the most important sources of nitrogen. Observations and studies carried out on the peninsula have shown that intensive grazing leads to changes in structure of vegetation cover, floristic composition and the ratio between its components of phytocoenoses, size and structure of the phytomass. The tolerance of the above groups of plants decreases in the following series: shrubs dwarf shrubs grasses lichens. The recovery potential decreases as follows: grasses shrubs dwarf shrubs lichens. Moderate grazing tends to increase species saturation and, less noticeably, species diversity. The percentage of lichen component in the makeup of phytocenoses has been noticed to decrease along with the intrasinusial cover of lichens. Such valuable species from the nutritional standpoint as *Cladina arbuscula* and *C. rangiferina* decrease in quantity. The frequent occurrence of these species combined with their small abundance may also be ascribed to grazing impact. Tolerant but less valuable species, on the contrary, grow in abundance and their reserves increase markedly. Lichens have also been noticed to decrease in height. Intensive grazing results in poorer species composition, damaged thalli, broken lichen cover and replacement of nutritionally valuable species by crustose ones. Consequently, it is lichens that should be used as indicators of grazing impact on vegetation. Three stages of lichen cover transformation on pastures are distinguished.

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Natural cycle of reindeer and its relationships with forage resources

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The population of reindeer (*Rangifer tarandus* L.) on the Kola Peninsula (Laplandsky reserve) was selected for simulation of plant - herbivores dynamics. The model described relationships of a reindeer population and forage resources (winter pastures). The predicted data matched observations of population size 1929-1995s. The modeling showed that dynamics of the population is cyclical. The oscillation period is 35-40 years. The increase of numbers is slow, lasting 25-30 years while declines are rapid, usually lasting only 10 years. The reindeer cycle is connected to the dynamics of winter forage. The growth of reindeer population causes reduction of the standing crop of lichens which, in turn, results in a decrease in the number of a reindeer. The recovery of the biomass of lichens begins after the population size has been halved. The dynamics of populations of reindeer has a lag and acts in phase opposition with changes in the biomass of lichens.

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Does quality of summer pastures depend on reindeer density?

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Our aim is to test the hypothesis that reindeer influence the quality of their summer pasture in a density-dependent manner. Our quality measures are species composition and the aerial standing crop (biomass) of different plant species estimated by the canopy intercept method. Measurements are conducted inside (experimental) and outside (control) small exclosures (50 cm x 50 cm x 70 cm; 12-15 per site) at six sites in Troms and Finnmark, northern Norway, at the peak of the growing season. These sites have similar ecology but are located in three different reindeer herding districts with reindeer densities in summer ranging from 8 to 20 animals/km^2 and with different grazing histories. Total standing crop in 1998 was not significantly affected by exclosures in any of the six study sites and was not correlated with the reindeer density of the districts. This, we believe, was because the very warm summer forced the animals to feed at higher altitudes than the study sites which were all located at 200-300 m altitude. A preliminary conclusion is that in very warm summers, standing crop at these altitudes seems to be independent of the reindeer density of the districts. Our results indicate that different grazing histories have no effect on standing crop of plants in these reindeer summer pastures. The project will continue until 2001. We will later include measurements of nutrient content, e.g. proteins, and anti-herbivore compounds, e.g. proteinase inhibitors and phenols, in selected plant species.

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New perspectives on reindeer rangeland management; equilibrium *vs.* non-equilibrium in an ecosystem dominated by dynamic interactions

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Rangeland management in high northern, alpine and Arctic regions has been dominated by the classic equilibrium theory, relying on the relationship between density dependency and carrying capacities and some manageable balance between them. In Scandinavia, a notion exists that poor reindeer husbandry and reindeer management has caused rangeland degradation for wild and domestic reindeer pasture. I present the perspective that this notion and the classic equilibrium theory are inappropriate for range management in high mountain and Arctic ecosystems dominated by unpredictable weather events and patchy resource distribution. As a function of stochastic weather events, theses systems are in non-equilibrium and productivity of herds and pasture can not be manipulated in a predictable manner by adjusting animal density. The new climate-pasture-herbivory interactive model, similar to traditional pastoral systems, considers the dynamic ecological interactions in non-equilibrium grazing systems and can contribute important insights and possibilities for improving present management of reindeer rangelands.

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Satellite inventory and biomass assessment of Finnish reindeer summer pastures

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After the completion of the winter pasture inventory in 1996 it was decided that before any conclusions could be made concerning sustainable pasture use, also the summer pastures had to be mapped. The winter pasture inventory included areas which are also in use as summer pasture, e.g. mountain areas, areas with deciduous trees and grassy meadows and clear cut areas. To analyse the amount of suitable reindeer fodder, biomass samples were gathered. Collecting biomass samples is much slower than the evaluation method during the winter pasture inventory. Therefore fewer field sites could be studied. Both sites on mineral soil and bogs were sampled. To maximise randomness and ensure even dispersion the sample sites were pre-defined taking into consideration bio-climatic zones. The winter pasture inventory distinguishes only two bog types, namely open and pine bogs. As bogs are major sources of reindeer fodder it was decide to concentrate the satellite image classification on procedures to identify different bog types. The classification of bog areas is a well-known problem as we are dealing with spectrally similar, spatially very variable and complex environments. For the classification we used the same 21 Landsat 5 TM images as were used for the winter pasture inventory. All images were analysed and classified using ER Mapper 5.2 software. The first phase of the classification process was to rectify the images to conform to the Finnish co-ordinate system. Thereafter we masked all non-peat areas, resulting in an image containing only information relating to bogs. The ground truth data from the field inventory was used to delineate test area for extraction of classification statistics. We distinguished three main bog classes e.g. open bog, pine bog and spruce bog classes. Each of these three classes was again divided into three tropic classes, poor, medium and rich, in relation to the biomass of reindeer fodder species. The classification was accepted when the overall classification accuracy exceeded 70%. The results were exported to the ARC/INFO GIS program. The 21 images were combined in one ARC/INFO grid, covering the whole reindeer herding area. The field sites on mineral (n = 532) and on peat soils (n = 798), were divided into bio-climatic zones. The mean biomass values for all summer pasture classes were calculated for every bio-climatic zone. By using the area of each pasture class the amount of fodder per reindeer and per hectare can be calculated for each reindeer district. It can clearly be seen that there are major differences in the quantity and quality of summer fodder between the northern parts and southern parts of the reindeer herding area of Finland.

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Productivity and demography of reindeer forage plants in Svalbard

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This project, currently in its first field season, will (1) compare the vegetation of two neighbouring regions with contrasting histories of grazing pressure from Svalbard reindeer *Rangifer tarandus platyrhynchus*. The relationship between peak season standing crop, net primary productivity (NPP) and biodiversity of major plant community types in Brøggerhalvøya and Sarsøyra in north-western Spitsbergen will be examined; (2) initiate measurement of the NPP of major foliose lichens (*Cetraria nivalis*, *C. delisei* and *C. islandica*) which reindeer eat; (3) evaluate the potential of contrasting vascular plant species to provide retrospective information on links between climate, NPP and population demography (e.g. seedling recruitment) in any particular year over the last 1-2 decades. Methodologies will be tested and a workable system developed for retrospective analysis of, e.g., *Dryas octopetala* and/or *Salix polaris* using annual growth increments (shoot extension and/or radial growth of stems). Our data will be used to relate vegetation productivity and diversity to temporal variations in the intensity of reindeer grazing and climatic stochasticity.

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Development of a muskox habitat map for northern Alaska using GIS

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The population and distribution of muskoxen (*Ovibos moschatus*) in northern Alaska have been increasing since their reintroduction into the area nearly thirty years ago. However, their distribution and habitat selection within the local landscape remains inadequately documented. Furthermore, there is no accurate record of their historical distribution. As a consequence, it is currently difficult to establish a knowledge base to project habitats that may be occupied in the future by muskoxen in northern Alaska and to assure their potential productivity for both management and land-planning purposes. This project is compiling information on habitat use by muskoxen in a Geographical Information System (GIS) in order to provide a resource base for land use planning as it relates to proposed oil and gas and other mineral exploration and development activities and the

conservation and management of muskox populations. The sustainability and proper management of the muskox population is critical: the tendency of muskoxen to remain in suitable local habitats, combined with their sedentary disposition, makes them particularly vulnerable to over-harvest and disturbance (as evidenced by past extinctions); it is likely that where muskoxen are found, conditions are also favourable for other wildlife, increasing the importance of these areas and their need for preservation; lastly, native communities rely on wildlife for the continued sustenance of their traditional way of life. Existing muskox location, vegetation, topographical and terrain characteristic data and maps have been obtained and compiled into a large database using ARC/INFO. This information was then assimilated, providing information about the interactive effects of these characteristics. Based on the confirmed presence of muskoxen in certain regions and existing literature and reports on muskox habitat, a model of muskox habitat characteristics and requirements is being developed. In addition, field work was also done to establish familiarity with muskox habitat and to conduct vegetation analyses to produce a basis for ground truthing of the vegetation maps. Extrapolation from the ground truthed maps to broader scale maps for Alaska's North Slope will then be possible. The final product is a GIS database showing both current and potential muskox habitat in northern Alaska, information crucial to effective and proper management and sustainability of the population.

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Ungulates and snow-affected pastoral ecosystems of the central Asian highlands - can our knowledge of Arctic ungulate systems inform husbandry and wildlife conservation in these rapidly developing regions?

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Modernisation of animal husbandry practices, social experiments, market forces and government imposition of rangeland management prescriptions are rapidly changing the traditional nomadic herding systems of central Asia. The consequences to both livestock management and wildlife conservation are dramatic in some regions and the parallels to Arctic systems provide important insights to both regions. From a range ecology perspective, the Tibetan plateau and northern Scandinavia illustrate well the importance of environmental variation, ungulate mobility, predator relationships and carrying capacity concepts to our understanding of wild ungulate ecology and domestic ungulate husbandry in these similar ecosystems. And in both regions the application of mainstream rangeland management practices, developed in more stable ecosystems, can lead to unanticipated consequences. With the University of Tromsø beginning a co-operative project of wild and domestic ungulate ecology and nomadic pastoralism in western Tibet, the experience from northern ecosystems provides an important foundation.

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Modelling caribou response to seasonal and long-term changes in vegetation: II. Estimating seasonal changes in forage quality

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This project was undertaken as part of a larger piece of research focused on developing a dynamic system for integrating modelled vegetation changes into a model of caribou energetics which requires forage quality and quantity parameters as input. Information on forage quality (nitrogen, neutral detergent fibre and dry matter digestibility) and biomass for 10 plant functional groups was gathered from existing scientific literature. The literature review was restricted to habitat types found within the summer and winter range of the Porcupine Caribou Herd in Northwest Canada and Northeast Alaska, U.S.A. Available data sets were synthesised to develop theoretical forage quality and biomass curves over time within a calendar year. The majority of information available was for the summer period and focused on vascular plant species. For most plant functional types, nitrogen content and digestibility of green biomass peak at the onset of the growing season, with the exception of graminoid growth forms, which tend to peak approximately 30 days after growth initiation. Concentrations of neutral detergent fibre in green biomass were found to be inversely related to nitrogen concentration for several forage types. Many plant groups, however, showed a high level of variability across species in forage quality parameters. Substantial data gaps were found for the winter periods and non-vascular forage types. The generation of realistic models of forage quality and quantity for use in caribou energetics

modelling will require additional information on fall and winter forage groups and data on poorly documented forage classes such as mushrooms and graminoid/deciduous standing dead.

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Climate, vegetation, caribou and people: a regional integrated assessment model for investigating the sustainability of Arctic communities

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Climate change forcing in the Arctic has important regional effects on both biophysical and social systems. These systems are obviously coupled and there is increasing recognition of the need to understand their interactions and feedbacks. We have developed an integrated assessment simulation model to help answer three major questions about future change in small rural native communities within the range of the Porcupine Caribou Herd. The questions relate to the impact of climate change, increased levels of tourism and oil development in the 1002 area of the Arctic National Wildlife Refuge (ANWR). In order to understand the impact of these three forces for change, we model vegetation, caribou population dynamics, caribou distribution, community employment, household harvest of caribou and community demographics. Our components therefore span the biophysical and the socio-cultural systems. Using disciplinary research and local knowledge we have outlined a conceptual model of the linkages between these components and have developed a dynamic simulation model to address the three questions above. The model has a 40-year time horizon and works mostly on an annual time-step. The vegetation part of the model simulates nutrient dynamics and competition between 20 plant species found in high and low Arctic habitats. We model the biomass and phenological changes of these plant species in response to imposed climate warming, then use the vegetation results to generate a diet for the caribou. Diet plays a major role in caribou energetics that then drives caribou population parameters (parturition and calf survival). We model the effect of oil development on calf survival based on research on the Central Arctic Caribou Herd and use a stochastic population model to project caribou herd dynamics for a 40-year period. Our socio-economic model of the community is based on a household-level analysis. We simulate the mixed wage-subsistence economy by modelling wage-employment and its effect on time and money available for caribou hunting. The household model for caribou harvesting has a seasonal time-step and simulates the effort and success of representative community households. Our project has taught us some important lessons about integrated assessment and how to go about interdisciplinary research. This paper not only describes our synthesis model and some preliminary results, but also concludes with a discussion of the factors we believe are required for successful interdisciplinary integration.

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Climatic influences on forage quality for Arctic ungulates: implications of climate change

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Experiments to simulate the effects of increased cloudiness on forage quality of willow (*Salix* spp.) during summer were conducted in alpine habitat of the Delta Caribou Herd in Alaska and in muskox habitat in northern Greenland. Using control and shaded (50% reduction of solar insolation) plots in stands of *S. pulchra* (Alaska) and *S. arctica* (Greenland), comparative post treatment measurements were made of nitrogen, tannins and dry matter digestibility (DMD) in leaf tissues. In both areas and in both species of willows, tannin levels were substantially lower in leaves from plants shaded during the growth season, whereas, in these plants nitrogen levels were higher in leaves early in the growth season than in those from plants exposed to full sunlight, but this difference declined in later phenology. In Alaska in 1993, under wet conditions, presumably associated with cloud cover throughout much of the 1993 growth season, DMD was higher in *S. pulchra* leaves than in those from the 1994 season, with lower precipitation after the early growth period. *S. arctica* in northern Greenland, DMD was not significantly different in leaves from shade and control plots. *S. pulchra* and *S. arctica* leaves are important components of the early summer diets of caribou, reindeer and muskoxen, where they are available, however use declines markedly as leaf tissues mature, presumably in relation to buildup of protein-complexing tannins. A major variable in the influence of global climate change on the quality of forage for Arctic ungulates

will be through changes in cloud cover. Expected increases in cloud cover as a function of decreases in extent and duration of sea ice may therefore result in extension of duration of peak forage quality of Arctic willows.

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Landsat 5 TM images in mapping winter pastures of reindeer, in the Näkkälä reindeer herding district

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The occurrence of the timber lines cause difficulties in classifying satellite images. The resolution of the Landsat TM images is too coarse to define timber lines. It is possible to distinquise barren mountain land from forested areas, but defining pine and spruce timber line going through mixed forest is very difficult and uncertain. Misclassification is very likely to occur. Almost certainly 'forest' pixels will be found above the actual timber lines. Näkkälä herding district is an area where timber lines cause problems in classification. In the southern part of the area is the northern limit of spruce forests, pine timber line goes in the middle of the district and the north-east part of the district is treeless mountain land. The aim of this study was to reduce misclassifications in timber line areas, so that more accurate results of the different pastures types can be achieved. Pine and spruce timber lines were marked on the GT-map 1:200 000 and after that they were digitised as a polygon and saved separately as pine and spruce coverages. Satellite image classification was done using ERMapper 5.2 software and exported to ARC /INFO. After the GIS processing was done a new map was produced. Misclassifications of the 'forest' pixels above timber lines were corrected. The study pointed out that it is possible to solve certain problems of the classification of satellite images by GIS and other map producing methods.

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Determination of the reindeer pastures carrying capacity in western part of Petchenga

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Determination of the reindeer pastures carrying capacity was made in forest tundra zone of Pethchenga region of Murmansk county in 1992 and 1995 to 1997 under the assignment of World Reindeer Herders Union and Administration of Petchenga region. Pastures of the region were not in use for up to 50 years. Characteristic for the region is also nearest disposition of Petchenga-Nickel Combine. Therefore investigations had two main aims: the first - determine reindeer pastures carrying capacity and optimal use, second - organise system of long-term monitoring of the plant communities for determination of grazing press and control pollution. Territory was investigated according one of the common-used methods of Schelkunova-Savchenko (1981) with geobotanic descriptions of the plant communities (n = 110), standing-crop of lichens were made in main types of plant communities (n = 9), annual growth of lichens was determined. Also plant simples for pollution level determination were collected. Analyses of pollution level show that from 4000 km^2 of territory planned for pastures 410 km^2 are in the zone of high and medium pollution level of Pethchenga-Nickel combine. On the other part of territory three main geobotanical regions were determined. The northern region is characterised by prevalence of lichen communities of mountain tundra but also a great number of complex and lowland marches reached by green and dry-grass forage. The central region has smooth relief and prevalence of the complex marches with lichen communities on the hillocks and sedge-cotton grass communities in the pools. The southern region - forested part of territory. Low shrub-lichen pine forests and light forests, birch with pine low shrub-lichen forests and birch-fear moss-lichen light forests prevail here. In general, communities with prevalence of lichens and complex grass-lichen communities occupy more then 70% of the territory. According the method of Schelkunova-Savchenko determination of carrying capacity show the following results: annual growth of lichens - 4.29 mm (1.05 to 10.5 mm), the largest economic stocks of lichens are 900 kg/ha (*Cetraria nivalis* in mountain tundra) and 394 kg/ha (*Cladina stellaris* in low shrub-lichen pine-birch light forest), total economic stock of lichens - 18664.8 ton. Calculation of the carrying capacity for use of pastures in 4 winter month shows result of 30 000 to 35 000 reindeer, or with the two year rotation of pastures 15 000 to 17 000.

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Seasonal and annual variability in the quality of forages consumed by Peary caribou and muskoxen on Banks Island

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A variety of forages consumed by Peary caribou and muskoxen on Banks Island were collected from June 1993 to May 1998 and analysed for their percent digestibility, crude protein (CP), fibre, lignin and energy content. Percent digestibility was determined by acid-pepsin *in vitro* dry matter digestibility. Most of the 424 forage samples were collected during mid-June (start of the growing season), mid-July (peak of the growing season) and mid-late August (senescence). Forage collection was replicated in areas of high (ca.1 to 2 muskoxen/km^2) and low muskox density (ca. 1 to 2 and 0.3 muskox/km^2, respectively). Sedge (*Carex aquatilis*), *Dryas integrifolia* and legumes (*Astragalus* spp. and *Oxytropis* spp.) were collected in both areas in early (Nov), mid- (Feb) and late- (Apr/May) winter from 1995-96 to 1997-98. In summer, digestibility was highest in mid-June and mid-July than August and was highest in legumes and willow leaves (range 36.1-61.8%). Digestibility was higher in late- than early or mid-winter and was highest in legumes (22.5-34.5%) and lowest in *D. integrifolia* (17.3-26.5%). CP levels were highest in mid-June and mid-July; August and winter levels were similar. Legumes, live grass, live sedges in wet sedge meadows and willow leaves had highest CP in summer (range 8.6-35.6%). During winter, CP was highest in legumes (11.4-15.3%) and lowest in *D. integrifolia* (4.8-6.9%). CP levels in sedges were significantly ($P < 0.05$) higher in winters 1996-7 and 1997-8 than in previous winters. Fibre was significantly ($P < 0.05$) lower in forages in summers 1996 and 1997 than in previous summers. In summer, fibre was lowest in mid-June and mid-July and was lowest in legumes and live sedge from wet sedge meadows (range 21.2-40.6%). Fibre was lowest in late-winter and was lowest in sedge (37.6-45.3%) and highest in *D. integrifolia* (42.9-63.2%). Lignin was significantly ($P < 0.05$) lower in forages during 1995-96. During summer, lignin was lowest in legumes, live sedge from wet sedge meadows and live *Cassiope tetragona* (range 0.3-8.3%); lignin was highest in *D. integrifolia* during winter and summer (1.2-25.3%). Energy was significantly ($P < 0.05$) higher in forages during summer 1994 than summer 1993 and was significantly ($P < 0.05$) lower in forages in winter 1997-98 than in previous winters. During summer, energy was highest in the woody forages, especially *C. tetragona* (23.2-24.8kJ). During winter, energy was highest in sedges (18.2-19.5kJ) and lowest in *D. integrifolia* (13.1-19.7%). Legume is an key food of caribou. Legumes were highest in CP and digestibility and lowest in lignin during winter. Willow is a key forage for both caribou and muskoxen in June and July when willow leaves are high in CP and digestibility and low in fibre and lignin.

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Reindeer population density impact on forage biodiversity

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How does a quickly expanding reindeer population affect forage biodiversity and soil in an Arctic habitat? After about 100 years of absence, 15 Svalbard reindeer, (*Rangifer tarandus platyrhynchus*) were reintroduced to Brøggerhalvøya, western Svalbard. The total area is ca. 180 km^2: 25% glaciers, 50% barren land and 25% potential forage vegetation. The reindeer population increased to ca. 30 animals in 1980, ca. 100 animals in 1985 and to more than 360 animals by 1994 before crashing to less than 70 animals. Impact of the rapidly growing reindeer population, from 2.2 animals/m^2 in 1985 to 8 animals/m^2 in 1994, on Dryadetum-type vegetation and soil was analysed. Dryadetum vegetation on the elevated beach ridges is snow-free in late winter and early spring when reindeer are in search of quality forage after surviving the long winter. Total species biodiversity decreased significantly from 1985 to 1994. Bryophytes and lichens, including the total cover of preferred reindeer lichens decreased while vascular plant diversity remained unaffected. The total biodiversity decreased from 23.6 to 11.5 species/m^2, bryophytes decreased from 9.3 to 1.2 species/m^2 and lichens decreased from 7.4 to 4.2 species/m^2. The important reindeer lichens, *Cetraria ericitorum* and *C. nivalis* were eradicated. Surviving reindeer were supported by less-preferred forage and less varied vegetation. Plant-cover removal and reindeer trampling on the thin Arctic humus layer resulted in a buildup of carbon, smaller soil particles (less than 2 mm) and higher calcium and magnesium content. Unless ungrazed vegetation across Kongsfjorden allows for reindeer population recovery, we may expect the increase in reindeer population numbers to lag behind the slow reestablishment of soil integrity and establishment of the original forage biodiversity in the habitat.

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Anthropogenic transformation of Enisey forest tundra reindeer pastures during the development of oil-gas industry

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Preliminary determination of the prospecting drilling influence in Vankor region (Turukhansk area of Krasnojarsk province) was made in 1998. Exploration of three drilling areas showed destruction of plant

coverage decrease in four zones. The first zone is the nearest the drilling site (60-70 meters). It characterised by the total destruction of soil-plant coverage, floods of drilling solution and saltification of substrate. Only pioneer groups of the plants usually not characteristic for this area present here. The second zone (65-100 meters) includes substantial changes of micro-relief and destruction of plant cover. Vegetation consists of patches of graminoids. Low shrubs, shrubs and trees are absent. The third zone (100-200 meters) - zone of meadow and flooding. Plant coverage here is continuous, but a large changes in the flora are characteristic. Meadows with the domination of graminoids form on better drained areas. On the lowlands sedge (*Carex aquatics*) and cotton grass (*Eriophorum scheuchzeri*, *E. vaginatum*) communities with the participation of swamp forbs prevail. The fourth zone - tundra with low soil-plant coverage (mainly on the transport routes). On the routes cotton grass communities usually form. The other part of the territory has typical for zonal tundra vegetation. The main vegetation resources of Vankor area are reindeer pastures. Drilling does not only have negative impacts on the pastures. Of course, total destruction of the pastures is negative but the area involved is usually not large. The second zone of pioneer plant has a rather good stock of forage from different species of plants (e.g. *Senecio congestus*, *Descurania sophya*). Areas where typical tundra vegetation is transformed into graminoid meadows and sedge-cotton grass swamps have very high stock of green spring (cotton grass) and summer-autumn (graminoids and forb grasses) forage. Production of those communities is comparable only with the production of river meadows, which have very small area on the territory. River meadows have very low accessibility because of water obstacles and dense willow shrubs. Therefore presence of transformed communities is very important for the region where prevail low shrub-lichen tundra. Development of forest tundra reindeer husbandry in the region must be based on the spectrum of different seasonal pastures.

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Reindeer grazing and the soil processes in oro-Arctic ecosystems

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By influencing the vegetation of the tundra heaths of northern Fennoscandia, reindeer has an indirect effect on the soil processes, such as carbon and nitrogen mineralisation and microbial immobilisation. The changes in the soil processes will further affect the vegetation, as vegetation and nutrient cycling constitute complex feed-back mechanisms. The soil processes are essential for ecosystem function and interact strongly with the productivity of the ecosystem. We have studied the effect of reindeer grazing on the gross and net nitrogen mineralisation, carbon mineralisation and the size of soil microbial biomass in four oro-Arctic sites with adjacent grazed and ungrazed areas (Jesnalvaara, Nuorttitunturi, Reisduoddar and Lagisduoddarar). The vegetation was dominated by lichens in two of the sites and by dwarf-shrubs in the other two. We hypothesised that grazing would affect soil processes variously according to the vegetation type and productivity of the ecosystem, as grazing favours different plant groups in low and high nutrient availability. The results showed that the hypothesis was not correct, but there were other mechanisms involved, too. There are complex interactions between the tundra heath vegetation type, grazing intensity and grazing patterns, which together determine whether the overall effect of reindeer grazing on the nutrient mineralisation is positive or negative. The vegetation is probably changed by both sensitivity of plants to the loss of biomass and responses to nutrient availability, both varying among species.

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Modelling caribou response to seasonal and long-term changes in vegetation: I. Development of an algorithm to generate diet from vegetation composition and application to projections of climate change

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A major challenge in modelling the effects of vegetation change on animal performance is to project a realistic diet for the animal. We applied plant use versus availability curves determined under experimental conditions with reindeer grazing tundra in summer to; a) caribou grazing similar vegetation and b) to theoretical diets based on vegetation simulations in response to climate change. Equations were fitted to use-availability data to determine plant use (U_i, i = species or growth form) at any particular availability (A_i). Vegetation availability

was determined as the proportional contribution of each growth form on a plant biomass basis. The sum of A_is = 1. Contribution made by each component to the diet (D_i) was estimated as the fraction made by U_i to the sum of U_is. We used published use-availability data to fill some data gaps and extrapolated use-availability relationships to similar forage groups where necessary. The diet algorithm was verified by application to vegetation data and seasonal dietary shifts reported for caribou of the Porcupine Herd from pre-calving to mid-summer. Use of lichens and deciduous shrubs was underestimated and use of graminoids and evergreen shrubs overestimated. In a second round of algorithm development, we used published values for diet and plant biomass in combination with the experimental data (above) to develop new use-availability relationships and re-estimate Dis. These new relationships require testing with validation data from another herd. The adjusted diet algorithm has been applied in modelling the effects of global warming on vegetation change, caribou food habits and herd productivity in the range of the Porcupine caribou herd. In response to a mean annual warming of approximately 3 °C, a model projecting vegetation change in northern and more southern tundra in Arctic Alaska suggests that biomass may increase. Both tundra types are likely to become more dominated by both evergreen and deciduous shrubs. Our algorithm projects seasonal diet shifts of increased deciduous shrubs (*Salix* spp.) and decreases in early summer consumption of moss and lichens.

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Factors associated with stabilisation of muskox numbers in north-eastern Alaska

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A population of muskoxen (*Ovibos moschatus*) grew rapidly during the first 15 years after its reestablishment in north-eastern Alaska in 1969 and 1970. After 1986, numbers of muskoxen in regions first occupied in the Arctic National Wildlife Refuge declined and stabilised at < 300. This shift from increasing growth to stabilisation of animal numbers was due to changes in calf recruitment and animal survival as well as changes in distribution. Mean number of calves per 100 females > 2 years declined from 61 calves per 100 females in 1983-1986 to 31 calves per females in 1995-1998. The mean interval between calves produced by radio-collared females increased. Factors that influenced calf recruitment and animal survival included predation by brown bears and wolves, human hunting and weather conditions that affected the availability of forage. Dispersal of muskoxen also contributed to the stabilisation of animal numbers.

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Microsatellite variation of the muskox *Ovibos moschatus* - historical, metapopulation and conservation implications

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Natural populations of the muskox *Ovibos moschatus* are distributed across most of the Canadian Arctic and northern and eastern Greenland. Microsatellite variation in 14 loci in 175 animals reveals 3 major lineages; mainland, southern Arctic island and the northern Arctic island. Expected heterozygosities are 0.5349, 0.2221, 0.3435 with Ne/N ratios of 0.119, 0.004 and 0.0375 respectively. A glacial refuge origin is posited for each of the 2 Arctic island lineages. These lineages inhabit different landscapes and are likely to have different metapopulation dynamics: Arctic island muskox inhabit a fragmented landscape with more extreme climate fluctuations. Dissimilar relationships between genetic interindividual distance and geographic distance among the three lineage's suggest metapopulations characterised by unequal levels of gene flow. In Canada, 5% of muskox in each of 29 management units may be harvested by locals. We use this limited microsatellite DNA data set to re-evaluate the delimitation of these units.

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Status and factors affecting the Western Arctic Caribou Herd

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The Western Arctic Caribou Herd (WACH) numbered approximately 463 000 caribou (*Rangifer tarandus granti*) as of July 1996, making it one of the largest herds in North America. This herd last peaked at approximately 243 000 caribou around 1970, then declined to 75 000 caribou by 1976. From 1976 to 1990 the WACH grew approximately 13% annually. From 1990 to 1996 the WAH grew about 2% annually. This herd ranges over the north-western third of Alaska. As the number of caribou in this population increased, so did its range; however, range expansion has not kept pace with population growth. This poster reviews harvest, disease, predation, emigration, weather and range condition in relation to recent population dynamics of the WACH.

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Evolutionary history of Peary caribou and Arctic-island caribou on the Canadian high and central Arctic islands

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Peary caribou *Rangifer tarandus pearyi* are only found on the high Arctic islands. Arctic-island caribou *R. tarandus*, found on the southern Arctic islands, were originally considered to be intergrades between Peary and barren-ground caribou *R. t. groenlandicus* although their appearance and ecology are similar to Peary caribou. We investigated the evolutionary history of caribou using sequence data from the entire control region of mitochondrial DNA. Neighbour-joining pairwise deletion analysis suggested that there is no evidence for isolation of caribou in a Pearyland or any northern refugium during the Wisconsin glaciation. The sequence data indicate that Arctic-island caribou are not intergrades between barren-ground and Peary caribou, but are more likely the ancestral stock for Peary caribou and have evolved from barren-ground spreading north after glaciation. We suggest that the extreme Arctic environment imposes intense selection, resulting in the rapid appearance of local adaptations.

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Phylogenies and the future of Russian Tagil cattle

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Tagil cattle (*Bos primgenius*) have history stretching back 300 years. The breed was developed in southern Nizhni Tagil by the crossing of local cattle with Kholmogor, Yarolsalv, Black and White, Braun and Holland breeds. Cows weigh 460-500 kg, bulls 750-850 kg and calves weigh 25-28 kg at birth. The milk yield of cows ranges from 2700-3500 kg; fat content 4.2% and protein content 3.7%. The hair is black, white and red in motely pattern. Immunogenetic comparison of Tagil cattle and other Russian breeds has shown greatest similarity (r = 0.8052-0.8293) with Kholmogor, Aulieat, Brown Carpatian, Black and White, Kalmyk, Angeln and Red steppe and least similarity (0.6924-0.7626) with Limousine, Svetlaja akvitanskaja, Kostromskaja, Chianina, Hereford, Suksun, Red Megrel, Khevsur and Shorthorn breeds. Numbers of Tagil cattle have decreased from 636 000 in 1969, to 449 000 in 1985 and to 8870 (*sic*) in 1996. In 1985 Tagil cattle were crossed extensively with Holland and Holstein cattle. This trend was reversed in 1997 by a programme of crossing cross-breed animals with Tagil bulls.

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Muskox genetics from the past to the present

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The muskox (*Ovibos moschatus*) is a species which has survived in Arctic regions from prehistoric times to the present. During this time the species has survived repeated bottlenecks as population numbers fluctuated dramatically. Studies of allozymes and mitochondrial DNA of modern muskoxen have revealed low levels of genetic variability across the entire species. Microsatellites are hypervariable regions of nuclear DNA which

have proven to be useful genetic markers that often are informative at levels ranging from the individual to populations and even to species. A survey of microsatellite markers developed for sheep and cattle that were polymorphic in muskoxen also revealed low levels of variability. The mean expected and observed heterozygosity of eight markers across populations from Alaska, the Canadian mainland and Arctic islands as well as Greenland was 0.43 and 0.28, respectively. The number of alleles per locus ranged from two to five. DNA also has been extracted from muskox bones found on the North Slope of Alaska ageing from the late Pleistocene to early Holocene. Comparison of ancient muskox DNA sequences and microsatellite profiles suggest muskoxen have survived with reduced genetic variability for thousands of years.

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Comparative - morphological analysis of sculls of contemporary and fossil muskoxen (*Ovibos moschatus*)

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Nowadays muskoxen inhabit territory of Canada, Alaska, Norway and Greenland, Sweden. Reacclimatization of the muskoxen on the territory of Russia (Taimyr peninsular, Wrangel Island) took place in the 70-ties. 10 animals of the subspecies (*Ovibos moschatus Wardi*) were imported from Canada (Banks island) and 20 - from Alaska (Nunivak Island). The goal of the present research was to evaluate of the difference degree between the reintroduced muskoxen and fossil (Pleistocene and Holocene) Taimyr species. The authors had at their disposal sculls of 6 specimens of contemporary and 5 of fossil adult muskoxen from Taimyr peninsula. Age of the specimen was estimated from tooth wear. Painted thin sections and ground ends of the first molars, prepared by the generally adopted method, were used to provide more accurate estimating of the age of the contemporary and fossil specimen. Analysis of thin sections and ground ends showed that dental annuli may be seen most clearly in cementum of the inter - root pad. Degree of tooth wear of the muskoxen is probably species specific. Noticeable process of the muskoxen's dental surface wear of the first lobe of the first molar starts at the age above five years, unlike the dental wear of reindeer (*Rangifer tarandus*) inhabiting the same area. All sculls were measured by 60 cranial indications. Then, the calculation of distance between the specimen was made by the dimension characteristics and scull proportions. Cluster analysis and dendrograms were made. It was determined that there is no significant difference in morphometrical scull parameters of the contemporary and fossil specimens. Analysis resulted into suggestion that inter-population difference of muskoxen (both fossil and contemporary) are generally found in body size, which is determined by the condition of the feeding area. Thus, reintroduced muskoxen subspecies (*O. m. Wardi*) are not morphologically different from the fossil Taimyr form.

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Morphological and genetic differentiation of Euroasian reindeer (*Rangifer tarandus*)

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Circumpolar spreading of reindeer over wide tundra and taiga territory has led to significant differentiation in the species and creation of complicated hierarchical structure of populations. Reindeer has two similar forms: wild and domestic. There has been collected significant amount of morphometrical and genetical information on the latter form. Analyses of it combined with available data on the wild form allows to give complete notion of population organisation of the species, helps to highlight possible origin and ways of spreading of subspecies and breeds, as well as defining the borders of their areas. Evaluation of differentiation in population of the different subspecies was made using an index of similarity. Calculation was made using five body measurements, 18 scull measurements and quantity of appearance of 5 alleles of transferrin albumin of 150 domestic and wild reindeer populations. Dendrograms of interpopulation distances were built according to the similarity indexes and indicated forms of reindeer which showed morphological differentiation and different frequencies of Tf locus alleles. There are three clearly defined forms of wild and domestic reindeer on Euroasia: European; Siberian tundra and Siberian forest forms, which belong to the following subspecies: *Rangifer tarandus tarandus* L., *R. t. sibiricus* Flerow, *R. t. valentinae* Flerow. Most noticeable changes in reindeer's exterior (enlarging of average body size) can be seen moving South from North from tundra zone to southern taiga zone. Three forms of reindeer may be determined there, which correspond to the popular scheme of dividing reindeer in tundra, forest-tundra (mountain-taiga) and forest forms. In spite of long existence (in evolution scale) of the wild and domestic forms, no significent differences were detected between them, as shown by close genetical and morphological

similarity between local wild and domestic populations on Taimyr, Evenkia, Yakutia and Norway. Similarity of Chukotka breed tundra and Siberian forest reindeer forms were also determined. The ancient Nenets breed is genealogically connected both with Siberian and European reindeer, which are bred by the Sami.

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Age determination of caribou (*Rangifer tarandus*) of the Wrangel Island by the degree of development and wearing of teeth

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Determination of the age structure of population is an important part of populations research. For more accurate age determination various methods, such as ground ends and painted thin sections preparation of teeth are used. However those time consuming methods are not useful when volume of material is significant or in the conditions of field expeditions. Age determination by the degree of teeth wearing, as reported (Klevezal, 1988; Gruzdev &Pronyaev, 1994) allows satisfactory accuracy. Collection of mandibles of 800 reindeer of different age harvested on Wrangel Island in November - December 1991 was available for the present research. On the basis of analysis of age development of teeth, the key for age determination was developed. Accuracy control of the age determination for each age group was performed by preparation of the painted thin sections of first incisors. Thin sections analysis highlighted correspondence between the quantity of annuli in the fist incisor cementum and degree of teeth wearing. Age determination showed presence of species of age 0.5 to 13.5 years and older in the available collection. The best accuracy for this method of age determination is seen for the age of 0.5 to 10.5 years. Age determination for species of 2.5 years old appeared to be the most complicated, for degree of premolar development among species of the said age was seen in numerous variants. Age determination for species older than 10.5 years is complicated due to significant degree of teeth wearing and destruction of the first molar.

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Sex and age classification surveys of Peary caribou on Banks Island, Northwest Territories from 1982-1998

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Sex and age classification surveys of Peary caribou on Banks Island were conducted sporadically between 1982 and 1991. Since then surveys have been conducted annually. Surveys were partitioned into 5 different circannual periods of Banks Island caribou. Between 1982 and 1998 Peary caribou were classified for 7 calving (May and June), 7 summer (July and August), 7 winter (11 November through March), 6 fall/rut (September through 10 November) and 4 pre-calving (April) periods. We calculated the ratios of calves and yearlings per 100 adult ($\geq$ 2 year-old) females and the percentages of calves and yearlings in the survey sample, for each of the 31 surveys. There were significant ($P < 0.05$) year effects on calf per 100 adult female ratios. Multiple comparison tests indicated that in 1995 and 1996 ratios were significantly higher than in 1993 and 1994. Calf production for 10 years, ranged from 23.3 (1994) to 75.6 (1982) calves per 100 adult females. Production was 50.0 calves per 100 adult females in 7 of 10 years. We determined overwinter survival of calves by dividing the best estimate of calf production in a given year by the best estimate of the number of yearlings recorded per 100 adult females in the following year. Overwinter survival of calves for 6 years, ranged from 23 (1991-92) to 86% (1993-94). Overwinter survival of calves was 50% in 4 of 6 years. The decline in caribou ($\geq$ 1 year-old) numbers caribou from 709 in 1994 to 425 in 1998 has happened in the face of high production and overwinter survival of calves.

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Phylogenetic status of Yakut cattle in relationship to other Bovinae

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Yakut cattle are normally classified as *Bos taurus turanomongolicus*. The genetic distance between Yakut cattle and other Bovinae was calculated using data on the distribution of the frequencies of the 40-50 antigenes of 9-11 genetic systems. More than 110 000 animals were investigated including 450 Yakut cattle reared in Yakutia

(Sakha). Yakut cattle are very distantly related to buffalo, aurochs, yak and zebu cattle. Within the species *Bos taurus*, Yakut cattle are most distantly related to zebu cattle and some meat-breeds.

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The immunophylogenesis of Estonian, Finnish and Vietnamese cattle

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Between 33 and 44 antigens of blood groups of Red Estonian, Red Denmark, Angler, Estonian local, Estonian black-motley and Leisind (Vietnam) breeds of cattle were studied. Leisind cattle had significantly higher frequencies of antigens A_1,P_2,Q,B',R_1,W,X_1,X_2,L',L and H' and lower frequencies antigens of Q', G'', C_1, C' and M compared to all other breeds. Local Estonian breeds had very high frequencies of antigen V which is characteristic of Asian but not European breeds. This probably reflects the movement of cattle from Asia accompanying the migration of Finno-Ugric peoples to their present habitat in Estonia. Genetic distances are lowest between Red Estonian and Angler breeds (d = 0.1403) and highest between Leisind and Finnish cattle. Red Estonian and Angler breeds formed one dendrogram sub-cluster which forms the basis of a cluster of breeds from which European breeds are derived.

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Defining herds within the range of 'Bluenose' barren-ground caribou

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Historically, barren-ground caribou occupying the region from the Mackenzie River east to Kugluktuk and south to Great Bear Lake were considered to belong to the Bluenose caribou herd. Analysis of historical survey and radio-location data suggested that there were three geographically distinct calving areas, two rutting areas and two wintering areas within that region. In March 1996, caribou near the Mackenzie Delta, Great Bear Lake and Kugluktuk were captured and equipped with satellite collars. Movements of those caribou between March 1996 and February 1999 indicated that there were at least two herds and possibly a third, within the region. One herd calves in the Rae-Richardson rivers, ruts north-east of Great Bear Lake and winters north, east and south of Great Bear Lake. The second calves in the western Melville Hills, ruts in the Anderson River area and winters from Husky Lakes south to Great Bear Lake. The third calves on Cape Bathers, ruts south and east of Husky Lakes and winters in the Husky Lakes-Tuktoyaktuk Peninsula area. Tissue samples were collected from caribou harvested by hunters throughout the region during winters 1996-97 and 1997-98. Recently cast antlers were collected from the 3 calving areas in summer 1998. Microsatellite DNA analysis of those samples indicated that these groups are genetically separate.

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Wild reindeer calf recruitment variations; biology or methodology?

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Calf recruitment (calves/100 females 2 yr+) and male frequency (males 1 yr+/100 animals 1 yr+) were recorded in Norefjell-Reinsjøfjell (1993-98), Rondane North (1995-97) and Setesdal-Ryfylke (1995, 1998) from ground counts of post calving wild reindeer herds in June-July. Estimated calf recruitment in June varied between 66.5 and 73.0 in Setesdal-Ryfylke, 62.7 and 66.9 in Rondane North and 79.4 to 86.4 in Norefjell-Reinsjøfjell. June recruitment rates were also estimated from composition counts in October in Rondane North 1985-92 and 1995-96. Rates ranged from 44 to 56; average 50.5 (s = 3.5) compared to 37 to 65; average 48.4 (s = 10.0) recorded from air photographs of post-calving herds in June/July during the same years (NINA's National Cervid

Monitoring Program). The air photograph method is based on the assumption that males are absent from post-calving herds and that the variability in calf recruitment figures reflects variations in reproduction and postnatal calf mortality. Ground counts in June/July in the three areas revealed that among animals 1 yr+ in the post-calving herds, males composed on an average 11.2% (range 4.7-27.9). These findings raise the question of the validity of the air photography method presently in use by NINA for assessment of calf production or calf mortality in the post-calving herds.

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Population of the reindeer from the Novaya Zemlya archipelago at the time of nuclear tests.

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The Novaya Zemlya Archipelago was used as a nuclear testing site in 1955 to 1990. We investigated mandibles of 107 Novaya Zemlya reindeer sampled in tundra in 1992-1994 and, for the comparison, mandibles of 86 Taimyr reindeer collected during hunting season of 1995. Demographic parameters of the Novaya Zemlya reindeer were compared with those of Svalbard reindeer (de Bie, 1977; Reimers, 1983). Using the condition of mandibles, the length of mandible diastema, the height of crown of cheek teeth and the annual layers in cementum and dentin of molars we estimated postmortem period, morphological abnormalities in the dental row, sex, age at death, season of death, age of sexual maturity, rate of development during the first year, tooth wear rate and tooth root resorption. The majority of the reindeer (82%) lived in the period of nuclear tests. The morphological abnormalities were discovered in 4.5% of the Novaya Zemlya reindeer and in 8.1% of the Taimyr reindeer. The ratio of females and males in the Novaya Zemlya population was 1:2. Mortality of the Novaya Zemlya reindeer occurred to be higher in the age of 1-3 years and lower in the age of 7-10 years than in the Svalbard reindeer; there was a decrease of maximum as well as mean expected life span and no drop in mortality curve in old age. Though most of the reindeer died in winter, 23.7% of the 1 to 3-year-old animals died in summer-autumn. The proportion of the Novaya Zemlya reindeer lagged in development toward the first winter among the Novaya Zemlya reindeer was larger than among the Taimyr reindeer. The Novaya Zemlya reindeer seemed to attend the sexual maturity later and the lately matured reindeer tended to live longer than the early matured ones. The cheek teeth wore rapidly and variability of wear rate was higher than in the Taimyr reindeer. The resorption of molar cementum was found not to depend on the tooth wear. In reindeer older than three years, the resorption did not correlate with the animal's age and was higher than in the Taimyr reindeer. Some of the Novaya Zemlya reindeer specific traits could, perhaps, result from the radiation stress; however, in general, the condition of the Novaya Zemlya population appeared to be better than could be expected taking into account the level of radiation contamination. Probably, the Novaya Zemlya population was pre-adapted to the high radiation contamination due to relatively high background natural radiation at the Archipelago.

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Persistent instability in Svalbard reindeer dynamics: tension between intrinsic and climatic processes

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The persistent instability found in populations of birds and small mammals is well known. Similar patterns have now been documented in several northern ungulates including. We analysed a 20-year series of census data to identify mechnisms responsible for the persistent instability of a natural population Svalbard reindeer (*Rangifer tarandus platyrhynchus*) in Adventdalen, Spitsbergen (78°N). In particular, we investigated the relative influence of density-dependent (intrinsic) and climatic (extrinsic) processes on the dynamics. Three vital rates, the apparent rate of birth, total population mortality and dispersal, all responded to changes in population size. An autoregressive model confirmed that intrinsic factors (direct density-dependence, partial $R^2 = 0.18$ and dispersal, $R^2 = 0.12$) and extrinsic factors (NAO; $R^2 = 0.18$) had statistically significant influences on the annual rate of increase of the population. A matrix model showed that survival of calves made a greater contribution to annual changes in population size (elasticity) than either survival of adults or variation in the apparent rate of birth. The elasticity of the apparent birth rate ($r = 0.71$, $P = 0.001$) and calf survival ($r = 0.71$, $P = 0.001$) increased with population size whereas the elasticity of adult survival decreased with population size ($r = -0.71$, $P = 0.001$). We conclude that the instability of the population of reindeer in Adventdalen is a consequence of both density-

dependent and density-independent variation in fecundity and survival as well as density-dependent dispersal of animals. Variation in fecundity and in calf survival were the most important density-dependent processes acting on the population. The remaining variance in population size may be attributable to factors including significant temporal changes in population age-structure as well as changes in forage growth mediated through summer weather conditions.

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Dynamics and state of muskox population on Taimyr

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Muskoxen were caught in Yakutia and Yam in 1996 to 1998 for settling and we carried out their registration. The number of animals in a herd in autumn 1996 (average for 8 herds) was 12 animals (lim 8-16), in 1997 - 20 (lim 14-25); per cent of calves was 24.7% (20.0-28.6) in 1996 and 18.7% (lim 8-32) in 1997. Comparable data were obtained in 1998, but in 1979 per cent of calves was 33.3% (Katsarski, 1987) and does not exceed 31,1% on island Banks (Urguhart, 1982). The average increase of population for 5 years (1994 to 1998) was 19.2%, in the previous 5-year periods - 19.5; 23.9; 24,8% accordingly and in 1979 reached 30.0% (Yakushkin, 1998). High temps of growth of population in this initial period of getting can be explained by the result of heteosis because founders were muskoxen from two non-related populations as well as by composition of the muskox herd on Taimyr in the beginning only of young animals. The increase of the muskox population in Taimyr is stabilised on the level which is characteristic of aboriginal populations of Canada and Greenland. The similar stabilization of productivity was observed on the island Nunivak in 15 years after introduction (Lent, 1974). Analysis of the count results permits to determine the number of animals on Taimyr in 1996 as 1000 animals, in 1997 - 1260 and in 1998 - 1450 animals. Tendency to stabilization of the population parameters on the level which is characteristic for aboriginal populations can evidence about successful adaptation of Muskoxen to the conditions of Taimyr. According to calculations the average coefficient of inbreeding was equal to 1.8%, that can be characterise as moderate. So the possibility of arising inbred depression in this population is excluded. But at settling Taimyr muskoxen it is necessary to take measures preventing inbred depression in new populations.

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Genetic relatedness and diversity in Peary caribou (*Rangifer tarandus pearyi*) from the Bathurst Island complex

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Microsatellite DNA analysis was used to determine genetic relatedness and levels of genetic diversity among 174 Peary caribou (*Rangifer tarandus pearyi*) from the Bathurst Island complex. DNA was isolated from cast antlers and carcasses, from samples representing individuals spanning several generations. Genetic diversity was quantified as heterozygosity, number of alleles and probability of identity, across ten microsatellite loci. Genetic relatedness of individuals within the population was determined by the number of shared alleles between pairs of individuals. Subpopulation structure among the Peary caribou within the Bathurst Island complex has been inferred by radio-telemetry and aerial survey data. In this study we establish a genetic basis for the postulated population genetic structure and attempt to determine the genetic effects of a severe population bottleneck experienced by these caribou during 1973-74.

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Genetic relationships of caribou herds in the Inuvialuit Settlement Region, Northwest Territories and Yukon Territory

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A number of herds of caribou have been identified that occupy ranges on the mainland or Arctic islands within the Inuvialuit Settlement Region in the north-western Northwest Territories, Canada. These include Porcupine (*Rangifer tarandus granti*), Bluenose-east, Bluenose-west and Cape Bathers (*R. t. groenlandicus*) barren-ground caribou and Arctic island or Peary caribou (*R. t. pearyi*) on Banks, Victoria (Minto Inlet and Dolphin-Union) and Melville islands. Tissue samples from caribou harvested by hunters or that died of natural causes and recently cast antlers were collected within the geographic range of each of those herds. Microsatellite DNA analyses of those samples were done to identify possible genetic relationships among herds. We present the results of these analyses.

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Variation in male reproductive success in reindeer herds with different male compositions

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Knowledge of a species' variation in lifetime reproductive success is of great importance for the understanding of demographic variables such as effective population size and inbreeding in populations. Reindeer, *Rangifer tarandus*, is a polygynous species with presumably high variation in male reproductive success. Reliable estimates of male reproductive success have, however, been difficult to obtain due to the difficulties in observing copulation under field conditions. Even when copulation is observed, there is almost no way to identify reproductive success if more than one male is involved. Novel genetic markers in reindeer open the possibility for accurate analysis of the number of offspring fathered by individual male reindeer. We have used genetic variation in twelve microsatellite loci to analyse paternity within herds having four different compositions of males, each together with approximately 40 females. Variation in male reproductive success for herds with only young males present (1.5 years-old) are compared to herds with both young and adult males present (2.5 years-old). The first year one herd was limited to 6 young males and the second herd was mixed with 3 adult males (4.5 years old) and 3 young males. In the second year one herd was limited to only four young males while the second herd had 9 adult males (3 of 5.5 years and 6 of 2.5 years) together with 9 young males. The herds were kept separated in two 14-15 km^2 enclosures from late September through early November after which they were kept together. The paternity analysis demonstrated that in all four herds there was a significant skewness in the distribution of reproductive success with the most successful males from each herd fathering approximately 50% of the calves. In both groups with mixed male composition the most dominant male was also the most reproductively successful while the young males fathered only some few calves the first year and none the second year. This suggests that increased number of young males in a herd with mixed male composition will not increase the effective population size.

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The fecundity of Svalbard reindeer in relation to age, fat and parasite burden

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The fecundity of Svalbard reindeer (*Rangifer tarandus platyrhyncus*) was studied from 1994 to 1998. In marked female reindeer fecundity was assessed in April-May using a progesterone assay and ultra sound scanning and through the summer by visual observation of presence/absence of calves with in total 547 observations of fecundity on 325 individual reindeer. The ovaries from reindeer culled in October were investigated to assess whether reindeer had ovulated. In reindeer culled in late winter the presence of a foetus was revealed. In all 213 culled female reindeer were included in the analysis. No reindeer had ovulated or were pregnant in their first year of life. Although 55% ovulated in their second autumn, only 15% were found pregnant or having a calf in the late winter-summer. The fecundity of 2 years and older reindeer (adults) varied between years, but did not

differ significantly between animals of different ages within years. Although ovulation rates varied little between years (82-100%) pregnancy rates in April were more variable. For example, in 1995 and 1996 approximately 64% of the adult females were pregnant in April and in 1996 only 25% carried a live calf. In 1997 and 1998 approximately 90 % of the adult females were pregnant in April suggesting that most reindeer that ovulated the previous October also become fertilised and were still pregnant in the spring. Generally there were small losses losses of foetuses or calves from April to the end of July. These findings suggest that between year variation in fecundity is due to variation in implantation and foetal survival more than variation in ovulation rate and neonatal survival. Backfat depth was a main predictor of pregnancy in the winter period, with fatter animals having a higher probability of being pregnant. Independent of this effect of fat, gastrointestinal worm burden affected pregnancy rates significantly with reindeer with high intensities of the species *Ostertagia gruehneri* having a lower probability of being pregnant than less infected ones. The effect of gastrointestinal nematodes on reindeer fecundity was also confirmed in an anthelmintic experiment. Reindeer that were treated in the late winter to remove their worm population, had significantly higher fecundity one year later. The effects of age structure, variable fat deposition and infection with gastrointestinal nematodes, on the population dynamics of Svalbard reindeer will be discussed.

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***Rangifer* bulls in rut: body composition and water kinetics**

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Rut is a metabolically demanding period for male ruminants. Bulls must fight, patrol harems and mark territories as well as maintain and repair their body tissues. Seven adult male *Rangifer tarandus* tarandus were studied in two herds with a total of 34 females. Bulls became aggressive to handlers in late August when the antler velvet was shed. Plasma testosterone was greater in early September (246 d; 2128 $ng \cdot dL^{-1}$) than in either June (176 d; 12 $ng \cdot dL^{-1}$) or October (301 d; 83 $ng \cdot dL^{-1}$). Subordinate males lost mass between September and November in a similar pattern to the dominant harem males. Peak mass and the date of peak mass did not vary with status or age in males 2 yr and older ($P > 0.05$). Two bulls died in September from infected wounds. Surviving animals did not recover mass in winter suggesting that both injury and low body reserves can cause mortality. Tritiated water dilution space declined with body mass. High rates of water flux in August probably reflect intakes of both food and drinking water to support mass gains and losses to panting for thermoregulation. Low water fluxes at the end of the rut may indicate low intakes of food and renal conservation when snow is the only source of free water. Animals lost 35% of the ingesta-free mass in 77 d of rut. Lean mass and body protein were depleted by 23% whereas 78% of the fat reserve was expended. Daily losses of protein and fat were 77 g and 437 g respectively which corresponded to a loss of $19MJ \cdot d^{-1}$ or 63% of body energy during rut. The daily energy deficit was equivalent to 90% of the standard metabolic rate. Body reserves probably provide sufficient energy for basal metabolism but additional costs of activity and thermoregulation must be supported by food intake.

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Distribution, timing and ecology of calving in a population of Arctic tundra caribou

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Populations of barren-ground caribou (*Rangifer tarandus groenlandicus*) that winter in forests migrate onto tundra and tend to have synchronised calving over a one week period during early to mid June. The distribution, timing and ecological conditions associated with calving by populations of this subspecies that are permanently resident on Arctic tundra have not been described extensively. This ecotype of barren-ground caribou has no need to migrate onto tundra during spring and thus may exhibit different calving characteristics. During June 1994 and 1997, I conducted weekly helicopter surveys to determine the distribution, timing and general ecology of calving by *R. t. groenlandicus* on northern Baffin Island. These sex and age classification surveys were augmented with information from three females with satellite telemetry collars. During May and early June, most females migrated from their wintering area within a complex fjord system that had a generally north aspect. Although extensive snow free areas were available within the wintering area during June, most calving females migrated 75 to 150 km south across a 1000 m high plateau to give birth on a rugged ridge of south facing slopes. A few females apparently calved at high elevations within the wintering area. Increasing calf:cow ratios within the main calving area indicated that calving continued throughout the last two weeks of June and probably into early July. Individual cows in the process of giving birth and with newly borne calves were seen consistently along the snow melt margin. Thus, the distribution of calving was somewhat ephemeral, shifting to higher

elevations as the melt progressed during late June. In June 1994 and 1997, wolves were seen within the wintering area, but not within the main calving area. By late June, groups of cows with calves had begun to congregate along the margin of extensive lowlands immediately south of the hills where calving occurred. Combined with observations from elsewhere on Baffin Island, the distribution of the snowmelt margin, timing of snow melt and the juxtaposition with productive post calving areas may the primary ecological factors influencing calving by *R. t. groenlandicus* on Arctic tundra. Interannual variability in the distribution and/or timing of snow melt may lead to greater variability in calving among some populations. Avoidance of wolf denning areas may be a secondary factors affecting calving distributions of some populations.

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Differences in calving time among three populations of wild reindeer in southern Norway

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Changes in calving time during the time period from 1969 to 1998 were studied in reindeer (*Rangifer tarandus tarandus*) populations of South Ottadalen, North Ottadalen and Snøhetta. The peak calving time was 11.9 May-14.2 May in 1996 to 1998 in North Ottadalen, 22.3 May-25.9 May in 1996 to 1998 in Snøhetta, and 10 May in 1997 and 11.2 May in 1998 in South Ottadalen. Comparing these results with recordings from 1969 to 1972, 1978 and 1985, peak calving time has advanced by 2 to 6 days in Snøhetta and has been delayed by 6 to 8 days in North Ottadalen. In South Ottadalen, the peak calving time has remained constant. From 1970 until 1995-1997, autumn dressed weights and mandible lengths for females 2+ years increased significantly in Snøhetta by 2.6 to 2.9 kg and 4.4 to 8.0 mm, decreased significantly in North Ottadalen by 7.9 to 8.4 kg and 1.8 mm and decreased in South Ottadalen by 2.6 to 4.9 kg. Linear regressions between calving time and the two physical condition estimates (autumn dressed weight and mandible length) showed significant negative relationships ($P < 0.05$). These results strengthen the hypothesis of later conception and calving when females are in poor condition in autumn. All populations calved later when autumn body condition decreased, but calving time in Snøhetta was still significantly later than in the Ottadalen populations in 1996-1998, when physical condition, environmental conditions and large bull:cow ratio was approximately equal in all three herds. Since the populations have different evolutionary histories, the Ottadalen populations being of domestic origin, a genetically determined difference in calving time is possible.

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Does maternal dominance rank influence calving dates or calf weights?

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The age and weight of females is known to have an influence on the calving date and birth weight of the calves. The possible effect of maternal rank on calving date and calf weight is to our knowledge not previously investigated in reindeer. We determined the rank among individuals by observing dominance interactions in two groups of female reindeer in two consecutive years. Both groups consisted of approximately 40 adult females with similar age and weight compositions. The dominance observations were conducted just before and just after the rutting season each year. A highly significant relationship was found between dominance rank and the parameters: weight ($r = 0.78$, $P < 0.001$, $n = 43$); age ($r = 0.62$, $P < 0.001$, $n = 43$); and antler size ($r = 0.70$, $P < 0.001$, $n = 43$). A multiple regression model built with weight, age and antler size as parameters found that weight contributed most to the multiple model. The rank order of the females remained stabile between the two years ($r = 0.78$, $P < 0.001$, $n = 35$ and $r = 0.89$, $P < 0.001$, $n = 39$). No significant relationship was found between calving date and dominance rank. Nor did either of the parameters: age, or weight correlate significantly with calving date using linear regression analysis. Birth weight of calves was correlated to both weight and dominance rank. The birth weights of calves was more closely correlated to female weights in April prior to calving than to female weights the previous autumn after rut ($r = 0.73$, $P < 0.001$, $n = 29$ versus $r = 0.56$, $P < 0.001$, $n = 33$). The correlation between calves birth weight and mothers rank ($r = 0.68$, $P < 0.001$, $n = 33$) is probably due to a high correlation between rank and weight of females. In a multiple linear regression model between the calves birth weight and the parameters; females weight in spring and rank, only females weight contributed significantly to the model. It can therefore be concluded that the females weight in spring is the most important factor affecting the calves birth weight. The females weight gain during the winter (November-April)

was to a certain extent correlated to the dominance rank (r = 0.40, P = 0.03, n = 29). Since the females weight in spring was the most important factor affecting the calves birth weight, dominance may have an indirect effect on the calves birth weight by influencing the females weight gain during winter and thereby the females weight in spring. Only statistics from one group the first year is shown. The results from the other group and the next year is in the same size order.

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A methodological study of retrospective reproduction analysis in female reindeer

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The objective of this study was to investigate the possibilities of making inferences on female reproduction and early calf mortality of wild reindeer (*Rangifer tarandus tarandus*) based on the analysis of reproductive organs. Reproductive organs were collected in South Norway from 36 wild reindeer from Forelhogna during the hunting season 1996, 15 semi-domestic reindeer from Trollheimen in November 1996 and 3 semi-domestic reindeer of known age from Røros in January 1997. Ovulation scars apparently from many years back in time were found on the ovarian surfaces. Such old ovulation scars have apparently not been described previously in *Rangifer*. Last year's ovulation scars could be distinguished from older scars. The presence of ovulation scars, and their appearance, facilitated identification of *corpus rubrum* (CR) and made it simpler to find the more obscure *corpora albicantia* (CA). Ovulation scars were more difficult to find on the surface of the distended ovaries of pregnant females than in females from the hunting season. If regressing accessory corpora lutea (CAA) last more than one year, and thus may be confused with CA, the ovulation scars will facilitate separation of CA and CAA. Ovulation scars should be identified on the surface of intact ovaries, before sectioning of formaldehyde fixed ovaries into 1-2 mm slices for locating CR and CA by back-lighting at low mangnification. Only in special cases need stained microtome sections be prepared. Paraffin embedding should then be used for ovaries that were never frozen. Otherwise a freezing microtome will suffice. Material for retrospective reproduction analysis in wild reindeer should be collected preferably from females shot during the hunting season, both because CR, CA and ovulation scars are more easily identified at that time of the year, and because animals that are shot for other reasons can be utilised. CR could be identified in all lactating females. The occurrence of CR in non-lactating females in early autumn identified females that had lost their calf. Counts of CA+CR relative to the female ages indicated that CA+CR tended to underestimate the lifetime reproduction of older females. This was probably caused by disappearance of some CA with time. The pregnancy rate for calves in Forelhogna was estimated to be more than 40%. This was based on finds of CR in one-year old females in 1996, pregnant calves killed during winter in 1984, and the proportion of females shot in autumn 1996 with a number of CA+CR equalling their age (total n = 25). The pregnancy rate based on CR for older females in 1996 (96%) was in good agreement with the rate in 1984 (98%) based on the presence of foetuses in winter.

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Effect of male composition during rut on reproductive parameters in semi-domestic reindeer

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During 1996 and 1997 we manipulated the research herd at the Experimental Reindeer Research Station in Kaamanen, Finland, to document the effect of different male compositions, both age and numbers, on: pregnancy rates; birth dates; birth synchrony; birth weight and autumn weight of calves; and body weight loss/gain of both females and males during rut. Prior to the breeding season we separated the females into two isolated herds of about 40 females each. At the end of main rut in early November the two herds were again joined and they stayed together until the next breeding season. We varied the proportion and/or age composition of the male component as follows: 1996: six 1.5 year-olds *vs.* three 1.5 year-olds and three - 4.5 year-olds; 1997: three 1.5 year-olds *vs.* nine 1.5 year-olds, six 2.5 year-olds and three 5.5 year-olds. Pregnancy rates were not significantly different between years or herds and varied from 81% to 87%. Mean calving date was earlier in the numerous mixed-age male herd in 1997 (19 May) compared to the young male herd with only 3 males present (23 May) and compared to both herds in 1996 (24 May). Birth synchrony, defined as the most compressed 50% interval of births, was tighter in the numerous mixed-age male herd (4 days) than the other herd compositions (5, 6 and 8 days). Birth weight and autumn weight of calves varied between years but showed few effect of treatment within

years. Weight gain of females during main rut in 1997 was significantly higher in the numerous mixed-age male herd compared to the young male herd, whereas no difference was found between treatments in 1996. In the numerous mixed-age herd in 1997 the 1.5 yr. old males gained more weight during main rut compared to the 1.5 yr. old males in the other herd compositions and compared to the 2.5 year-olds in the same herd that kept their body weighs constant. The adult males (4.5 yr. and 5.5 yr.) lost around 10% of their body weight during main rut in both 1996 and 1997. The results indicate an earlier and more synchronous calving in the numerous mixed-age herd with about 35% males but showed no significant effect on the autumn body weight of calves. There is no support that the mixed-age herds put any extra stress of the females. However, the adult males lost much more weight than the other males.

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Recovery and cryopreservation of *in vivo* produced reindeer (*Rangifer tarandus tarandus*) embryos after oestrus synchronisation and superovulatory treatment

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Ten reindeer females were assigned in an oestrus synchronization and superovulatory treatment program in order to 1) develop an oestrus synchronization and superovulation regimen as a part of an artificial insemination project of semi-domestic reindeer, 2) generate methods for embryo recovery from reindeer females and 3) freeze reindeer embryos as a part of a conservation project of wild forest reindeer (*R. t. fennicus*) using semi-domestic reindeer as a model. Oestrus cycles of the females were synchronised by a 14-day treatment with intravaginal CIDR devices containing 0.33 g of progesterone. For superovulation the females were injected twice daily for 4 days with 0.55 mg of follicle stimulating hormone in each dose starting 72 hours before the CIDR removal. Eight of the 10 females were mated one to three times during the synchronised oestrus. The matings started 43 hours after the CIDR removal. Two females were not mated and were removed from the study. Six to 7 days after the matings embryos of 4 females were recovered *'post-mortem* and embryos of the 4 remaining females transcervically under general anaesthesia. Number of *corpora lutea* was counted from ovaries of the *'post-mortem* flushed females and during anaesthesia through a laparatomy incision of the transcervically flushed females. Embryos were recovered using a commercial embryo flushing solution supplemented with bovine serum albumin. Total number of *corpora lutea* was 55 and total number of recovered embryos 11 (2 early blastocysts, 1 compact morula, 1 morula, two 8-16 cell stage embryos and 5 unfertilized oocytes, which were discarded). Embryo recovery rate was 20% (11/55). Developmental stage of six embryos was considered to represent the appropriate days after matings. These six embryos were frozen using a commercial embryo holding solution, 1.5 M ethylene glycol and 0.25 ml straws in a programmable freezer. The results of this study indicate that embryos can be recovered after oestrus synchronization and superovulatory treatment in the reindeer. The methods need to be defined and studied further in order to achieve a better embryo recovery rate.

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Body weight and reproductive status of female muskoxen in north-eastern Alaska

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Body condition is often correlated with reproductive success in ungulates. We weighted and evaluated body condition and reproductive status of female muskoxen (*Ovibos moschatus*) captured in north-eastern Alaska in August 1994 and September 1996. Females were observed from the ground in late June 1995 and 1997 to determine the presence or absence of a calf. Body weights of females estimated to be > 3 years old (n = 11) ranged from 195 kg. to 254 kg. and averaged 226 kg. No difference was observed between lactating females (mean = 227 kg., range 195-254 kg., n = 7) and non-lactating females (mean = 225 kg., range = 197-254 kg., n = 4), but sample sizes were small. Two females producing calves weighed 218 kg. and 240 kg. The heaviest female weighed 254 kg. in 1994 and in 1996, had a calf and showed evidence of breeding behaviour in 1996, but was not accompanied by a calf in June 1995 or in June 1997.

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Comparison of plasma progesterone, transrectal ultrasound and pregnancy specific proteins (PSPB) used for pregnancy diagnosis in reindeer

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The study aimed to compare plasma progesterone concentrations, rectal ultrasonography and plasma concentrations of pregnancy-specific protein B (PSPB) used for pregnancy diagnosis in reindeer. A total of 1687 blood plasma samples were collected between 1991 and 1996 from three semidomestic reindeer (*Rangifer tarandus tarandus*) herds on the Norwegian mainland (Magerøy, Sørøy, Filefjell) and from 92 wild Svalbard reindeer (*R. t. platyrhynchus*). Samples were collected between January and late April. Plasma levels of progesterone and PSPB were measured and used as indicators of pregnancy. In addition, animals from the Filefjell herd and the Svalbard reindeer were investigated using transrectal ultrasound. The results showed that plasma progesterone lower than 7 nmol l^{-1} rarely occur in females diagnosed pregnant either by ultrasound or by observing a calf at foot 7 months after blood sampling. A very good agreement was found between plasma progesterone and PSPB when used for pregnancy diagnosis. On the Norwegian mainland, but not to the same extent on Svalbard, a high proportion of females with a high progesterone concentration were diagnosed not pregnant by ultrasound. This probably reflects a high rate of false negative diagnoses by the ultrasound method rather than false positives in the progesterone analysis.

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Appearance of PSPB following mating and its disappearance after induced abortion in caribou and reindeer

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Pregnancy specific protein B (PSPB) is produced by the foetal trophoblast and can be measured in maternal plasma throughout pregnancy. Assays, developed in cattle, have been successfully used in a diverse number of ruminant species to provide a qualitative assessment of pregnancy. This paper looks at the first reliable appearance of PSPB in caribou/reindeer plasma and its disappearance following prostaglandin induced abortion. Seven caribou (CB) and six reindeer (RD) were used in the trail. Five CB and 2 RD were assessed as pregnant (based on consistently elevated progesterone profiles) while the remaining 2 CB and 4 RD served as non-pregnant controls. All the females remained separated from males except for a 4-day mating period at the beginning of the trial. Jugular blood samples were collected from all the females starting on the day of harem formation, again at harem breakup and on an alternating 3, 4-day schedule for the next 11 weeks. Between weeks 6-7 the cows were given $PGF_{2\alpha}$ to terminate pregnancy. Plasma was analysed for PSPB and progesterone. In pregnant animals, progesterone concentrations began to rise by the first week post-harem and remained elevated for 6 weeks. Following $PGF_{2\alpha}$ injection, progesterone concentrations returned to baseline in all animals. The mean appearance of PSPB in 6 pregnant animals was 4.4 weeks post-harem (range 4-5 weeks). In 1 CB, PSPB was detected briefly between 1.5 and 2.5 wk post-conception and then consistently from 5 wk through to $PGF_{2\alpha}$ injection. PSPB disappeared from maternal plasma between 4-7 days post-injection in 5 of the 7 pregnant animals. In 2 CB, PSPB was detectable at 7 and 14 d post-injection of $PGF_{2\alpha}$. Two false positives occurred, at 3 weeks post-abortion in one and at the first cycle of the season in a non-pregnant animal. In both cases, progesterone was declining and a new oestrus cycle beginning. The first reliable appearance of PSPB between 4 and 5 wk post-conception is consistent with other ruminants. The disappearance of PSPB between 4 and 7 d post-injection likely reflects the relatively small amount of placental mass at this early stage of pregnancy and rapid death of the conceptus. The continued presence of PSPB in plasma, extending to 14 d in 1 CB, may reflect persistence of placental/embryonic tissues and/or differences in maternal clearance rate.

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Genetic resources of reindeer and their conservation by method of cryopreservation of germ cells

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Reindeer in Russia has extensive area. Taxonomists distinguish 4 to 6 subspecies of reindeer but there is no concensus about how these should be classified. At the present time there is not sufficient information about genetic polymorphism of this species and the degree of peculiarity of aboriginal populations. The number of populations on island Sakhalin, in mountains of Saian and Altai, tundra form in western Siberia do not guarantee the maintenance of their genofond. The increase of diversity of the population genofond in consequence of hybridisation with domestic reindeer which easily hybridise with wild reindeer is not known. This kind of hybridisation occurred on Novaya Zemlya. The creation of a comprehensive genetic cryobank guarantees the maintenance of the reindeer genofond and allows the time for working out evolutionary relationships and carrying out measures for conservation of the genofond of rare forms of reindeer. We have shown that testes contain the sufficient quantity of sperm in 2 to 3 months after rut. Optimal medicines and their doses for immobilisation of animals have been determined. A method of semen extraction from epididymis as well as the method of electroejaculation has been developed. The optimal composition of cryoprotector and regimen of cryopreservation have been elaborated (Mkrtchian & Rombe, 1973; Deriagentsev, 1974; Sipko *et al.*, 1997). Experiments on the artificial insemination with frozen-thawed sperm were carried out successfully on domestic reindeer.

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Correlation between pregnancy and body weight on reindeer (*Rangifer tarandus tarandus)*

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In many species (e.g. pigs, sheep) a correlation between pregnancy and body weight has been found. Young sows will not conceive until they weigh 100 kg. In sheep the threshold weight varies between breeds. Reindeer herders believe that reindeer in Finland seldom conceive if they weigh less than 60 kg. The pregnancies of reindeer have been studied in Kaamanen since 1994 with a real-time ultrasound scanner. The examination is done rectally. Data on live body mass prior to the rut is available from 1970-1998 and from ultrasound studies from 1996-1998. The ages of the reindeer were from 2 to 13 years, the weights ranged from 54 kg to 107 kg. Twenty-five 2 year-old reindeer which weighed less than 61.3 kg were non-pregnant while 16 animals which weighed more than this were pregnant. Older reindeer (n = 298) were heavier. The examinations were done in December and January each year. Pregnancy is difficult to detect early in the autumn because the uterus is small and not filled with fluid. Late in winter the uterus lies deep in the abdomen and can be difficult to detect. In the most cases a positive pregnancy diagnosis is made in about 10 seconds. The movements of the reindeer and emptying of the rectum extend the time. A confirmed negative diagnosis takes longer. In individual cases the procedure should be repeated at several weeks' interval. The best method to save the results of the examination is to record it on video-tape.

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Harem dynamics of semi-domestic reindeer under different herd compositions of males

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During 1996 and 1997 we manipulated the research herd at the Experimental Reindeer Research Station in Kaamanen, Finland to document the effect of different herd compositions on reproductive success for both females and males. Prior to the breeding season we separated the females into two isolated herds of 40-50 females each. With each herd we varied the proportion and/or age composition of the male component (1996: 15% young males vs. 15% mixed-age males; 1997: 7% young males vs. 35% mixed-age males). All reindeer were individually marked or radio-collared; dominance rank was ascertained for males and females; the maternal lineage of the females was recorded and the herds were released into separate 14-15 km^2 enclosures. We then located each male daily throughout the breeding season (25 Sept. to 4 Nov.) and recorded the harem

membership (I.D. of females) for each harem-holding male as well as activity budgets of selected harems. Analysis of the harem dynamics included: female age, dominance rank and relatedness to other females in the harem for 5-7 day periods prior to oestrus, during peak oestrus and after oestrus. Results showed that in 1996 (young males vs. mixed-age males) there were very similar harem formations with the most dominant male from both groups consistently having the largest harem indicating that even a young inexperienced male will function as an 'old bull' given top dominance status. In both herds the next 3 most dominant males managed to hold harems of smaller size for varying lengths of time. Analysis from the female perspective showed that females were able to 'switch harems' at will with no significant difference in the frequency of harem switching as related to the onset of their oestrus indicating that males are unable (unwilling?) to hold females within their harem as the female nears peak oestrus. Preliminary analysis from 1997 (7% young males vs. 35% mixed-age males) showed that in the young male group only two males held harems and the females appeared to move between the two groups with a much higher frequency than earlier. These two males appeared to be less capable in servicing the females. Multiple copulation attempts (10 mounts) were observed regularly as well as the secondary copulations by the ever-present satellite male. In the mixed-age group the harem strategy appeared to degenerate substantially into one large group spread over several hundred meters with the most dominant male defending only those females that were in his proximity. We conclude that when this information is combined with the production data (weights and calving dates) and the DNA data (male reproductive success) managers can develop a better herd structure for their given situation.

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Early reproductive failure in female Svalbard reindeer in relation to age, fat and body mass

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The reproductive performance of populations of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) is characterised by large annual fluctuations in summer [cow:calf] ratios (mean 50.4%, range = 9.0-73.3%, n = 20 yr.). In the absence of any evidence of substantial perinatal mortality that might potentially explain this variation, we studied ovarian productivity and measured pregnancy rates in 80 females aged $\geq$ 2 years (46 lactating, 34 non-lactating) shot in the Colesdalen-Semmeldalen-Reindalen valley system four to six weeks post-rut (median date 29 November) 1988-1990. With one single exception, all females had ovulated in the current season, evidenced by the presence of a corpus luteum (CL) in either the left (n = 39) or the right (n = 40) ovary; anovulation is therefore not an important cause of reproductive failure in Svalbard reindeer. In 15 of the females which had ovulated (19.0%; lactating n = 9, non-lactating n = 6) we found no foetus nor any trace of foetal membranes in the uterus and were therefore unable to confirm pregnancy. The CL in 13 of these non-pregnant animals were examined and classified in one of two categories. A minority (n = 3) were small (mean diameter 2.5 mm, range = 2.0-3.3 mm) and apparently in advanced stages of regression; a majority (n = 10) were substantially larger (mean diameter = 9.9 mm, range = 8.8-11.0 mm) and did not differ significantly in size from CL in pregnant animals (mean diameter = 10.1 mm, range = 6.8-12.8 mm, n = 64). All ten large CL appeared under histological examination to be in only very early stages of regression. In *Rangifer* the CL of metoestrus is normally significantly smaller than the CL of pregnancy. We therefore propose than the ten females with large CL but no macroscopic foetuses may have been pregnant in the current season but had suffered early mortality of their embryos. There were no significant differences in age, carcass mass, fat or muscle reserves between pregnant and non-pregnant females and the causes of this apparent early reproductive failure remain unknown.

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Progesterone production during pregnancy in reindeer

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Progesterone is essential for the maintenance of pregnancy in ruminants and is normally formed in both the corpus luteum of the ovary and the placenta. In some species (goats) the corpus luteum is essential throughout gestation but in others (sheep and cattle) it remains functional until term but can be removed in late gestation without causing abortion. In muskoxen and some gazelles the corpus luteum regresses during pregnancy which is then maintained by placental progesterone alone. The ecophysiological significance of these differences is

poorly understood. The situation in deer has been little investigated but available information suggests that luteal progesterone may be very important. We obtained uterine and peripheral venous serum and samples of luteal and placental tissues from 2 to 7-year-old, Eurasian, tundra reindeer (*Rangifer tarandus tarandus*) from a free-living, semi-domesticated herd in northern Norway in November 1995 and February and March 1996. In November, ovarian venous blood was also collected. The sera were assayed for progesterone and oestradiol. The tissue samples were examined by light and electron microscopy, steroid dehydrogenase histochemistry and northern blot analysis for RNAs for 3β-hydroxysteroid dehydrogenase (3β-HSD) and P450(side chain cleavage). Peripheral progesterone concentrations in pregnant reindeer (3.2, s = 0.5, ng/ml, n = 9) clearly exceeded those in non-pregnant animals (0.31, s = 0.12, ng/ml; $P < 0.0001$, n = 9) but oestradiol levels were only marginally higher in pregnant (6.1, s = 0.6, pg/ml) than non-pregnant (4.6, s = 0.6, pg/ml; $P = 0.10$) animals at the stages examined. In pregnant animals, there was no significant change in progesterone concentrations between November and March ($P = 0.4$) but oestradiol levels rose slightly from 4.7, s = 0.4, pg/ml in November to 7.1, s = 0.7, pg/ml in March ($P = 0.03$). In November, progesterone concentrations in the ovarian vein (78.6, s = 14.6, ng/ml) greatly exceeded those in the uterine vein (9.6, s = 1.4, ng/ml) which in turn exceeded the levels in the peripheral blood (3.2, s = 0.4, ng/ml; $P < 0.0014$). Oestradiol concentrations were slightly but significantly ($P < 0.014$) higher in the ovarian (19.7, s = 2.8, pg/ml) than the uterine vein (13.3, s = 1.1, pg/ml) and, in turn, greater than in peripheral blood (6.1, s = 0.6, pg/ml). All samples of luteal tissue consisted exclusively of healthy active-looking cells and stained intensely for 3β-HSD. Isolated groups of placental cells also stained strongly for 3β-HSD. RNA for P450(scc) and 3β-HSD was abundant in all corpora lutea and lower concentrations of P450(scc) were present in the placenta. 3β-HSD RNA in the placenta was below the limit of detection. We conclude that the corpus luteum is the primary source of progesterone in pregnant reindeer but that the placenta is also steroidogenic.

Session 9 Activity and movements, feeding behaviour and habitat selection

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Red deer and roe deer diets in forests of northeastern China

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We investigated the diets and dietary overlap of sympatric red deer (*Cervus elaphus xanthopygus* Milne-Edwards) and roe deer (*Capreolus capreolus bedfordi* Thomas) in coniferous and broad-leaved mixed forests of north-eastern China. Seasonal pattern of diet selection differed between red deer and roe deer. Dietary overlap was largest during winter when forage availability dropped to the lowest point. In contrast, the lowest dietary overlap was observed during summer when forage resources were most abundant. Dietary quality (CP, NDF, ADF, IVDMD, Ca, P, Na, K) varied seasonally for both cervids. No significant differences were demonstrated in dietary quality between red deer and roe deer. Dietary CP, Ca, P, K appeared to be adequate, but forage concentrations were near minimal levels throughout the year. Low IVDMD in both cervid diets during winter indicated that energy was a key limiting factor.

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Winter foraging ecology of a population of Arctic tundra caribou after a predicted range shift

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Major population declines of caribou on Arctic tundra have been attributed to either density-independent variations in accessibility of forage due to snow and ice, density-dependent forage depletion, or both. Evidence of forage depletion has been restricted largely to caribou populations with little or no predation. In 1985, Inuit predicted a major shift in the traditional winter range of caribou from Foxe Peninsula (FP) on southern Baffin Island where there were wolf predation and unlimited subsistence harvesting. Based on satellite telemetry, the emigration began in 1988. In 1992 we examined winter forage resources, snow cover and food selection of caribou that emigrated to Meta Incognita Peninsula (MIP) and those remaining on FP. Foraging sites of caribou on both peninsulas were similar in size, slope and aspect. Cratering density within foraging sites was greater on MIP. Caribou on FP dug feeding craters in shallower, softer snow. The biomass of most fruticose lichens was greater within foraging sites on MIP than on FP. The biomass of shrubs, other than *Cassiope tetragona* and

Dryas integrifolia, was greater on MIP. *D. integrifolia* was the only plant class that had higher biomass on FP than on MIP. Ordination suggested 3 natural groups of plants within caribou foraging sites. Two of these groups showed overall evidence of impacts from cumulative overgrazing. *Cladina* spp., *Cladonia* spp., *Sphaerophorus fragilis* and *Cetraria nivalis* were found less frequently in the rumens of caribou from FP than those from MIP. Graminoids were important forage on both peninsulas. Mean occurrence of fruticose lichens in rumens on both peninsulas (i.e., 4% on FP and 10% on MIP) was similar to that on other overgrazed tundra winter ranges. This supports our suggestion that the high density of immigrating caribou on MIP had already impacted forage supply during the first four winters of occupation. Caribou on MIP rarely consumed *C. tetragona* but most caribou on FP consumed *C. tetragona* in quantities that rivalled their mean consumption of fruticose lichens. Long-term cumulative overgrazing on FP reduced the absolute supply of important forage plants on foraging sites accessible to caribou through the snow in most winters. We suggest that the physical condition of caribou on FP was impacted by largely density-dependent ecological processes. Although grazing had affected forage resources on MIP, physical condition of the caribou had not yet deteriorated. Cumulative overgrazing on winter range enables compounding density-dependent and independent processes that are typical of tundra environments to influence caribou populations, allowing Inuit to predict future population changes.

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A multi-scale approach to understanding the feeding habits, movements and distribution of woodland caribou in northcentral British Columbia

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We examined the foraging habits and movements of a population of northern woodland caribou (*Rangifer tarandus caribou*) at several spatial scales over three winters (Dec 1996 to Apr 1999). To understand foraging behaviour at the scales of the forage species, feeding site and patch we trailed animals in snow-covered forested and alpine habitats and measured vegetation characteristics (species composition and abundance) and snow conditions (depth, density and hardness) at terrestrial and arboreal feeding locations. We used movement rates generated from frequent animal relocations collected with Global Positioning Collars (GPS) to define scales of behaviour larger than the patch. We tested the scale-specific effects of vegetation, patch structure, predation risk, regional snow depth and topography on the movements and distribution of our study animals across the landscape. We discuss our findings in the context of woodland caribou conservation and the necessity of adopting a multi-scale approach in studies of animal behaviour and habitat use.

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Partial migration by large ungulates: characteristics of seasonal moose (*Alces alces*) ranges in northern Sweden

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Animal populations which exhibit partial migration present an interesting opportunity to understand migratory behaviour by contrasting individual animals which migrate to others in the same geographic area which do not. Among moose in Sweden, the proportion of migrants and residents within a population varies geographically. Moose populations south of 60 °N have mainly non-migratory individuals; in more northern populations more (or all) individuals migrate between seasonal ranges. Factors which have been suggested to influence migration in moose fall into two inter-related groups: food and snow. Regarding snow, most previous studies have focussed on snow depth, but snow quality (i.e. snow density and hardness) may also be involved. Snow quality affects the depth to which an animal sinks into the snowand thus the amount of energy needed for locomotion. Regarding food, moose consume different types of forage during different seasonsand these foods generally grow in different habitats so this may also influence the migratory behaviour of moose. In a partially-migrant population, some moose decide to migrate whereas other do not -- an 'average' moose does not exist so it is important to study the decisions made by individuals. In this study, we investigated the seasonal home ranges of 36 migrant and 30 resident radio-collared moose in a population where both exist. At the level of the entire range, our analyses revealed that there was no difference in snow depth or habitat composition between summer vs. winter ranges of migrants, nor between ranges of migrants vs. residents, except for migrants having less field

habitats. When considering habitat selection at a lower level (i.e. within a range), moose selected areas which had significantly less mire, clear cut and field habitats, as well as less snow. The quality of the snow (as indexed by the depths to which moose sank in the snow) did not differ between the seasonal ranges of migrants. However, calves sank less deeply in the snow in ranges of migrants that at ranges of residents, suggesting that snow quality might also be involved. These observations suggest that habitat composition and snow depth are important at lower levels of habitat selection, but that snow quality may also affect the habitat choice of moose and their decision to migrate or remain resident.

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Foraging trade-offs by wood bison: empirical tests of patch selection under captive versus free-range conditions

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There is much debate concerning the importance of short- versus long-term constraints on forage intake of ungulates. It is generally believed, however, that forage quantity constrains instantaneous intake at low forage biomass, while at high biomass plant quality constrains the passage rate of digesta. We measured these two constraints for sub-Arctic wood bison feeding on sedges, a natural forage that constitutes the majority of their diet. From these constraints, we modelled the biomass at which energy gain should be optimal and tested model predictions on an intermediate scale for bison foraging in both captive and free-ranging conditions in the southern Northwest Territories, Canada. In captive trials, patches were arranged in a 5 x 5 Latin square design, in 3 replicate 50 m x 25 m enclosures. Patch biomass was manipulated with a rotating mowing/re-growth regime. We recorded bison foraging time in each treatment. We found that grazing time was highest in patches of intermediate biomass, in accordance with predictions of the model. On a somewhat larger spatial scale and with less control under free-range conditions, we recorded grazing intensity and patch use along systematic transects in five meadows among a mosaic of boreal forest and correlated these measures of intake with concomitant measures of patch biomass. As in the captive trials, we found that free-ranging bison preferred grazing patches of intermediate biomass. Our results indicate that foraging decisions by bison, with respect to forage quality and quantity, are based on tradeoffs between short- and long-term constraints and have strong implications for management of grazing ungulates.

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Caribou movement as a correlated random walk

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We used correlated random walk models and satellite telemetry to investigate long-distance movements of migratory and sedentary female caribou. Individual paths were quantified using measures of mean move length and angle and net squared displacements at each successive move were compared to predictions from the models. Movements were modelled over an entire annual cycle and over shorter paths delineated by behavioural changes of caribou. For paths recorded at the larger extent, the CRW model over-predicted displacement. For paths recorded over shorter temporal extents there was excellent correspondence between model predictions and observations for most periods for both migratory and sedentary caribou. Models significantly over-predicted displacements of migratory caribou during three months following calving; this was also the case for sedentary caribou in late summer and in late winter. In all cases of over-prediction there was significant positive autocorrelation in turn direction, indicating that movements were more tortuous than expected. In cases of underprediction, significant negative autocorrelation of sequential turn direction was evident, indicating that caribou moved in straightened paths during spring migration to their calving grounds. Results are discussed in light of known migration patterns and possible limiting factors.

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Activity patterns of wild reindeer in summer; 24-hour periodicity?

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Studies using direct observational methods to document reindeer activity have mostly occurred during daylight hours; nocturnal activity is seldom addressed. Extreme variation in 24-hour summer activity patterns of reindeer can result from external environmental stimuli, for example, harassment by parasitic insects. In many cases, use of only diurnal observations may not represent realistic 24-h behaviour patterns. Wild reindeer behaviour was observed during summer 1997 and 1998 in Setesdal, southern Norway. We used 3 direct observational sampling methods to document 24-h activity patterns, resource use and animal and group distribution in the terrain. The data was examined to see if and how reindeer summer diurnal and nocturnal behaviour differ. As a result of severe insect harassment throughout summer 1997, behaviour patterns did not follow polycyclic rhythms; reindeer cycles of activity, resource use and distribution were not uniformly distributed over a 24-h period. Furthermore, in summer 1997, reindeer did not exhibit equal amounts of respective activities (feeding, lying, standing, walking/running) day and night (nycthemeral). In contrast to summer 1997, summer 1998 had little or no occurrence of insect harassment. This resulted in relatively uniformed behaviour patterns diurnal and nocturnal (throughout a 24-h period). In neither summer did reindeer attune behaviour rhythms to 'set points' of sunrise and sunset (no crepuscularity). The influence of hour-of-day, period of summer (early, mid, late), year, sunrise and sunset, temperature, amount of parasitic insect harassment, cloud cover, wind, distance to closest snow patch, occurrence of sheep and group size are discussed.

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Possible energy compensation at night as an adaptation to severe energy use and limitations during day due to parasitic insect harassment

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It is inaccurate to estimate an animal's energy budget and resources use without a complete 24-hour record of the animal's activity pattern. Extreme variation in daily summer activity patterns of reindeer can result from harassment by parasitic insects. The possibility of nutrient and energy compensation during nocturnal hours following days with intensive parasitic insect harassment was studied for wild reindeer in Setesdal, southern Norway. 24-hours activity patterns were recorded using direct observational sampling methods during summer of 1997 and 1998. We hypothesised that in periods of severe insect harassment, nocturnal behaviour patterns should reflect an energy/nutrient acquiring and energy conserving strategy and support the following prediction; reindeer will compensate for the diurnal constraint of insect harassment by increasing nocturnal time spent feeding and ruminating and decrease time standing, walking or running. Summer 1997 was extremely warm and sunny with severe insect harassment. Summer 1998 was cold, wet and windy with little insect harassment. Averaged over the summer seasons for scan samples, reindeer used 33 and 52%, 30 and 31%, 18 and 6%, 13 and 9% and 6 and 2% of the time feeding, lying, standing, walking and running in 1997 and 1998, respectively. There was a significant difference in diurnal feeding activity between 1997 and 1998, with much more feeding in 1998. This was significantly correlated with insect stress. However, comparing 1997 and 1998, there was no difference in the proportions of feeding during nocturnal hours. This indicates that reindeer are not able to increase total amount-feeding time during nocturnal hours following days with severe insect harassment. The preliminary results do not lend support to the prediction.

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Behaviour interactions between reindeer and sheep on shared summer range

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Wild reindeer and domestic sheep 24-hour behaviour patterns, including activity rhythms, resource use, group and individual distribution in the terrain and behaviour reaction in direct contact with one another was studied during summer 1997 and 1998 using direct observational sampling methods. Sheep were almost entirely active (feeding, searching and ruminating) during diurnal periods and inactive during nocturnal periods of the day. Compared to reindeer, sheep behaviour patterns were less effected by variable climatic and biotic (mainly parasitic insect harassment) factors. Reindeer behaviour patterns were significantly effected by climatic variables correlated with the occurrence and intensity of parasitic insect harassment. During periods of intense insect harassment, reindeer mostly fed during nocturnal hours of the day. During periods of minimal or no insect harassment, reindeer feeding activity was more evenly distributed throughout a 24-h period. This revealed that direct interactions (direct contact) between the 2 species mostly occurs during diurnal hours of a 24-h period

with minimal or no insect harassment towards reindeer, while indirect interactions may occur evenly throughout a 24-h period. Compared to sheep foraging behaviour, when reindeer were allowed to forage during diurnal hours and when foraging at night, we observed that reindeer and sheep mostly occupied and foraged in the same vegetation types. When reindeer foraged during the day, we observed that both species often foraged in close vicinity (within 500 m) of each other. Thus, in Setesdal, reindeer and sheep resource use overlaps considerably in space and depending on the environmental stimuli effecting reindeer, also in time. Disturbance reactions (raising the head, grouping together, standing and watching, termination of foraging and fleeing) recorded during episodes of close direct contact (within 100 m) revealed no tendency of one species to show dominance significantly more often towards the other. Data and results from the observational field study in Setesdal will be compared with data gathered in a controlled experimental study using tame reindeer and sheep.

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Utilisation of old meadow by reindeer in spring in northern Norway

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Coastal farmland pastures in northern Norway, formally using for grazing sheep and cattle but now abandoned as a result of prevailing agricultural policy in Norway, represent a substantial potential resource for semi-domesticated reindeer. Approximately 16 000 hectares of such pasture are available in Troms and Finnmark but the potential of these old meadows as food for reindeer in early summer has not been documented. Food intake was therefore estimated in four male yearling (13 months old) reindeer (*Rangifer tarandus tarandus*) feeding on an old meadow (abandoned in 1990) on the island of Reinøya near Tromsø (69°N) in northern Norway after the animals had moved from their inland winter pasture. Trials, each lasting one week, were conducted in late June 1996 and July 1997. Food intake was measured by measuring faecal production with faecal collecting bags in conjunction with in vitro dry matter digestibility. Mean daily food intake was 82 (s = 13.5) g/DM/kg$^{0.75}$ (1996) and 131 (s = 15.8) g/DM/kg$^{0.75}$ (1997). Based on the intake data, the mean daily digestible energy intake (DEI) was 0.96 MJ/kg$^{0.75}$/d in 1996 and 1.85 0.96 MJ/kg$^{0.75}$/d in 1997, which was 3 and 5.8 times, respectively, fasting metabolic rate in young male reindeer. The mean body mass of the animals increased by 10% in 1996 ($P < 0.05$) and 5% in 1997. Thus, the herbage on old meadows represent a potential rescource for reindeer. Differences in DEI between years were attributed to 10% higher *in vitro* digestibility of the plants eaten in 1997.

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Comparison of activity levels throughout the year in two herds of domestic reindeer in Finnmark, Norway

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Two herds of reindeer (*Rangifer tarandus tarandus*), reported to be under different predator burdens from lynx (*Lynx lynx*) and wolverine (*Gulo gulo*) in their normal summer and winter ranges, but otherwise kept and managed in comparable ways in Finnmark, Norway, were identified. Activity levels of reindeer from each herd were monitored to assess potential effects of differing predator burdens on the locomotor activity and, hence, energy expenditure in the animals. Ten female reindeer from each herd were equipped with collars with a VHF-radio transmitter (Televilt AB, Sweden) and an Actiwatch AW4 activity data logger (Cambridge Neurotechnology, Ltd., UK). Each transmitter was assigned a separate frequency (distributed with 10 kHz intervals between 142 155 and 142 345 MHz) and was continuously active, to allow tracking of the reindeer for recovery of collars. The activity loggers had a memory of 32 kbytes and were programmed to integrate and store activity counts every 15 min (based on an omnidirectional accelerometer and a sampling frequency of 32 Hz). Tagging took place in December 1997 and all but one tag were recovered in September or December 1998. Both herds were maintained on summer ranges with similar predator burdens during that particular year, while the predator burden was considered higher on one of the winter ranges than the other. In the herd with the lower reported winter range predator burden, all 10 loggers contained data (mean sampling period 235 days, s = 83, n = 10), while in the herd with the higher reported winter-range predator burden, 5 out of 9 recovered units contained data (mean sampling period 251 days, s = 26, n = 5). Activity levels displayed typical diurnal variations during winter and spring (from mid-December to mid-May) and also in autumn (from mid-August to end of September) in both herds, with minimum activity around dusk and dawn. In summer, however, no diurnal activity rhythm was evident. Activity levels were significantly higher in summer (June-August) than during the remainder of the

period. Moreover, average daily relative activity levels were higher throughout the year in the herd with reported higher winter range predator burden, than in the other, particularly in summer. Analyses of possible differences in insect harassment and other factors to explain the difference in activity levels between the herds (particularly during summer), as well as of the body mass distributions in the two herds, are currently under way.

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Reindeer summer activity pattern in relation to temperature and insect harassment

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Grazing conditions during summer is an important factor determining body size that correlates with survival and calf production in *Rangifer*. The summer growing season is short and undisturbed grazing is crucial in order to maximise nutritious pasture. Data on weather, abundance of parasitic flies and female reindeer behaviour were collected from two wild reindeer populations in southern Norway during summer of 1997. Oestrid fly harassment had the greatest influence on activity budgets, rates of activity changes and average m^2 per animal in the herd. Harassment of oestrid flies caused a decrease in feeding ($P < 0.0001$) and lying ($P < 0.0001$) and a increase in walking ($P < 0.0001$), running ($P < 0.0001$) and standing ($P < 0.0001$). Rates of activity changes increased (P=0.001) with the presence of oestrid flies, while average m^2 per animal in a herd decreased ($P < 0.0001$). The size of herds decreased from beginning to end of summer ($P < 0.0001$), while an increase of oestrid fly harassment resulted in an increase in group size ($P < 0.0001$). With increasing ambient temperature, feeding ($P < 0.0001$) and lying ($P < 0.0001$) decreased, while standing ($P < 0.0001$) increased. In the absence of oestrid flies, only a decrease in lying ($P = 0.0322$) and an increase in standing ($P = 0.0254$) was significant for increasing ambient temperature. Mosquito abundance during observations was low throughout summer. Due to inconsistent results, no trend was apparent for the effect of mosquito abundance on activity budgets. Mosquitoes did not influence rates of activity changes. Temperatures at ground level, ambient temperature and solar irradiation had a strong positive effect ($P < 0.0001$) and relative humidity had a strong negative effect ($P < 0.0001$) on oestrid fly abundance. Analyses of recordings of wind speed had no negative effect on oestrid flies. Mosquito abundance had a strong negative correlation with wind speed ($P < 0.0001$), a positive correlation with ambient temperature ($P < 0.0001$) and negative correlation with relative humidity ($P < 0.0001$) and solar irradiation ($P < 0.0001$). While winter pasture (food availability) is believed to set the carrying capacity for a *Rangifer* population, summer grazing determines animal condition and possibility of individual winter survival. These results show that during warm and sunny summer days, oestrid fly harassment alters reindeer behaviour dramatically. A decrease in feeding, combined with an increase in energy expenditure promotes a negative energy balance during oestrid fly intense days.

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Comparative habitat and diet selection of muskoxen and reindeer on the Seward Peninsula, western Alaska

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Since the reintroduction of muskoxen to the Seward Peninsula in western Alaska, herders of semi-domesticated reindeer have voiced concerns about potential competition for forage between muskoxen and reindeer. In response to these concerns, characteristics of late winter habitat and factors influencing choice of feeding sites, cratering microsites and diets of semi-domesticated reindeer and reintroduced muskoxen were examined on the Seward Peninsula in western Alaska during 1996 and 1997. No significant differences were found in snow depth and hardness as well as percent cover of major vegetation classes between muskox and reindeer feeding sites and craters. Three quarters of feeding sites of either ungulate were located in exposed upland habitats characterised by low snow depth, high lichen cover and low occurrence of graminoids. Spatial overlap in the use of late winter feeding sites between the two ungulates was considerable. Muskoxen and reindeer did not select differently when choosing feeding sites and cratering areas. Both species selected primarily against snow depth when choosing feeding sites and against snow depth and snow hardness when selecting cratering areas within feeding sites. Diet selection differed between muskoxen and reindeer. Reindeer diets were dominated by lichens. Muskoxen showed more generalist feeding habits and had significantly more sedge and moss and less lichens in their diets than reindeer. Due to relatively low densities and different movement patterns of the two species, direct encounters between muskoxen and reindeer are rare. Few behavioural interactions were observed and none seemed to result in the displacement of either species. We conclude that despite similar use of late winter feeding

sites competition between muskoxen and reindeer in the study area does not occur at the moment, but may become more likely if severe snow conditions or increasing densities of one or both ungulates restrict the amount of available winter habitat.

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Summer feeding habits of a muskox herd on the Seward Peninsula, western Alaska

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The foraging habits of a herd of 30 muskoxen on the Seward Peninsula/western Alaska were observed during summer 1997. The herd alternated between foraging along river gravel bars where they fed mainly on *Salix* spp. and in bogs formed by old river arms where they fed on dense stands of *Equisetum fluviatile* and *Carex* spp. Five composite faecal samples were collected from the herd between July 2 and September 1 for analysis of plant fragment composition. *Equisetum* and *Carex* were collected five and three times, respectively, over the course of the summer to be analysed for in vitro dry matter digestibility and nutrient content. *Equisetum* was the major component in the faeces in early summer (44% on Jul 19) but declined towards the end of summer (4% on Sep 1) while Carex was used sparingly in early summer (3% on Jul 19) and became the major component in the faeces towards late summer (37% on Sep 1). Willows were present consistently in the faeces throughout the summer at 18-19%. Nitrogen content and IVDMD of Equisetum were higher than those of *Carex* in early summer but declined to values below those of *Carex* by Sept. 1, while values for *Carex* changed little throughout the summer. The results suggest that muskoxen select forage to maximise nitrogen intake and that *Equisetum*, where locally available, can be an important forage for muskoxen during early summer.

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Pasture use of reindeer in northernmost Lapland - GPS-tracking and satellite image data as a study method

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We tested the use of GPS-tracking system and satellite image data (Landsat-5 TM) for studying the pasture use of reindeer. Four males and six females carried 3.5 to 14.0 months GPS-receiver collars (750 to 1500 g) in three areas in northernmost Lapland in 1996-97. The GPS-receivers were programmed to obtain and store a position fix 3 to 8 times per day. Median location error was 58 m (n = 1000), at which 90% of the positions were within 105 m. The data of two GPS-receivers was transferred monthly by TUBSAT-satellite to the ground station in Germany and then to Finland. The other GPS-receivers were equipped with radio transmitters (40 g) to enable field tracking. Pasture use of reindeer was studied by forming two circles (diameter 300 and 3000 metres) around each location on the classified pasture map. The average proportion of each pasture type inside the circles was compared monthly to the proportion of these pasture types to the land area of a study district. The insulating material of GPS-receivers was not sufficient in harsh climate conditions and the actual working time of the GPS-receivers was 22 to 227 days. During that time they collected 3944 locations. The mean GPS observation rate was 0.79. Vegetation cover or winter conditions did not affect essentially the GPS-observation rate. The males in Paistunturi were relative migrant in early winter and grazed mainly both on bare mountain area with thin snow layer and on lichen pastures. When the snow accumulated in mid winter the males used mainly scanty lichen pastures and were sedentary. When snow conditions became harder in late winter, the males migrated mainly on mountain birch forests and browsed much lichens from birch trunks and also consumed birch buds. Grazing of lichen pastures and submesic heaths was intensive in May. Reindeer in each study area grazed most strongly bogs on June but if there was not much bogs, reindeer got their main diet from submesic heaths. Bogs were still grazed on July but grazing of mountain birch forests prevailed. Reindeer were migrant in summer season. The main pasture types were grazed according to their availability from August to September. The method proved to be effective to study the pasture use and migrations of reindeer. However, for future tracking, the GPS-collars should be able to prevent effectively snow and ice accumulation. Also the weight of GPS-collars should not exceed 0.7% of the body weight of reindeer (weight of a GPS-collar: 500 to 600 g).

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Long-term patterns of activity in relation to photoperiod in free-ranging reindeer and sheep

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At high latitudes the photic environment is arrhythmic for large parts of summer and winter. Under these circumstances it is uncertain if polar animals can extract sufficient photic information to regulate circadian functions in metabolism or activity. In most animals investigated, daily rhythms are controlled by endogenous circadian pacemakers that are synchronised by the daily light-dark cycle. Very few data exist for Arctic species but one, the Svalbard ptarmigan (*Lagopus mutus hyperboreus*), shows no daily rhythm of feeding activity during the polar night or the polar day. We investigated the extent to which daily rhythms of activity in reindeer persist under the continuous photoperiodic conditions of the Arctic summer and winter. The persistence of circadian rhythms of activity under such conditions would indicate their control by strong endogenous pacemakers. We also studied activity rhythms in sheep to be able to compare results with a ruminant which is not adapted to high-latitude photoperiodic conditions. General locomotor activity was recorded continuously every 10-15 min. with accelerometer-based activity loggers in free-ranging Svalbard reindeer (*Rangifer tarandus platyrhynchus*, n = 5) at Svalbard (78°N) from October to May and in free-ranging reindeer (*Rangifer tarandus tarandus*, n = 12) and domestic sheep (Norwegian Steigar sheep, *Ovis aries*, n = 5) in northern Norway (69°N) for one year and from June to September, respectively. Svalbard reindeer maintained weak ultradian cycles of activity throughout winter but we detected no overall daily rhythm of activity during the polar night (November to February); instead, the animals were intermittently active around the clock. On the mainland, by contrast, the daily activity rhythm of reindeer remained synchronised with the 24 hour cycle of twilight throughout winter. Mainland reindeer and sheep were intermittently active throughout the 24 hour day in the polar summer (June and July). When exposed to the daily light-dark cycles of autumn, however, sheep showed robust, strictly diurnal rhythms of activity while reindeer showed significant amounts of night-time activity. These results suggest that reindeer have weak circadian mechanisms: either weak endogenous pacemakers or reduced sensitivity to the light-dark cycle, though with a clear latitudinal gradient. Hence, while Svalbard reindeer feed opportunistically around the clock, as conditions permit, during the polar night, the activity of mainland reindeer appears to be masked by the twilight cycle in winter which, therefore, reduces the tendency for opportunistic feeding. The continuous light conditions of summer, by contrast, mask all 24 hour rhythmicity permitting opportunistic feeding around the clock in both mainland reindeer and sheep.

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Migrations of north Yakutian reindeer

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There are three large tundra herds of reindeer in Yakutia: the Yana-Indigirka (1), Sundrun (2) and Lena-Olenek (3). The population of Herd 1 decreased since 1987 to 1993 due to irrational hunting from 130 000 to 85 200 animals. In 1996 Herd 2 estimated 34 000 and in 1994 Herd 3 counted 77 800 animals. In the year cycle of animal grazing pastures are singled out in the following way: summer optimal (northern sub-Arctic tundra) and suboptimal (southern tundra and forest-tundra), transitional and winter (northern and mountain-taiga). Autumn migration is in October-November. Herd 1 breaks up into 4 to 5 groups dispersing widely (500 to 700 km) over Momo-Selennyakh depression and the Moma Montain Range, the Yana River basin and the Kular Mountain Range. Herd 2 has two main routes going out to the Alazeya Tableland. Herd 3 migrates within a relatively narrow passage (170 to 200 km) to the Molodo, Motorchuna and Muna Rivers basins. Migration distance for herds 1 and 3 extends over 750 to 1000 km and for herd 2 about 600 km. The annual differences of the autumn migration was seen in deviation of terms and length of movements and in different distribution of reindeer on the main routes. An early and quick leaving for the south made the extention of migration bigger. In Herd 1 vertical (mountains-plain) transfers of migration routes were observed. In Herd 3 there were long-existing (for 10 to 20 years) horizontal 'pendulum' oscillations. The main pattern of migration is almost the same and can be predicted. But there are many occasional deviations of reindeer groups from the main way depending on snow cover, weather conditions, pursuing by the hunters. So it is impossible to predict every pattern of reindeer migration. The spring migration northward is led by pregnant females. They leave their winter pastures in February-March reaching the calving places in the northern sub-Arctic tundra in late May-June. Herd 2 is an exception coming to the tundra in April. All adult bulls migrate northward in late April-May, depending on when the snow melts and green plants emerge. In June-July the herds graze in the northern sub-Arctic and Arctic tundras. In late July-August when vegetation becomes less digestible and mosquitoes and gadflies disappear they reutrn south to the forests and mountains bordering the tundra. From this time on a new cycle of populational movement begins

along the zonal pastures. It is necessary to ban early spring hunting and arrange zones of protection on the main routes of migration for pregnant cows allowing them to reach their usual calving places.

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Patch use in Svalbard reindeer: food quality, quantity or parasite avoidance?

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In the summer of 1998, two experiments were carried out to test for factors influencing patch choice in Svalbard reindeer (*Rangifer tarandus platyrhynchus*). These were part of a study on plant-reindeer-parasite interactions in the Colesdalen-Semmeldalen-Reindalen valley system, which aims at understanding annual fluctuations in number of reindeer. Both food availability and gastro-intestinal nematodes are candidate factors for regulating reindeer. We regarded habitat use a crucial aspect, since it integrates both factors and tested 1) whether reindeer respond to changes in plant quality or quantity and 2) whether reindeer avoid pastures contaminated with reindeer faeces (enhanced risk of infection by nematodes). Plant quality and quantity were manipulated by either removing or adding snow from 10 replicated 2 x 2 meter plots on *Luzula* heathland. A 14 day difference in snow melt was created between advanced and delayed plots, which is equivalent to approximately 1/6th of a growing season. Fences were opened simultaneously to test reindeer selection. Early in the season, reindeer selected plots in which snowmelt was advanced, i.e. snow free longest. By doing so, reindeer select for highest biomass of both *Luzula confusa* and *Salix polaris*, major components of reindeer diet at that time of the year. Moreover, the proportion of live leaves was highest in advanced plots. Plant quality, however, measured as nitrogen content and C:N ratio of leaves, was lowest in the selected plots. Phenolic content did not differ among treatments and is therefore unlikely play a role in reindeer selection for plots with early snowmelt. Since differences in plant quality among treatments were small compared to biomass differences, selection for high biomass is likely to reveal highest nitrogen and energy return. To test whether reindeer can avoid heavily infected pastures, we selected areas with graminoid vegetation in late August 1997 and fouled 13 replicated 5 x 5 m plots while leaving similar sized control plots untreated. During the next summer, reindeer grazing was recorded in all sites by counting number of grazed and ungrazed shoots. Fouling led to significantly lower grazing by reindeer; by doing so they reduce the risk of becoming infected by Trichostrongyles. Diet of marked reindeer was determined and related to infection level of individuals. In summary, we showed that both plant quantity and pasture risk of infection influence patch choice in Svalbard reindeer. These aspects, therefore, may interact and play a role in the regulation of number of reindeer in Svalbard.

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Habitat selection by calving caribou of the Central Arctic Herd, 1980-1995

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Habitat selection by calving caribou of the Central Arctic Herd was compared between calving areas in developed (treatment) and undeveloped (reference) regions on Alaska's Arctic Slope, 1980-1995. Distribution of calving caribou was estimated by using fixed kernel analyses on 183 calving sites of 96 radio-collared females. Concentrated calving occurred in both developed (between the Sagavanirktok and Colville Rivers) and undeveloped regions (between the Sagavanirktok and Canning Rivers). Distance between centroids of concentrated calving areas was greatest ($P = 0.07$) and the shift directional (inland and away from development) during initial development in the treatment area and remained more constant in the reference area. Habitat attributes (e.g. vegetation type, snow cover, plant biomass (Normalized Difference Vegetation Index, NDVI), rate of increase in plant biomass) in concentrated and available calving areas were compared by area through time. Availability of habitat attributes differed between treatment and reference areas. Because of the greater shift in concentrated calving location in the treatment area, use and selection of habitat attributes was more variable in the treatment than in the reference area. In the reference area, caribou consistently selected wet graminoid vegetation types while in the treatment area caribou tended to select moist graminoid-shrub only after their distribution had shifted in the post-development phase. Snow cover was variable in both treatment and reference areas and caribou showed no consistent selection for any snow cover class in either area. A climate-warming signature, in the form of increasing NDVI at calving, was evident on both the treatment and reference

areas and was positively correlated with increasing population level of the Central Arctic herd. This warming effect on forage may have masked the effect of development associated habitat shifts at the herd level.

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Impact of the range expansion of the Western Arctic Caribou Herd onto traditional reindeer ranges of the Seward Peninsula, Alaska

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The reindeer industry has existed in Alaska since the turn of the century. Ownership of reindeer by Native Alaskans has become both culturally and economically important in the villages of north-western Alaska during that time. Reindeer herding, directly or indirectly, has generated millions of dollars in revenue critical to the economies of rural Alaskan communities. Both subsistence and commercial reindeer meat production in Alaska has been stable for the last 20 years. The reindeer herding industry has largely been concentrated on the Seward Peninsula because of the lack of a major and permanent presence of caribou. Since 1976 the Western Arctic Caribou Herd has increased from 75 000 animals to the present population of 485 000 animals. Concurrently, seasonal migratory pathways of the WACH have shifted westward onto traditional reindeer ranges of the Seward Peninsula. Herders have lost many or all of their semi-domesticated reindeer due to commingling and out-migration with wild caribou, radically changing the economic base for many villages. This paper will delineate the westward shift of caribou presence on the Seward Peninsula and quantify the consequential loss of reindeer from 1989 to present. Two reindeer herders have suffered 100 percent loss while four herders have suffered over fifty percent loss of their herds due to the migration of caribou through their ranges. Reindeer meat production is likely to be affected by these changes.

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Economically optimal stocking rates in reindeer husbandry

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Sustainable slaughter yields presume that population densities are kept below the ecological carrying capacities of the different seasonal pastures. It is likely that target stocking rates (SR) applied by herders are around densities corresponding to maximum sustainable yields, although animal numbers fluctuate over time. Economically optimal SR are assumed to be lower than those for maximum yield, but it is not obvious how to predict an economically optimal SR in practice. An age-structured dynamic herd model was parameterised from empirical data and used to compute equilibrium slaughter yields over a range of physical conditions of animals (AC, expressed as autumn weight of adult females) and varying slaughter policies. Animal productivity components were connected to AC and further to pasture resources via relationships between AC and SR. The various slaughter policies were evaluated at equal total pasture consumption in order to make the comparisons at equal forage availability or quality and therefore at assumed equal AC. Pasture consumption was based on energy requirements computed for each individual animal type with a bioenergetic model. Maximum meat yields were consistently found at herd AC close to 70 kg, which largely agrees with the common conditions in practice. The maximum productivity of e.g. a calf-slaughter policy with 90% females in winter stock was about 40% higher than that of a policy with proportional harvest in each age class and 80% females in winter stock. Other alternatives were in between these two. Economic optima were found at AC levels around 75 kg when a meat price of 50 SEK/kg and marginal management cost of 200 SEK/animal in winter stock was assumed. The economic optima require SR to be up to 25% lower than at maximum meat yield, provided a linear relationship between SR and AC where a 50% change of the SR at AC level 70 kg causes a 10 kg change in adult animal weight. At economic optima the areal productivity of meat was projected to be 8 - 14% lower than productivity maximum, but net economic returns were between 10 and 27% higher. The calf slaughter alternative was projected to give nearly 60% higher net economic return than the proportional slaughter alternative. These results suggest the changes of SR, which are needed in order to reach economic optima, but for the particular cases the slope of the relationship between SR and AC must be known.

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Changes in reindeer area in Yamal region in 20th century and prospects of conservation of northern Yamal population

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The first description of reindeer distribution in Yamal (Zhitkov, 1913) shows that the reindeer inhabited only the northern part of the peninsula. In the western part no reindeer was observed to the South from the middle reaches of Morda-yaha river and in the eastern part - to the South from the drainage-basin of Venuy-yaha. V.P. Evladov (1929) points at the fact that reindeer could be met starting from the latitude of the northern end of lake Neyto, which is south of the area boundary determined by Zhitkov. During the following decades the wild reindeer area boundary steadily moved the North and in the 1940s it was marked significantly further north - approximately from the cape Harasavey in the West to the factory Tambey in the East (Drury, 1949; Geptner *et al.*, 1961). Number estimation conducted in 1978 with help of aircraft (Bahmutov & Azarov, 1981) shows that the reindeer area boundary moved further to the North. Separate small groups of reindeer were met only in the drainage-basin of Yahada-yaha in the extreme north-western part of Yamal. These data are confirmed by the land estimations carried out in 1980 (Sosin *et al.*, 1985). Single reindeer and groups of 3-5 animals were met near the mouths of the rivers Yahada-yaha and Paindte-yaha and neighboring sea-side low ground. Foot-prints of single reindeer and small groups were found in the region of cape Skuratov and in the lower reaches of Syadora-yaha. The latter is the southern boundary of reindeer area in summer period. In the beginning of the century (Zhitkov, 1913) one could meet wild reindeer herds as big as 100 animals. In 1920s and 1930s the average size of a herd was 20-30 animals. A.N.Tyulin (1938) estimated the number of wild reindeer in 1928 at 8000 animals. In accordance with the data of the same researcher the number of wild reindeer in Yamal in 1937 was 2700, while 300 from them were annually killed by natives. In 1930 there were about 5000 reindeer on the Beliy island during the summer; several hundreds stayed there for the winter, the others left for the continent (Tyulin, 1938). In the next years the number of reindeer severely decreased and up to the year 1949 there were not more than 300 animals left (Uspensky, 1949). In the following years the number, apparently, balanced on this level. The data of air estimation carried out in 1978 (Bahmutov & Azarov, 1981) showed that the number of reindeer in Yamal was not more than 60 animals. Besides that about 50 to 80 reindeer inhabited the Beliy Island. Thus the number has become more 50 times lower than it used to be 40 years ago and the area has become 4 to 5 times less. The basic reason of the wild reindeer number collapse is domestic reindeer breeding. Conservation of the reindeer population in the northern part of Yamal will be possible only after creation of a sanctuary.

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Status of muskox populations in Alaska

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Disappearance of muskoxen from Alaska by the late 1800's and decline of populations world-wide resulted in efforts to re-establish the species in Alaska. Muskoxen acquired from Greenland were released on Nunivak Island, Alaska, in 1935 and 1936. Between 1967 and 1981 animals from Nunivak Island were successfully relocated to four sites in northern and western Alaska. In some regions muskox numbers stabilised within two decades, while in others numbers are still increasing. Since their return to Alaska muskoxen have increased to over 3000 individuals. Range expansion has occurred, although not all original range has been reoccupied. This poster reviews estimates of muskox numbers, population trends, distribution and harvest levels in different regions of Alaska.

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Reindeer herding in northwest Europe - biological limits and challenges

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Wild reindeer were once dispersed over must of northern and central Eurasia. At present reindeer herding is restricted to the forests and mountains of the north and is closely associated, in Fennoscandia, with Sami culture. Both the trade and culture are based on knowledge of the natural environment. The goal of the modern trade is to create a healthy economy suited for a money-based society. Reindeer husbandry differs from domestic husbandry because it is the natural pastures, not the animals themselves, that are that are the primary resource. The reindeer is a ruminant. It is wholly dependent on symbiotic micro-organisms in its rumen for digesting the plants it eats. It utilises pastures with high nutritional value during the short summer and it survives winter owing to a much reduced appetite and a mixed diet including lichens rich in carbohydrates. Reindeer compensate for low intake of protein in winter by an effective recycling of nitrogen. The digestibility of forage plants is an important criteria by which to assess their nutritional value. Reindeer are gregarious animals whose selection of habitat varies seasonally. Pasture use is very uneven as a result. Sedges and grasses tolerate grazing better than herbs. Predators, bloodsucking and parasitic insects influence habitat selection. The carrying capacity of pastures can be considered in terms of both biological production and economic return (ecological and economic carrying capacity). Few satisfactory field methods are available for determining optimal stocking density at either carrying capacity. This report summarises knowledge and provides recommendations for the herding units and management authorities on how to achieve better planning and administrative procedures for reindeer husbandry.

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Fright distances of Forelhogna reindeer after disturbance by humans on foot or ski

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The main purpose of this study was to record reindeer (*Rangifer tarandus tarandus*) fright distances in Forelhogna, Norway and identify factors involved in Forelhogna reindeer's fright response towards humans on foot or skis. The study was carried out in March, July and September/October 1996. A comparison among seasons was used in testing whether reindeer in Forelhogna became more shy directly after the hunting season (Aug 20-Sep 20) compared to the insect- (Jul) or winter season (Mar). Reindeer in Forelhogna were not more shy towards humans after the hunting season compared to the other seasons. Fright and flight distances were longest in winter, while running distances were longest in summer. All distances were significantly shorter ($P < 0.01$) in autumn. Large groups exhibited significantly shorter ($P < 0.01$) response distances and showed a curiosity response more often ($P < 0.05$) than small groups. When a mixed group showed a curiosity response towards humans, calves (< 1 yr.) were most often ($P < 0.01$) the closest animal to the provoker. When provoked, reindeer moved up slope significantly more (73%, $P < 0.01$) than level (11%) or down slope (16%). The reindeer also retreated into the wind significantly more (54%, $P < 0.01$) compared to with the wind (21%) or side wind (25%). In autumn, when a mixed group began to move, an adult female most often led the group away from the provoker (67%, $P = 0.24$).

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Milk production and health in cold freestall barns

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Before 1990 there were 6 warm freestall barns in the Västerbotten County; all other other dairy cows were tied in traditional barns. Since then more than 20 cold unisolated freestall barns have been built, 14 of which have been in use for more than one year. Health and production results in 1991 and 1996 were compared between the two kinds of barns. The average size of 'warm herds' increased from 49.6 to 55.3 cows and their production increased from 930 kg to 8158 kg ECM. The average size of 'cold herds' increased from 34.1 to 65.3 cows and their production increased from 765 kg to 8606 ECM. Veterinary treatments for mastitis in the 'cold herds' decreased from 23.6 to 9.9% per cow and for other diseases from 22.2 to 9.6%. The corresponding changes in the 'warm herds' were from 23.8% to 15.3% for mastitis and from 11.2% to 15.2% for other diseases. The proportion of stillborn calves increased from 6.3% to 9.8% in the 'cold herds' and from 5.1% to 6.9% in the 'warm herds'. Cows in the 'warm herds' silage were fed concentrates *ad libitum* through transponder systems.

Five of the 'cold herds' had the same system while the other used total mixed rations (TMR). The production in the TMR-herds was 8716 kg ECM and 8408 kg ECM in the transponder herds.

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Rendeer diet and pasture carrying capacity

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Like other Nordic Cervids reindeer show pronounced seasonal variation in diet. This is combined with a shift in home ranges winter and summer and reflects plant availability and plant or plant part quality, both due to climatic conditions. Monitoring of lichen ranges and animal condition is today necessary to balance reindeer numbers to pasture production and make an economically sound reindeer husbandry. Reindeer husbandry takes place in a very varied climatic range in the Nordic countries. Annual precipitation varies from 300 mm to 2000 mm, mean July temperature from 4 °C to 16 °C and for January from -4 °C to less than -16 °C. Despite this, we find a remarkable similarity in diet. In the snow free period reindeer choose fresh leaves and shoots of trees, bushes, herbs and graminoids. Through a continuous shift to new species they obtain high quality food that is easily digested. In winter, food availability is very important. Regions with shallow snow are preferred. In most of northern Fennoscandia this means mostly continental inland areas, but in winter ranges along the Norwegian coast persistent snow cover for more than a week is rare at sea level. In both these very different winter ranges lichens are a preferred food. Lichens grow slowly and a perennial species often found in mats covering large areas. Grazing removes many years of growth. The entire thallus is edible and often destroyed by the grazing. A too high reindeer density may ruin regrowth, leaving large potential areas barren for decades. The alternative food, withered graminoids and bushes have low digestibility compared to lichens. In the modern reindeer husbandry the goal is to maximise the meat production. A prime interest is to secure winter pastures in a good condition. This means to graze so to maintain a high proportion of the lichen productive area intact. To achieve this monitoring lichen grazing is necessary. Husbandry practices must not violate this very important food search patterns in the snow free period. The reindeer growth and reproduction depend on access to high quality food in the growing season. The economics of reindeer husbandry suffer from large deviations from the normal grazing behaviour. A monitoring of animal reproduction and condition is necessary. The economic carrying capacity is lower than ecological carrying capacity. The latter is a question of survival of the reindeer only, the first the survival of the reindeer husbandry.

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A program for monitoring lichen grazing in Finnmark, Norway

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The goal of modern reindeer husbandry is to maximise meat production on the total available grazing areas. A prime interest is to secure winter pastures in a good condition. This means to graze so to maintain a high proportion of the lichen productive area intact. To achieve this a monitoring of lichen grazing is necessary. A total of 22 000 km² holds 15 000 km² heath plant communities with dominating lichen mats. The regulations allow from 181 to 289 days of use annually by reindeer. On several occasions during the last 20 years the lichen mats have been characterised as overgrazed. Reindeer carcass weights have dropped. There is currently a strong interest in improving the economy of reindeer herding. Several measures have been and will be taken to improve the situation. A monitoring program was commenced in 1998 to measure changes in lichen biomass. Satellite data survey large areas; small areas are mapped using a netwerok of fixed plots. The plots are 80 x 120 cm², in a group of 6, with one are protected against grazing. Groups are set out in N-S transects 10 km apart. Five parallel transects cover western Finnmark. 300 plots were described in 1998 and 200 more are planned for 1999. The description of each plot includes of a species list and a standardised photograph. The photograph is later digitised and processed for percentage cover of different species or species groups. All plots are positioned by modern GPS equipment.

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Immobilisation of wild reindeer for the rational utilisation of its resources on the territory of Chukotka

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Methods for the mass live capture of reindeer by immobilisation with myorelaxants in combination with the SL-28 syringe are described as well as the technology for long distance transport of reindeer with low losses. Reindeer in Chukotka inhabit mountainous places and migrate in small groups, precluding hunting organised in the same way as on the Taimyr Peninsula where reindeer are shot en masse while crossing rivers. Large scale shooting causes a great deal of noise that frightens the animals away; haematomas resulting from wounds reduce both the harvest and the quality of the meat. Killing males for their velvet antlers in late spring or early summer is wasteful for the meat cannot be stored and is therefore lost. Immobilisation of reindeer before slaughter enhances both the quality and the quantity of meat harvested. Immobilisation of animals for the collection of velvet antler has been successful: more than 50% of the animals survived the treatment. The application of immobilisation equipment which produces little noise and does not frighten the animals, and which therefore permits selective hunting, is described. The optimal immobilisation doses of the myorelaxant ditilin is 0.12 to 0.15 mg/kg live weight.

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Assessing the effectiveness of wild reindeer management systems in Iceland

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The wild reindeer, numbering around 2000-3000, are managed under a harvest quota system for sport hunting in Iceland. Population estimates are yielded by ground counts in April and aerial censusing photography estimations in July. These, along with ground counts of sex and age composition, provide the basis for setting harvest quotas. A model has been developed to determine an annual quota and it has been used for eight years. On top of this, hunters and farmers make recommendations for herd management through a reindeer advisory committee, which has an active role in the management system. We evaluate the developed harvest model and the co-management system in the eastern Iceland.

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Status and conservation of goral (*Nemorhaedus goral*) and serow (*Capricornis sumatraensis*) population of oak forest in Kumaon Himalayas, India

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We surveyed 19 oak patches of the middle altitude oak forest in the Kumaon Himalayas to document status and abundance of goral (*Nemorhaedus goral*) and serow (*Capricornis sumatraensis*). Random searches, trail monitoring and quantification of pellet group along trails were employed to document the status and abundance of two species. Habitat characteristics were recorded in 634, 10 m radius circular plots. Goral and serow occurred at 14 and 3 sites respectively. The mean pellet group density for goral was 8.05 and 0.84 for serow. The mean pellet group density of goral and serow differed significantly viz. Habitat type, topography and habitat parameters. Illegal poaching for meat and habitat loss was found to be the main threat to conservation of these two ungulates. Immediate check on poaching and creation of more protected areas is recommended for better conservation of population of these two goat antelope species.

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Regional features of changing of domestic reindeer population in north Russia: cultural, economic and ecological factors og importance

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The report is based on Official Statistic data about population changes of domestic Reindeer in 19 Northern Regions of Russia from 1941 to 1998, wild reindeer from 1961 to 1998 and on expedition investigation results. In course of those expeditions in 1993 to 1998 traditional knowledge and values of reindeer herders and reindeer hunters in Taimyr were collected and summarized (8 national settlements and 20 groups on nomadic and semi-nomadic population were inspected) and the economical situation in reindeer-breeding of Nenetsky Autonomous Region has been studied. The analysis of statistic data allowed to ivide North Russian territory into 3 areas: Western tundra area (west of the Yenissey river) where number of domestic reindeer during least years keeps stable or grows. Eastern tundra area (east of the Yenissey River), where number of domestic reindeer decreased sharply last years (2-3 times) and number of wild reindeer has increased. Taiga area, where number of domestic

reindeer was always low and now it decreased nearly to zero. These differences in changing of domestic reindeer population could be explained by different factors: ecological factors including grow of wild reindeer population, overgrazing of pastures and climate variations etc. Social factors. The transformation of the economy is different in different regions. Cultural factors. Different reindeer nations response in different way on the economical crisis. Remarkable domestic reindeer population growth is observed only among Nenets. Some nations lost domestic reindeer herding completely. The comparative study of the influence of these factors was held in Taimyr, where 4 different indigenous Reindeer Peoples; Dolgans, Nenets, Nganassans, Evenks are living. Three kinds of habitant reaction on the changing conditions in dominated society were established like those: isolation, passive and active adaptation. Only last type allows to preserve reindeer breeding as traditional way of life under unfavorable conditions. It is specific for Nenets reindeer breeding. This is the reason why growth of domestic reindeer is notable only among Nenets.

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Towards a research plan on the human role in reindeer/caribou systems

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An international group of eighty *Rangifer* users, managers, and social and natural scientists gathered at the Arctic Centre in Rovaniemi, Finland this past February for an interdisciplinary workshop with a circumpolar focus. The goal was to formulate a research plan for studies of the human role in reindeer/caribou systems. Small group discussions were organized with six themes: hunting systems, herding systems, rangeland/habitat protection, minimizing industrial impacts, maintaining the strength of indigenous cultures, and responding to global change. Each group generated substantive research questions and focused attention on issues related to research practices. An overview of the research guidelines follows: Facilitate better communication among players - Research projects need more effective communication that enables Arctic residents to understand better the findings of studies, assume a role in framing research questions, and participate in research information exchanges. Research agendas should be formulated in closer cooperation with user organizations. Understand better the dynamics of Human-*Rangifer* Systems - Among the approaches recommended are circumpolar comparative studies, new approaches to integrated regional monitoring and assessment, the creation of a meta-database of information sources, and studies that consider how cultural perspectives shape norms and values in the use of *Rangifer* resources. Improve the ability to anticipate and respond to change - Today's unprecedented socioeconomic, environmental, and political changes underscore the need to investigate more thoroughly and articulate more clearly the risks and benefits associated with policy choices. Central to this enterprise is the problem of assessing cumulative impacts. Reframe the paradigm - The complexity of Human-*Rangifer* Systems and their current rate of change point up the need for a critical review of theories and assumptions used in conventional *Rangifer* analysis, and for frameworks that account for differing cultural perspectives. Develop new methods - Among the most forcefully stated directives was the call to develop new research methodologies that are holistic in approach and provide meaningful involvement for indigenous resource users in the co-production of knowledge. Organize researchers into a stronger and better coordinated network -There is a need to capitalize on emerging technologies (e.g., the internet) to develop stronger links among researchers, create improved circumpolar collaboration and make the Rovaniemi research-planning exercise an on-going process. The research plan is established as a living document and developed through an interactive web-based *Rangifer* resource guide, located at http://www.dartmouth.edu/~arctic/conf/. The workshop's transactions illustrate the challenges of circumpolar research planning, and the evolving plan offers a model for formulating and coordinating Human-*Rangifer* System research agendas.

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Role of cropping in regulation of the harvest of wild reindeer in Taimyr

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Between 1971 and 1998 more than 1.6 million wild reindeer were culled from the Taimyr population during which time the population increased to 359 000 animals. Cropping was low in 1971-72 and the adult sex ratio in the population was approximately 1:3 M:F. Cropping was increased thereafter and the ratio fell to 1:2. Prior to 1972 the age structure of the population resembled that typical of a lightly harvested population with a large

segment of females aged 4-11 years old and a substantial number of males aged 5-11 years old. By 1980 the population contained few females older than 8 years and few males older than 7 years. The harvest decreased after 1987 and by 1998 the proportion of males in the population aged >8 years increased from 12.9 to 29.8% of the population. The productivity of this population can only be maintained by rigidly maintaining recommended culling strategies.

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Problems of wild and domestic deer interrelations and condition of pastures in the north of Yamal

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During the whole 20th century the number of domestic reindeer in northern Yamal has been steadily rising and in 1989 it has reached 496 000 animals. Besides that the density of population in some regions has come to 2.1 reindeer per 1 km^2 of pasture. In northern Yamal, in the zone of cohabitation of wild and domestic reindeer, domestic reindeer browses on the pastures of typical and Arctic tundra and its density being a little higher than 1 animal per 1 km^2 of pasture in 1986. The number of domestic reindeer goes over the allowable limits here and this leads to a progressing degradation of pastures. The degradation comprises decrease of palatable plants, especially lichens, and in substitution of nutritionally valuable plant species by less valuable ones. The actual number of reindeer in northern Yamal in 1979 was 35 000 animals, while the optimum for the pastures should not have been higher than 28 800. In 1986 there were 42 600 animals. The practical stock of lichen forage was significantly reduced during that period and it amounted to 67% from the stock of 1979. The rate of population growth of the herd is at that period 3.6% per year, while the rate of lichen stock decrease is 5.5% per year. Considering this rate one can expect a double decrease of the forage stock in 12 years, while the capacity of pastures and correspondingly the permissible of the herd size would be not more than 10 000 animals. This situation could have been expected already in 1998. Further deterioration of lichens on the pastures in northern Yamal will lead to a collapse of reindeer-breeding in this region. The worsening of the pastures condition and growth of the domestic reindeer population in recent years makes it a complex problem to restore the wild reindeer population in northern Yamal. Even if the domestic reindeer breeding collapses in the near future, which is very likely, the pastures will stay degraded for a long period of time and thus a fast restoration of wild reindeer population will be blocked. In this situation the only reasonable measure to be taken to conserve the wild reindeer population would be a creation of a reservation in the northern part of Yamal where certain economic activities, in the first place domestic reindeer pasturing, would be prohibited.

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Current populations and numbers of reindeer in Russia

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The numbers of wild reindeer (*Rangifer tarandus*) in Russia in late 20th century is about some 1.5 million. The State Service for Game Reserves Management gives the following reindeer locations: in European North of Russia (from Komi Republic in the south to Novaya Zemlya in the north) there live about 35 000 wild reindeer. Easily identifiable populations in these areas stand up to heavy pressure of hunting. In Western Siberia (from Tyva Republic and Buriatia in the south and on to Taimyr open spaces in the north) there live about 700 000 wild reindeer including 100 000 forest ones and the biggest in Russia Taimyr population of tundra reindeer. In normally utilised tundra populations the female/male ratio is 1:3, while in the forest reindeer the ratio is closer 1:2 (Novikov, 1982). In Eastern Siberia the most numerous group are forest reindeer of Evenkia. In the Far Eastern Region which first of all includes Republic of Sakha (Yakutia) three Yakut tundra populations stand out: Bulun in the west, Yano-Indigirsk and Sundrun in the east. The total numbers of the above three is over 200 000. Around 70 000 of the forest variety of wild reindeer graze in vast expanses of Sakha Republic. Over the last decade in Chukot Autonomous Region, due to primarily social factors theres been a rapid growth of the wild variety. Chukotka, traditionally a stronghold of developed reindeer breeding, could not cope with the restructuring of economy and lost its herds of domestic reindeer. Today the numbers of wild reindeer in South West Chukotka exceed 200 000. Forest reindeer of southern Magadan Region, Khabarovsk Territory and Amur Region are not so numerous, around 25 000. Populations of Kamchatka and Sakhalin reindeer are depressed. Overall in Far Eastern Region there live over 500 000 wild reindeer. Hunting load on wild reindeer in Russia has never been too high, on average 5.8% of the total per decade. The poaching numbers are roughly the same. In normally functioning populations of wild reindeer the annual growth should be over 20% of the total. In Russia,

annual elimination of reindeer, never too strict, has led to a big growth of this species among most heavily hunted ones of our fauna.

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Restoration of the historical area of muskox on north of Russia

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For restoration of the historical area of muskox on north of Asia for the nearest 10 years it is necessary to create as a minimum 8 new mainland populations. The number of each population has to be not less than 50 animals. For that it is necessary to bring 2-3 groups of muskoxen with 15 to 25 animals in each group, from the different populations. To avoid inbreeding it is desirable to bring 1 to 2 populations into the each region, from island Wrangel and peninsula Taimyr and if it is possible - from the aboriginal populations of Canada, Greenland or USA. The distance between the sites of releasings ought to be 500-600 km. The aim of these stages of the work is the adaptation of muskoxen to the surroundings in the sites of releasing and forming of the steady natural populations. As the result of self-reproduction the formed population will guarantee the growth of breeding herds for the reintroduction of species into other regions, its natural settling and enlargement of area. 8 regions were selected as suitable for releasing of muskoxen in north of Asia (Tsariev, 1996). For three years 79 muskoxen were caught and settled in three regions. It was shown that for 10 years after releasing in Taimyr and Alaska muskoxen settled for the distance 300-650 km from the site of release. According to optimistic prognoses in 10 to 15 years after creation of 8 isolated centres of reproduction on the North Asia we can expect the confluence of isolated progressing populations and restoration of unbroken historic area of muskox on the shore of Northern Ocean from Yugorski to the Chukotka peninsula.

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Potential response to calf selection in reindeer (*Rangifer tarandus*)

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The objective of this survey was to evaluate the efficiency of calf selection in the Tännäs herding community (Sweden), where calf slaughter has been the main practise. Five reindeer herders practised calf selection continuously since 1986, utilising individual ear tags and weights recorded in a data base. To estimate the potential selection response, calves owned by Tännäs reindeer herders not practising selection were also weighed in autumn in 1996 and 1997. A total of 3100 calves were weighed from the two groups. Mean calf body weights were 41.7 kg and 43.2 kg in 1996 and 1997, respectively. The observed difference between groups, adjusted for non-genetic effects, was 0.7 kg (statistically significant, $P < 0.05$). This difference can be attributed solely to selection carried out on female calves and the subsequent gene flow from mothers to daughters. The potential response, i.e. the expected response if the two groups had been isolated during the rut, is estimated to be in the range of 2.9 to 4.9 kg. The potential effect of male gene flow is large because the male generation interval is much shorter than that of females (2.5 vs. 6.3 years). The results show that calf selection has been successful and imply that the selection system could be improved by avoiding contributions from unselected males.

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Effects of overflights by low-altitude jet aircraft on habitat and terrain use by caribou

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Military training exercises have increased in Alaska in recent years and effects of low-altitude overflights on wildlife such as barren-ground caribou (*Rangifer tarandus*) have caused concern among northern residents and resource agencies. We evaluated the effects of overflights by low-altitude U. S. Air Force (USAF) A-10, F-15 and F-16 jets on habitat and terrain use by free-ranging female caribou, using the Geographic Information System (GIS), ARC/INFO. Habitat was derived from a classified LANDSAT-TM image defined jointly by Ducks Unlimited and the U. S. Bureau of Land Management (BLM). Terrain variables, including aspect, slope and elevation, were deduced from Digital Elevation Maps. Terrain ruggedness was estimated via circular statistics using the GRID module of ARC/INFO. This study was conducted on caribou of the Delta Caribou

Herd in interior Alaska during each of 3 seasons in 1991: late winter, post-calving and insect harassment. Noise levels experienced by caribou were measured with Animal Noise Monitors (ANMs) attached to radiocollars. We used multivariate analysis of variance (MANOVA) to test for differences among 3 treatment groups (treatment and control caribou and random locations). Treatment caribou were subjected to overflights by jet aircraft while jet aircraft avoided control caribou. Caribou subjected to overflights in late winter did not alter habitat or terrain use. Post-calving caribou responded to overflights by selecting closed mixed forest (75% aspen [*Populus tremula*], 15% spruce [*Picea* spp.] and 5% each of willow [*Salix* spp.] and bare ground) less frequently (P = 0.049) but otherwise utilised terrain and habitat similarly to control caribou. In the insect season, caribou subjected to overflights selected sites of greater ruggedness (P = 0.039), higher elevation (P = 0.008) and more frequently used sites dominated by gravel and rock (P = 0.007) than did caribou not subjected to overflights. Thus, responses of caribou were nonexistent in late winter, intermediate in post-calving and strongest during the insect season. The insect season is a critical period of weight gain for caribou attempting to reach the threshold weight necessary to enhance the probability of conception in autumn. Consequently, increased time spent in areas of little or no forage during this season could have significant deleterious effects on individual reproductive success and, hence, on population pregnancy rate. Military training exercises should be curtailed during the cool of the day in the insect season when caribou may benefit from the greatest foraging opportunities.

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Wild reindeer of the Kola peninsula at the end of the 20th century

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In the beginning of 20th century on the Kola peninsula (Russian Lapland) the number of wild reindeer (*Rangifer tarandus*) was low. The development of reindeer farming especially in connection with occurrence per 80 years at the last century of the domestic reindeers of *ijemski* kind was resulted to intensification of pressure on wild reindeer, driving back it to difficult places. The traditional migration routes were broken and population was divided. With construction of the railway in the 1920s the communication between the eastern and western parts of the population of wild reindeer stopped. Gradually the numbers of domestic reindeer in the western region reduced. At the same the amount of wild reindeer increased due to organisation of Lapland Nature Reserve (zapovednik) in 1930. At the end of the 1960s this herd achieved maximum of 12 000. On the East the number of wild reindeer was 8000 at the same time. In the same area - on the East of the Kola peninsula- the main herd of domestic reindeer was concentrated and the contacts with the wild reindeer were marked more often. In connection with intensive hunting and degradation of the pastures the number of wild reindeer sharply decreased and hardly totalled 1200 to 2000 to the beginning of the 1980s. Nowadays a crisis has passed. The herd of wild reindeer on the West of region (basically in Lapland zapovednik) grows and already numbers 1000. On the eastern part the wild reindeers are more - from 2500 to 3 000 and the hunting is permitted by license. Taking into considerable that wild and domestic reindeer are the competitors in using of pastures, the inventory of pastures of the Kola Peninsula and preparation of the common project is necessary. The breeding of domestic reindeer on the West of the Kola Peninsula is inexpedient. It leads to danger to lose the purest race of wild reindeer which was nearest to the origin. The expansion of protected area or the introduction the special regime on the territory situated to the West from Lapland zapovednik will play stabilising role in the preservation of the western population of wild reindeer of the Kola Peninsula.

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Optimal adaptation of reindeer herds to rangelands under uncertainty

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The problem of optimal adaptation of reindeer herds to rangelands under uncertain environmental conditions and measurement errors was studied by stochastic dynamic programming (SDP) and by stochastic optimisation in policy space (SOPS). We maximised the expected net present value of yearly profits from reindeer husbandry. The yearly profits were made up by incomes from calf slaughtering according to a fixed rule and slaughtering of breeding stock as a consequence of policy decisions, and variable production costs determined by the size of the retained stock after slaughter. The amount of meat produced was dependant on calves produced, survivals and average weights of calves and adults. Calving fractions and survivals were logistic functions of average body weight, which in turn depended on feeding levels determined by lichen and summer food resources. Lichen

growth and wastings during cratering depended on density of lichen. Random variation was allowed in lichen growth and summer feeding level and availability of winter forage due to weather conditions. Model parameters were developed from published information and own estimates of variation in environmental factors. With SDP optimal policies were found using a Markov transition matrix constructed by Monte Carlo simulations. Winter grazings dominated policies at low and summer grazings at high lichen densities. The skewness of lichen growth as determined by lichen density, was very important when lichen density was low. Hence, it is important to get precise estimates of lichen growth. The importance of alternative winter forage depended on its digestibility; when low, it did not effect the policy, but when above a certain limit, it mattered at low lichen densities. The policy was not sensitive to the weight level of the animals. Variable costs mattered when summer grazing was limiting but not when winter pasture was the limiting resource. Discounting with normal interest rates did not affect the policy. The policy was not sensitive to the degree of natural variation, but the value of reindeer husbandry was significantly reduced by increasing climatic variation. Evaluation of the effects of measurement error required SOPS, where a prior choice of policy function is needed. While there can be a considerable value of more precise measurements even when the relationship between lichen density and lichen growth is known, it is even more important to adapt the policy to the degree of error.

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Necessity of circumpolar approach for keeping of reindeer husbandry as a traditional branch of economy and culture of north natives

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The crisis of reindeer husbandry in Russia demonstrates how unstable can be economy of people even in a peaceful time. During 10 years Russia lost half of reindeer quantity. There are not more than 200 000 reindeer now in former world biggest center of reindeer husbandry - north of the Russian far East. Many settlements of natives don't have reindeer now. The real threat of disappearance of some reindeer kinds exists. Meanwhile deficiency of reindeer ranges for developing of reindeer husbandry in Scandinavian countries is felt. As a result supplementary feed is a big part of daily diet of reindeer in these countries. Traditional system of reindeer sustaining is transforming gradually in specific industrial technology of reindeer meat production. We must ask ourselves: should we promote to keeping of traditional branches and connected with them culture of north natives similar to as we try to conserve rare plants and animals or should we just observe as unique cultural and economic traditions die under attacks of civilizations? Obviously, death of north culture of natives is damage of the whole world culture. Therefore we should join our efforts for keeping of cultural traditions and economic habits taking in account circumpolar approach. Native society is heterogeneous in its desires. This is a problem. Some people of this society try to enjoy material wealth of western culture, improve the traditional kinds of economic activity in order to commercialize and get the maximal profit. Other people use traditional habits for survival. They prefer to migrate or stay as their ancestors lived. Support should be provided for those Native communities that try to live traditionally, who would like to be engaged in reindeer husbandry, caribou hunting, sea animals hunting, salmon fishing. Inventory and regulation of biological resources is also important for support of economic activity of natives. Domestic and wild reindeer are investigated separately in biological science. But if we consider keeping of cultural and economical traditions in circumpolar relation we should coordinate inventory and regulations of reindeer number for these aims. We can predict that only part of biological resources, for example, domestic reindeer or wild reindeer will be needed for keeping of native culture. The rest animals can be used by natives or other population for hunting (wild reindeer) or sustaining (domestic reindeer) according to industrial technologies. In this respect exchange by legislative experience between countries supporting northern culture of natives is very important. Circumpolar approach is necessary to solve problem of elaboration of optimal legislation for keeping of economic and cultural traditions of north natives.

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Introduction of muskox on the polar Ural

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In November 1997 15 muskoxen (6 females and 9 males in the age from 0.5 to 2.5 years), which were captured on East Taimyr, were brought and set free. After release the animals climbed onto a plateau of about 70 km^2,

where they spent the winter successfully. In the beginning of summer muskoxen descended into the valley of river Bolshaya Khadyta. The animals then left the area and were observed in the region of the coast of Karskoe Sea, not less than 100 km from the place of release. In December 1998 muskoxen from this group were noticed not far from the point of release in the valley of river Shtshuchia. The next group of muskoxen captured on east Taimyr consisted of 15 animals (9 females and 6 males in the age from 0.5 to 1.5 years). These animals were brought to the same region in October 1998. Six animals were liberated while the rest were kept in an enclosure. For the increasing of alternative variability and preventing of inbreeding depression two mature females were brought from Moscow zoo in summer 1998.

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State of the Putoran snow sheep population

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Area of the sheep on the Putoran plateau is situated 300 km to the north from North Polar Circle and occupies 120 000 km^2. Distribution of the subspecies has interrupted-ribbon like character and is habituated to convenient valleys. 12 sites with more than 100 animals were uncovered. The population of the sheep is situated in 1000 km from areas of other representatives of this species. According to discount the number of animals of this subspecies was about 1400 individuals in 1977, 3500 in 1986 and 5500 in 1995. Effective number reached from 1985 500 individuals, that has to guarantee the maintenance of population. The conservation of genetic diversity is complicated by scanty distribution of the animals. In consequence of the territorial conservatism of this species it is likely that the rate of exchange of genes between them is very slow. A the high degree of homozygosity has been confirmed by the preliminary genetic analysis. This subspecies is included in the Russian Red Data Book and the program of creation of another population on the Polar Ural is elaborated.

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Harvesting importance, rational using and guarding of reindeer in Yakutia

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Yakutia is unique region in Russia there are nearly equal numbers of domestic and wild reindeers (approximately, both 200 000). Pastures of wild and domestic reindeers widely recovered and remove contacting animals in present day impossibly, though in future this problem will solve differentiation of pastures territories. Main aspect of this problem is maintenance number of wild reindeer in accordance with pastures capacity and evolution domestic reindeer breeding. Possible level number of wild reindeer must determinate with taking in account priority domestic reindeer husbandry. But important role of harvest wild reindeer convince us present time it is form and self-dependent economic branch unless important for aboriginal people then domestic reindeer raising. Key condition of rational using tundra populations of wild reindeer in Yakutia is putting optimal period of harvest and keep hunting rate by sex-age structure. Base of protection of intensively exploitation wild reindeer populations must be, at first time, ecological prove and rational using this harvesting reserves. Of no small importance role in saving population may became creation reserved zones on calving grounds and mass winter-spring migration of partition females. Annually during mass migration of wild reindeers in spring and fall a few thousands of domestic reindeers lose. Now it is complicated at the same time harvesting wild and save domestic reindeer. For guaranteeing prey harvest wild reindeer and saving domestic reindeer it is necessary continuous watching for wild reindeer migrations. Using aviation for this aim is very expensive and not effective owing to changeable weather in tundra. For solution this problem we suggesting using satellite telemetry method.

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Wild reindeer and human disturbance - a study of decreasing human disturbance and use of winter pastures

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During summer 1997 an investigation was carried out on the possible influence of tourism on wild reindeer's access to the winter pastures of the Hardangervidda mountain plateau (Norway). The study area was approximately 8 km wide and 22 km long, representing a decreasing degree of human disturbance from the outskirts, with tourist activities, towards the more central area and less influenced winter grazing grounds of the Hardangervidda. Amount of reindeer-faeces were registered and the vegetation was studied at 30 *Cetraria*

nivalis-dominated bluffs. The 30 sites were distributed restricted randomly in 3 sub-areas. Within the 30 bluffs a total of 150 faeces counts and vegetation registrations of the lichen cover and 43 lichen biomass samples were carried out. The 3 sub-areas are compatible in respect to climate altitude, vegetation and topography. A total number of 100 faeces groups (of more than 10 droppings) were found in sub-region A, representing the highest intensity of human activity, compared to 792 in sub-region C, representing the least disturbed part of the winter pastures range. Lichen covered about 60 percent of the ground on the investigated bluffs in area A, but only 35 percent in area C. There was a significant correlation between percentage of lichen cover and lichen biomass on the bluffs. The abiotic cover showed a corresponding tendency, with 15 percent coverage in area A, compared to 30 percent in area C. Results from area B, representing an area with medium intensity of human activity, fell between the results from the sub-regions A and C, with respect of faeces accumulation and lichen cover. This investigation indicate a possible 'avoidance effect', where the reindeer's use of the winter grazing grounds is reduced in the areas most influenced by tourist activities, resulting in over-grazing of the less disturbed winter pastures. Human disturbance may consequently result in a direct as well as an indirect loss of grazing ground and hence reduce the reindeer carrying capacity of the Hardangervidda.

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Comparison of vigilance behaviour in wild and semi-domestic reindeer (*Rangifer tarandus tarandus*) in southern Norway

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Vigilance is related to the risk of being preyed upon and is affected by influential factors like group size and composition, season, topography, forage distribution, disturbance from humans and history of domestication and hunting. During three periods (April/May, June/July and August) in 1997, we studied the vigilance behaviour of a wild reindeer (*Rangifer tarandus tarandus*) population in Rondane North and one population with semi-domesticated origin in Norefjell-Reinsjøfjell, both located in Southern Norway. The two areas studied have a different history with regards to hunting, domestication, predation and human activity. The Rondane North population displayed a much higher rate of vigilance in all periods, measured as vigilance bouts per 10 min. -activity, compared to the Norefjell-Reinsjøfjell population ($P < 0.0001$). The Norefjell-Reinsjøfjell reindeer also devoted more time on predator vulnerable activities, like lying head down and lying head flat, than the Rondane North population. Higher vigilance behaviour displayed by the Rondane reindeer compared to Norefjell-Reinsjøfjell reindeer is most likely related to the relative differences in selective elimination of animals during past history of domestication and hunting in the two areas. Habituation to humans and the presence/ absence of large mammalian predators, could also contribute to the large differences observed. The results support the hypothesis that the wild reindeer in Rondane North will display a much higher rate of vigilant behaviour than the semi-domesticated reindeer in Norefjell-Reinsjøfjell. Other factors that seemed to influence the vigilance behaviour were season, parental status, herd size, ambient temperature and the degree of insect stress.

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Co-management of the Western Arctic Caribou Herd in Alaska

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The Western Arctic Caribou Herd (WACH) is an important source of sustenance for over 50 small rural communities in north-west Alaska. This paper summarises attempts to improve the management of this large, remote caribou (*Rangifer tarandus granti*) population. Challenges include fluctuating population size and variable movement patterns of the caribou in addition to the cultural diversity of the Inupiat Eskimos, Athabascan Indians and Euro-Americans who use this herd. Rapidly changing social conditions, conflicts between user groups and a dynamic regulatory environment are more recent issues. An unanticipated caribou population decline in the mid-1970's prompted the Alaska Department of Fish and Game (ADFandG) to increase the number of biologists living within the range of the herd and further document community subsistence harvests by social scientists. Radiotelemetry and census methods have increased our technical understanding of the WACH. A greater difficulty has been to find meaningful ways to combine western resource management with the information and world-view of Alaska Native subsistence hunters who are still the primary users of this

population and view caribou as the lifeblood of the region. Historically, subsistence hunters have not participated fully in management of the WACH by ADFandG and other resource agencies. Recently, Alaska Native people have begun seeking more meaningful roles in management of traditional subsistence resources. Progress has been hampered by a highly polarised public debate over subsistence management in Alaska. There has been progress in two broad areas. First, community harvest assessment programs carried out by ADFandG and Alaska Native organisations are becoming commonplace. Second, the Native community and other major stakeholders have been investigating the possibility of co-managing the WACH. A series of stakeholder meetings indicated substantial interest in searching for new management approaches. In 1997, ADFandG organised a WACH Working Group consisting of all known stakeholders to explore these possibilities. The group has considered one draft tribal co-management proposal and now has goals and objectives developed by consensus. In February 1999, the WACH Working Group, organised on co-management principles, became permanent. These efforts reflect a desire for co-ordination of a complex management system, stronger participation by Alaska Native subsistence hunters and avoidance of crises-driven management decision making in north-west Alaska.

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Changing management strategies for Alaskan caribou herds

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Advances in ecological knowledge and a changing political climate in Alaska over the last 10-20 years have resulted in significant changes in management strategies and goals for Alaskan caribou herds. Previously, the state's Department of Fish and Game (ADFandG) and the Alaska Board of Game (BOG) established management goals and objectives on an ad hoc basis in response to perceived demands from the hunting public. ADFandG attempted to manage caribou herds for a variety of demands (e.g., meat production, aesthetic hunting, trophy quality, scientific study), primarily based on existing uses within a herd's range. Biologists accepted that predation was the major limiting factor in most herds and that predation by wolves was a potentially manageable factor. In addition, land ownership was not a consideration because almost all lands occupied by caribou herds were unreserved federal or state-selected public lands where the state had sole management authority. Since the late 1970s, passage of federal and state subsistence laws, demands for increased participation in decision-making by various user groups, changing land ownership, controversy surrounding wolf control and evidence of significant nutritional limitation in several of the state's major caribou herds have greatly changed management strategies for caribou. In this paper, I review the history of caribou management changes in Alaska since the late 1970s and discuss current, herd specific, management goals for the 33 recognised Alaska and Alaska/Yukon caribou herds.

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Avoidance of tourists and power lines by calving semi-domesticated reindeer

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We investigated possible avoidance behaviour of calving semi-domesticated reindeer (*Rangifer tarandus tarandus*) near recreational cabins and a power line in the Repparfjord Valley, Northern Norway. The power line was situated 5 to 8 km away from the ca. 800 cabins in an area generally not used by tourists and was therefore studied separately. The distribution, sex and general age composition of the reindeer (n = 611) was mapped during the 1998 calving season using systematic snowmobile and ski surveys. Density of reindeer increased with increasing distance to cabins and to power line. Density of females decreased with 97% from 5.5 females/km^2 8 to 10 km from the cabins to 0.18 females/km^2 0 to 4 km from the cabins. By the power line, density of females decreased with 79% from 8.0 females/km^2 4 to 8 km from the power line to 1.7 females/km^2 0 to 4 km from the power line. Maternal females were more sensitive to disturbance than were bulls and yearlings. There were no significant differences in phenological development of *Eriophorum* species or in graminoid biomass with distance to source of disturbance. Forage availability measured as percent snow free vegetated areas, however, decreased with increasing distance to cabins and the power line. Near 95% of the available forage was located within the avoided 0 to 4 km zones from cabins, roads, or power lines. While the redistribution of calving reindeer away from areas with technical structures and disturbance corresponds with previous observations in the area and in other studies, additional surveys in coming years are needed to verify this pattern. When forage availability is comparatively low, a redistribution of reindeer may lead to overgrazing in remaining undisturbed areas and, hence, lead to reduced intake of forage for the individual. This, in turn, may influence lactation, body condition and reproductive success in the long term.

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Status and conservation of Amur Goral in Russia

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The Goral inhabiting Russian Far East is subspecies Nemorhaedus caudatus raddeanus. Species Description: body size: adults 1150-1350 mm (1290 mm average); tail length 140-180 mm (155 mm); shoulder height 750-850 mm (810 mm); body mass: adult males 26-41 kg (33 kg), adult females 27-45 kg (32 kg); horns: males 140-212, females 130-221. Distribution: In Russia, gorals inhabit three isolated areas: 1) the South-Western spurs of the Bureya Range, 48°30'N, small area near the Amur River, which is closed with the South-Eastern part of the Little Khingan Range in China; 2) the Sikhote-Alin Range, 42°50' to 45°50'N.; 3) small area named Black Mountains (43°N) the South-West of Vladivostok City, occupying spurs of the Laoelin Range (in China). The first part is situated in Khabarovsky Krai, second and third - in Primorsky Krai. Thus, range borders for *Nemorhaedus caudatus* (and genera *Nemorhaedus* accordingly) are: the Northern border - the Amur River (48°30'N), the Eastern - the coast of Sea of Japan (45°50'N, 137°30'E). The goral range has spotted structure because of specific habitat preference. The goral habitat is a complex of rocky-meadow and forest environments. Now, gorals exist in following 11 administrative districts of the Primorsky Krai. The Goral is typical dweller of the broad-leaved mountain forest. The main number of gorals inhabits the Sikhote-Alin Range, where they occupy 2 types of habitats: 1) rocky forests in mainland river valleys up to 800 m above sea leveland 2) rocky slopes along the coast up to 600 m a.s.l. Status: Most of the Goral in Russia live in the Primorsky Krai. There are two main goral populations concentrating in Lazovsky and Sikhote-Alinsky Reserves. The total numbers of these populations are about 500 individuals. Besides that, about 150 individuals are protected in refuges (sanctuaries). The total numbers of the Goral in Russia are about 700-800 individuals at present. It has stabilized in the past 20 years (Bromley, 1977; Voloshina & Myslenkov, 1990; Myslenkov, 1992). The principal factors affecting population size are poaching and natural mortality, which can be high in years with heavy snowfall. The main predator limiting the goral populations was wolf in the 1930's to 1950's, now it is lynx and rarely tiger. Legal status: The Amur Goral has been protected as a rare endemic species in Russia since 1924, when goral hunting was prohibited. It is included in Red Data Book of the USSR (Borodin, 1984) as Category I - an Endangered species threatenedwith extinction unless specific measures are taken and listed as Vulnerable in the 1996 IUCN Red List of Threatened Animals (IUCN, 1996). The Amur Goral is protected in Russia in three Nature Reserves (Ussuriysky - very small number of gorals, Lazovskyand Sikhote-Alin). Beside that, six specialized refuges (sanctuaries) covering 118 000 ha for goral conservation were organized on the 1970's. There are two nature refuges where gorals occur also. The total area of protected territories, where gorals live, in Russia is about 750 000 ha. Captive breeding programs were carried out successful in Lazovsky Reserve (1972 to 1990) and Sikhote-Alin Reserve (1977 to 1985).

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Encroachment bush as animal feed

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The farming of game and cattle is prominent in the northern semi-arid regions of South Africa where the average rainfall is only 400 mm per year. As a consequence of some very dry seasons and poor beef prices, many farmers have turned to game farming to supplement their income; sport hunters from abroad in particular pay prices that far exceed the meat value of the carcasses of the animals they kill. Inadequate management of game species has resulted in overgrazing and severe encroachment of bush. Herbicides are used to kill the encroaching bush vegetation have also killed grass and desirable trees, some of which are hundreds of years old. Heavy downpours shortly after application of herbicides have washed chemicals into natural fresh water systems. Burning of dead bush vegetation slows the rate of recovery of the land and delays rehabilitation for five to seven years which is very expensive. Since 1995, specifically designed motorised saws have been used to cut bushes at ground level. The resulting material had lower tannin levels compared to bushes that were grazed or cut with axes. It was shredded on site and the product was sun-dried, hammer-milled and fortified with maize meal and molasses before being pelletised. The final product contained 10% crude protein, 35% fibre, 1.2% Ca, 0.7% P and trace elements such as Cu (7mg/kg), Mn (30 mg/kg), Se (2.5 mg/kg) and Zn (21mg/kg) and was 60% digestible. It was successfully fed in combination with hay to captured game and free ranging animals. The treatment thus effectively restored the desired populations of trees and grasses and game soon prefered these sites. Spot treatment of cut stems with systemic herbicides prevented re-growth.