Review of factors affecting productivity of reindeer husbandry

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Introduction

The reindeer is an ungulate that inhabit the whole circumpolar area on the northern hemisphere. To survive these harsh conditions that characterize this area the reindeer have adapted to low temperatures, short growing season and deep snow. The species has evolved into several sub-species that inhabit different kinds of habitats, such as alpine forests and arctic tundra. Some subspecies migrate between summer and winter ranges like the Eurasian tundra reindeer (*Rangifer tarandus tarandus*), Tundra caribou (*Rangifer tarandus groenlandicus*) and Alaskan caribou (*Rangifer tarandus granti*), while others, such as the reindeer on Svalbard (*Rangifer tarandus platyrhynchus*), live on tundra all year round and tackle the storms during winter. The Peary caribou (*Rangifer tarandus pearyi*) are adapted to and lives in high arctic areas on the islands of northern Canada where it can migrate between islands on the sea ice.

The reindeer's nutritional requirement are also adapted to artic environment where the natural variation of forage, both availability and digestibility, follows the changing seasons. Its appetite and possibilities of growing is highest in late summer when the reindeer fills the body storages of protein and fat. This weight gain is later lost during winter and spring when forage is scarce, but not necessarily due to starvation.

The reindeer can be seen as refiner of pastures into fat and protein, hides, antlers and milk etc. or actually ultimately to human livelihood when herded by humans. The pasture and forage can be seen as the primary resources on which the reindeer is dependent and hereby all factors that affect the forage affect indirectly the reindeer, such as climate, weather, seasonal distribution of grazing lands, density of reindeer, and soil conditions. However, extremely harsh and long winters might reduce the survival of reindeer, especially of calves, and cold and wet autumns might reduce the possibilities of gaining enough weight before the winter season.

There are other factors that affect the reindeer or the reindeer's ability to avail themselves of the forage directly, such as parasites, large carnivores and disturbances. These factors might reduce the time needed for feeding or lock reindeer out of grazing lands. It all comes down to the reindeer's ability to utilize the forage and turn it into protein and fat, needed for survival, weight gain and reproduction. Hence one can conclude that the mass and quality of available forage and the amount of grazing time are the major factors for production and all factors affecting these major factors are relevant.

The aim of this review is to identify and examine potential factors which explain the variation in conditions for the reindeer production in Sweden. The factors on reindeer production are to be identified on which scale they affect productivity. Thereafter the most important factors will be sorted out from the lesser relevant factors by comparison on spatial impact on reindeer production and scale basis. A relevant factor which only affects the production locally and temporarily should maybe be seen as minor compared to a less relevant factor which occur on a larger spatial and temporal scale and therefore affects the reindeer production more. A severe local factor can also be abundant in an area and therefore be seen as a factor on a larger scale. The scale factor is very relevant to this study, both the spatial scale as well as the temporal scale.

The relevant factors identified will in later projects[1] be examined in multivariate statistical analyses in order to rank the factors and predict the prerequisites for reindeer herding in the different reindeer herding districts. Knowledge of this gives information on how the reindeer herding districts can be characterized, grouped, and compared. A concrete goal would be to divide the Swedish reindeer herding districts into productivity zones as those in forestry, agriculture and horticulture. The identification of the key factors that vary with herding districts is expected to give more understanding on where new research should be initiated and where counselling in the best way could be given to contribute towards a stable and positive development of reindeer husbandry. Hopefully it can give further possibilities to predict consequences due to changing conditions in the reindeer husbandry area and therefore can be a valuable support in consultations with other interests within the husbandry area, as well as regarding the internal land use and herding administration in the reindeer industry.

Hence, this report will be used in future investigation regarding characterization of the Swedish reindeer herding area, and in comparisons between herding districts on a larger and lucid perspective.

Reindeer herding in Sweden

Reindeer husbandry has existed in Sweden in the present large-scale type of herding not more than 300 – 400 years and was established under full legal recognition and protection by the state (Lundmark 1998; Danell 2000).

In Sweden about 1 900 people out of 17-20 000 Samí are active herding members/reindeer owners, and about 1 800 more involved as so-called “additional members”, also reindeer owners, in the herding communities. These numbers exclude about 1 000 non-Samí reindeer owners in the concession herding communities, situated in the eastern part of the county of Norrbotten. Reindeer herders have to be member of a Samí village i.e. reindeer herding district and the organisation within the district. A Samí village consists of reindeer herding enterprises which usually is based on families and relatives. In Sweden there are 930 enterprises year 2000 (SCB 2001). To meet the costs of the modern society, reindeer herding families depend on some members taking up other occupations, while the reindeer husbandry contributes between 10 – 50% to the family income.

There are 51 herding districts, or Samí villages, in Sweden and they are managing the grazing resources on a common property basis. The herding districts can be grouped in mountain, forest and concession herding districts. Generally the mountain herding districts are found all along the mountain range of the Scandes, the forest herding districts in the central north and the concession herding districts in the northeast. There are well-known difficulties in management due to the use of common access resources, together with the access to grazing lands has decreased significantly during the 20th century. Reasons to this are a gradual closure of the Swedish-Norwegian border for reindeer migration, expanding industrial forestry, regional and national economic interests in the winter grazing areas, pressure from tourism in especially summer grazing areas and conflicts with

[1] Ongoing dr thesis work of H. Lundqvist

land owners due to the lack of legally defined extents of the grazing rights (Danell 2000). The reindeer herders today merge their privately own flocks into large herds which are collectively herded during the snow-free season. During winter the herd is broken up into smaller units that are more intensively herded.

The total Swedish reindeer herding area is about one third of Sweden's land area, e.g. 150 000 km^2, divided in winter and all-year grazing areas. Summer ranges of the mountain herding districts are usually in the western alpine areas, land which by the state is categorized all-year-round ranges, and the winter ranges is in general in the eastern part of the herding area towards the Gulf of Botnia. The reindeer are allowed to be in the winter range between the 1st of October until the 30th of April (SFS 1971:437). Regularly the summer ranges are more extensive in size, but also include more impediments, such as bare mountains and glaciers. However, the winter and summer ranges of the southern reindeer herding districts are smaller and do not have such clear east-west gradient. The forest herding districts in the north and the concession herding districts are of same pattern, where the land are divided into summer and winter grazing areas. The division is not due to restrictions, but rather due to planning within each Samí community. The total Swedish reindeer herding district can be generalized suffering from lack of winter grazing areas, with exception for the southernmost part (Renbeteskommissionen 2001).

Through the harvest the total number of reindeer are down-regulated and therefore fluctuates less than a wild reindeer population might do under similar ecological conditions. As long as there has been records, the population size have regularly fluctuated around 225 000 ± 50 000 animals in the winter stock (see Figure 1). The annual harvest has been between 30 000 and 90 000 animals during the last 30 years, and during the last years calf slaughtering has been more common than earlier (Figure 2).

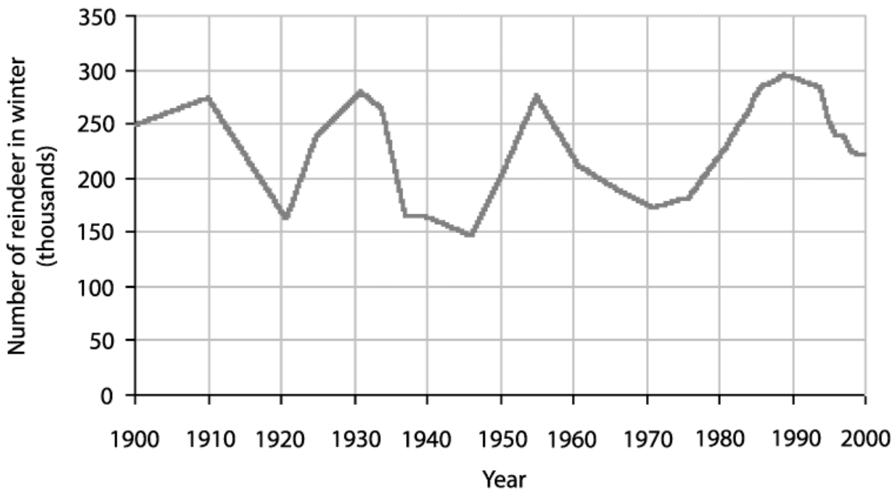

Figure 1. Numbers of reindeer in Sweden during the last century (SCB 2001).

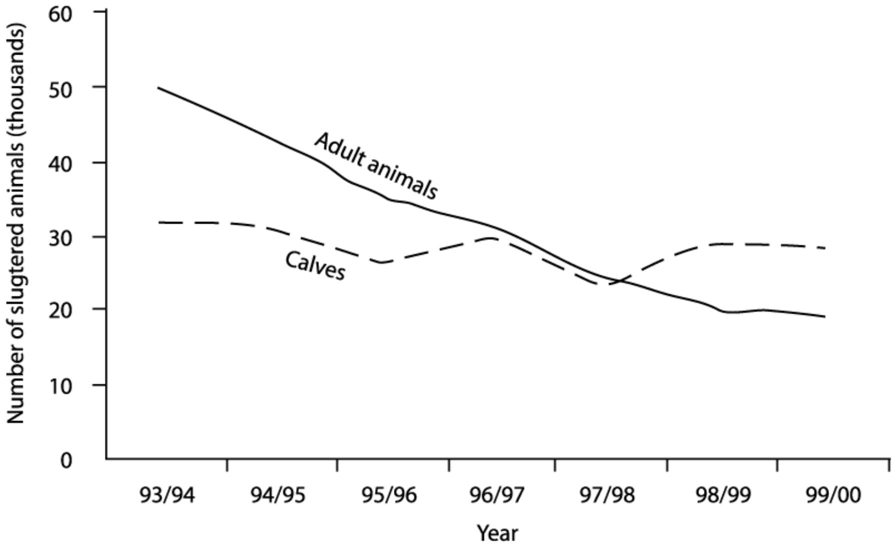

Figure 2. Numbers of slaughtered animals in Sweden between 1993 and 2000, divided in calves and adult animals (SCB 2001).

Table 1: Number of reindeer, enterprises and reindeer areas in 2000. (SCB 2001)

District/counties	Herding communitie s	Enterprises	Reindeer owners	№ of reindeer	№ of reindeer per owner
Regions in Norrbotten					
Northern mountain herding districts	9	332	1 264	51 209	41
Southern mountain herding districts	6	253	764	31 290	41
Forest herding districts	9	122	890	28 033	31
Concession herding districts	8	15	1 008	11 592	12
Counties					
Norrbotten	32	707	3 926	122 124	31
Västerbotten	7	108	317	54 231	171
Jämtland	12	100	282	44 809	159
Total in Sweden 2000	51	930	4 525	221 164	49
1999	51		4 522	220 107	49
1998	51	932	4 654	227 150	49
1997	51	943	4 698	238 567	51
1996	51	..	4 815	240 951	50
1995	51	..	4 806	253 300	53
1994	51	972	4 746	283 841	60

There is large variation between the reindeer herding districts (see Table 1), both in structure and total production. The northern herding districts are characterized by their larger areas, higher numbers of herders and higher reindeer numbers but still lower reindeer density. The mountain herding districts consists of many enterprises with more herders per enterprise, but also less reindeer per herder (see Table 1 and Figure 3). The southern herding districts are perhaps more production oriented and have more reindeer per herder and not as many enterprises, also due to smaller herding areas. The north-eastern districts are concession districts, which means that members of these enterprises are allowed to withhold max 30 reindeer (SFS 1971:437). Therefore the number of herders in concessions districts is high compared with the number of reindeer.

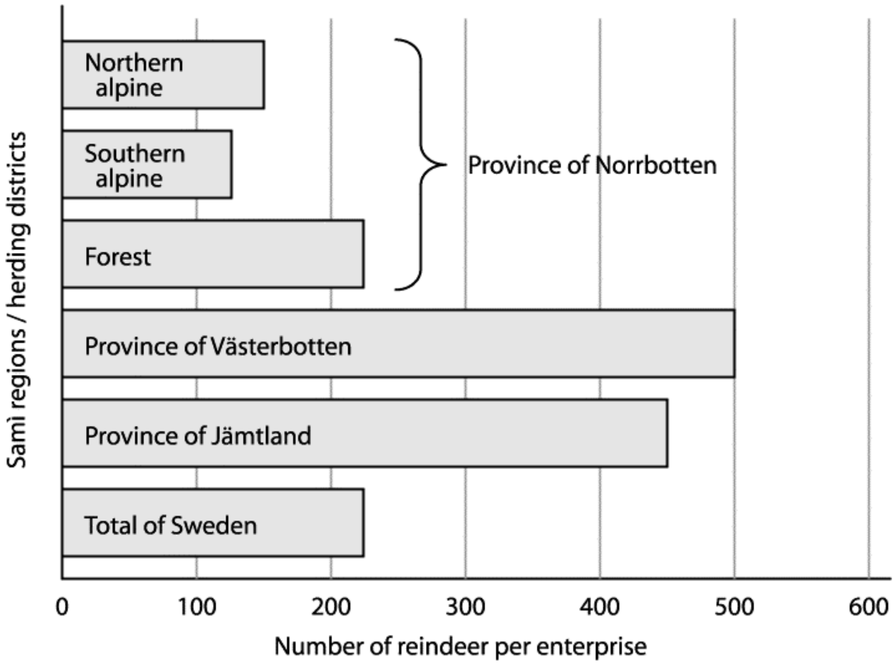

Figure 3. Number of reindeer per enterprise in 2000 in the reindeer herding area of Sweden (SCB 2001)

The production figures vary between districts and years which depends on the unique conditions of every year, as well as the slaughtering strategy and other contributions by the herders.

According to Statistics Sweden (1999), the normal productivity level is 7 – 8 kg per animal in winter stock under conditions where adult females weigh around 70 kg in the autumn, consumption by the household excluded. The harvest comprises around 40% calves and 25 – 35% adults of each sex and productivity has been both higher and lower during periods when animal numbers have been reduced, both intentionally and due to adverse conditions. Productivity in 1998 was 5.4 kg carcass per head. Danell & Gaare (1999) report that available empirical results from Norwegian reindeer herding indicate that the “normal” abundance in

Fennoscandia of 1.4 – 1.8 reindeer per square km corresponds to autumn weights around 70 kg in average for female reindeer.

The major economic output from reindeer pastoralism in Fennoscandia is from meat production. The two main strategies in harvesting is the traditional strategy to build a considerable part of the production on slaughter of adult males in September before they come into rut. The other strategy is to slaughter mainly calves in late autumn. In both culling of old females make up a considerable part of the production.

External factors affecting reindeer production

External factors included here are factors that affect the reindeer pastures or external factors that directly affect the reindeer. These factors are not possible for the herder to control, but maybe possible to in some sense mitigate. Topography is the underlying factor and foundation on which living organism live. Adaptation by herbs and animals have during the evolution made it possible to withstand the elements in alpine areas, but extreme topography are limitations for the reindeer and the organisms of which the reindeer are dependent on. Weather and climate are other external factors on which the ecosystem is dependent upon. All organisms have their optimal temperature, humidness etc. where the production is maximized. Deviations from these optima affect the organisms and the ecosystem in a negative way.

Other organisms also affect the reindeer in different ways, such as predators and parasites. Predators on reindeer are the large carnivores in Sweden, e.g. wolves *(Canis lupus)*, lynx *(Lynx lynx)*, wolverines *(Gulo gulo)*, brown bears *(Ursus arctos)* and golden eagles *(Aquila chrysaetos)*. Predators affect the reindeer production by direct loss of live stock and indirectly affect the reindeer herd structure which in turn might affect the production.

Parasites are usually insects, worms, bacteria, and virus, that infect the reindeer and spend at least some stages of their life cycle inside the reindeer. Internal and pathogenic parasites use energy from the reindeer and can via severe infections cause illness or death. External parasites, such as mosquitoes and adult warble flies, harass the reindeer and hinders the reindeer from grazing due to escape behaviours.

Disturbances and competing land use also hinder the reindeer to graze efficiently. Competing industries and infrastructure decrease available grazing areas and quality. Disturbances such as traffic, military activities, and tourism reduce grazing time due to avoidance behaviour and stress. Linear structures such as roads, railroads, power lines, hiking trails and dams fragment the grazing areas into smaller bits and might thereby reduce the grazing area more than just the local loss of grazing habitats.

Environmental factors, such as local or regional pollutions, may also affect reindeer production in a negative way, e.g. by reducing viable range area. The major pollution known affecting the reindeer herding area is the Chernobyl accident in 1986, which was followed by a fall-out of radioactive caesium in southern and western parts of the herding area.

A graphic description of the major factors are shown in Figure 4 below.

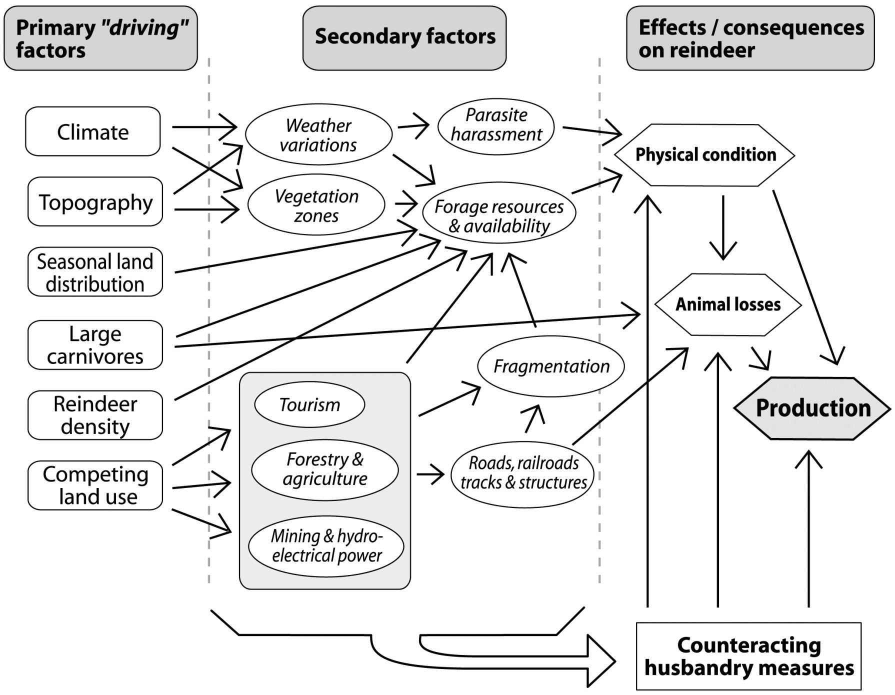

Figure 4. Major factors affecting reindeer production.

Topography

The Swedish reindeer herding districts are very heterogeneous in factors such as altitude, steepness, fragmentation by rivers and lakes, etc. These factors may affect the reindeer production in terms of how much of the herding districts can actually be used for grazing. The forage quality depends on topography as well as hydrology and soil composition, and indirectly affect the reindeer's condition. The topography is also one underlying factor for weather, parasitic insects, predators and human disturbances and in the end affect more or less all factors. The topological features of a landscape may be considered local, such as a precipice, or regional, such as a mountain, or merely global, such as a extensive mountain range. The topography affect the local weather e.g. orographic rain and fog, which occur when an air package is forced by wind towards a ridge and lifted. The pressure and temperature lowers in the air package and the water in the air is condensed into fog or cloud and fall out as rain or snow (Ackerman and Knox 2003).

Ruggedness can be the abundance of local conditions, e.g. an index of precipices per km^2 or differences in altitude in a certain area. Ruggedness gives more niches for organisms to inhabit and could therefore create a more divers grazing land in number of forage species. Ruggedness may also be positive since it gives snow patches the possibility to remain longer in the warmer season and therefore create patches of fresh herbs for the reindeer to graze late in the season. Ruggedness can be estimated on a global scale using GIS and digital topographic maps (Tappeiner *et al.* 2001). Larger lakes and broad rivers might be difficult for the reindeer to cross and the reindeer herding districts usually are oriented in same direction as the main rivers. Since reindeer often feed in wetlands the abundance of such may be a factor to be accounted on. These are often found on plains in the topographical map or are specified in vegetation maps. A diversity of both ruggedness and wetland plains, but not fragmented by topography or hydrological obstacles are likely to be favourable.

In the reindeer herding area of Sweden the main soil composition is moraine covered with coniferous boreal forests. This type of soil can support a favourable forage. However areas of boulders and flat rock are common which cannot sustain merely any forage and hence are not good grazing areas. Areas such as urban areas, roads, bare mountains, boulders and flat rocks, lakes, rivers, as well as agricultural plains, should be excluded as impediments and not regarded as favourable grazing areas (Renbeteskommissionen 2001).

Climate

Climate is the fundamental factor together with topography/nutrients for all living organisms. The climate is different in different parts of the Swedish reindeer herding area. From arctic deserts/tundra in the north and west, over sub-oceanic climate in the inland alpine areas and coniferous forests at lower altitudes to more continental types of climate in south and east. These biotopes are subjects to varying precipitation and snow conditions and the most rain falls adjacent to the mountain range of the Scandes and the snow-free season is longer towards south and east.

Climate acts directly on animal behaviour at different scales. In a short temporal scale we refer to it as weather. For example, the direct effect of severe cold, wind and rain chilling effects, or heat stress may lead to increased costs in thermoregulation (Soppela *et al.* 1986). In the other end increased energy cost due to movements in deep snow (Johnson *et al.* 2001).

Climate also act indirectly on reindeer productivity through its effect on forage (Gunn and Skogland 1997). Forage availability in summer through plant growth (absolute availability) is modified in winter by snow and ice (relative availability). Absolute forage availability is determined by two components: the amount of growth (plant productivity) and its timing (plant phenology). Calf losses has been observed to increase with low spring temperatures and late winter snow depth (Ropstad *et al.* 2001). Increased energy cost to obtain forage in deep snow and delayed melting of snow cover on calving grounds, that shortened the time to raise calves, may explain these result (Crête and Payette 1990). Lee *et al.* (2000) showed that wet and warm winters prior to the rut decreased the number of live calves the following year, and in contrast warmer autumns prior to their birth increased the number of calves. In literature various authors have used different weather variables with sometimes opposite effects on ungulates and few studies show consistent effects to the same climatic variables. According to Weladji *et al.* (2002) this may be because the effects of weather on ungulate population dynamics are scale dependent and the difficulties to distinguish the climate effects from density dependent factors.

Climate and weather also affects harassing insect abundance (Helle and Tarvianen 1984; Hagemoen and Reimers 1999; Mörschel 1999; Weladji 2001; Hagemoen and Reimers 2002; Weladji *et al.* 2002). Mosquitoes (*Culicidae*), nasal bot flies (*Chephenemyia trompe*), and warble flies (*Hypoderma tarandi*) in summer drive reindeer to stop feeding and try to escape the insects either by running from mosquitoes or watching for and evading warble and nose bot flies. The combined effects can be severe and enough to reduce body weight (Gunn and Skogland 1997).

In the North Atlantic region, winter climatic variations are, to a large extent, explained by a large-scale alternation of atmospheric pressure called the North Atlantic Oscillation (NAO) (Post and Stenseth 1999; Ottersen *et al.* 2001). The NAO is a meridional oscillation of the atmospheric masses between Iceland and the Azores and has been compared to the more well known El Niño in the Southern hemisphere. Depending on where the balance of atmospheric pressure lies, the NAO is either positive (mass balance over the Azores) or negative (mass balance over Iceland). This mass balance acts as a pressure corridor influencing the direction, magnitude, and speed of westerly winds across the Atlantic Ocean from North America to northern Europe, and thereby, wintertime temperatures and the balance of precipitation and evaporation over both continents. This large-scale climatic variation can influence plant phenology and growth, reproduction, and demography of ungulates (Post and Stenseth 1999). However, as the effects of this large-scale climatic index may result in different local weather patterns in different areas (Mysterud *et al.* 2000) this interactions must be considered complex. Data on both local and global scale must be taken into consideration in order to investigate the relation between climate and reindeer productivity.

Forage

During summer reindeer feed on grasses, sedges, green herbs and fresh leaves of shrubs and trees (eg. Klein 1990). In Russia, investigations on reindeer forage suggest that the diet consists of up to 600 species, that is the major part of the northern flora, including about 100 species of lichens, mosses and fungi (Syroechkovskii 1995). In Sweden the number is lower, but still a very varied diet is achieved. Nieminen (1994) suggest that 2 – 300 species are utilized by reindeer and Warenberg *et al*. (1997) lists around 60 central species. In South Georgia the reindeer feed on grasses and herbs during winter since lichen forage are limited due to the heavy snow cover if the islands, but in spring when the snow cover are reduced, the reindeer choose lichens where available (Leader-Williams 1988). During winter in the northern hemisphere, the diet is concentrated on lichen and easy digested herbs. Since the reindeer is a ruminant it takes first of all some time for the animal to adapt to a new diet, and secondly the forage cannot be too hard to digest. If reindeer feed too much on fibre rich forage the rumen gets filled due to slow fermentation and the reindeer may starve due to metabolic nutrient depletion (Nilsson 2003).

Lichens, on which reindeer partly live, can be divided into to major groups; mat-forming terrestrial lichens (*Cladonia, Cetraria*) and arboreal lichens (*Bryoria, Alectoria*). Mat-forming lichens are abundant in boreal forests and is of great importance to reindeer husbandry, especially during winter and early spring. These lichens often form closed mats, and are loosely attached to the ground since the thalli component grow vertically upwards at the apices and die off in the basal regions (Crittenden 2000). Some genera of lichens are in symbiosis with cyanobacteria which fix nitrogen from air and therefore are among the principal agents of nitrogen fixation in boreal-arctic regions. Mat-forming lichens are sensitive indicators of atmospheric deposition, partly because they occur in open areas in which they absorb precipitation and particles, and also because they achieve all their nutrients and water from the atmosphere and not from the ground as vascular plants. Mat-forming lichens are easily fragmented by trampling, especially at dry conditions during the snow-free season.

The arboreal lichens are important during 2-4 week during spring when ice-crust is formed, and also during other harsh forage conditions (Warenberg *et al.* 1997; Ihl and Klein 2001). Arboreal lichens are spread by strong winds to adjacent trees and lichens fallen to the ground is grazed by reindeer (Warenberg *et al.* 1997). The abundance of arboreal lichens has decreased the last decades due to changed forestry methods. Large clear-cuts and short rotation hinder the lichen to re-establish in industrial forests.

In average, depending on herd structure and slaughter strategies, a reindeer herd consumes around700 kg of dry forage per reindeer and year at optimum number of animals on lichen-rich pastures. This is equivalent to around 1 000 kg forage per km^2 of reindeer herding area in Fennoscandia (Danell and Gaare 1999). However, the forage limitations for reindeer is apparent during winter. At that season the diet may consist of up to 80% lichens and the grazing areas usually is on the lower limit.

Foraging during the summer season is normally not limited due to extensive summer grazing areas and number of species reindeer feed upon, although density effects may occur. During the snow-free season the forage consists of vegetation types dominated by lichens, grasses, sedges and herbs as early in the season as possible (eg. Klein 1990; Warenberg *et al.* 1997; Ihl and Klein 2001; Renbeteskommissionen 2001). During late spring and early summer the reindeer graze on southbound slopes, snow-free plains and mires. Thereafter the birch stands (*Betula sp*.) get an more important role and the reindeer follow the snow-line to get spring herbs in as large amount as possible. These new herbs are more easily digested and the fibre compound is low. The snow-patches are more important the later into the summer season it is. Hereby we can conclude the importance of ruggedness in the landscape where the possibilities of snow-patches remaining until late in season is high, as well as shadowed patches where plant growth occurs somewhat slower than in direct sunlight.

In autumn mushrooms are selected for feeding by reindeer which moves again down to the forests. Mushroom is a good source of minerals and the reindeer seem to fill their mineral depots during this time of year (Gustavsson *et al.* 1989; Warenberg *et al.* 1997). In the autumn grazing the mixture of both lichens and herbs is important for the reindeer and enables the reindeer to adapt slowly to winter forage which again consists of larger amounts of lichens. On the typical inland winter grazing areas the quality and availability of the forage are depending on small amount of snow and rugged terrain to prevent the snow from packing (Renbeteskommissionen 2001).

Large carnivores

A strain on the reindeer industry is caused by large carnivores. The main predators among them are wolf *(Canis lupus)*, lynx *(Lynx lynx)*, wolverine *(Gulo gulo)*, brown bear *(Ursus arctos)* and golden eagle *(Aquila chrysaetos)*. The numbers of these animals have been decreasing during the 20th century but national commitments are trying to restore the numbers towards viable populations. The distribution of the carnivores differs; lynx and bear are concentrated to the southern part of Fennoscandia whereas wolverine is normally found in the western mountain areas and golden eagle in the southern and eastern areas (SOU 1999b; Naturvårdsverket 2000a; 2000b; 2000c). They also differ in how they affect reindeer populations and therefore are handled separately when it comes to economical compensation in the Swedish herding districts. Since the abundance of predators differ, due to reasons such as climate, infrastructure, prey availability, previous human control and habitat features, reindeer herders are affected differently. Some have predators only in their summer ranges whereas others register predator attacks all year round. Two predators are only abundant seasonally, the brown bear which hibernate during winter, and golden eagle that migrates to more southern latitudes during the cold season (SOU 1999b). Predators affect the reindeer herds directly by predation, but also as a fragmenting and stressing factor which may prevent reindeer to utilize certain grazing areas efficiently.

Wolf

Today there are only few occurrences of wolves in the Swedish reindeer herding area but still the wolf is regarded as a very severe predator on reindeer. Wolves tend to break up reindeer herds which make them more difficult to handle. The wolves hunt in packs, often as persistent followers, and they tend to kill as many as possible once they get the opportunity (Sikku 1999).

Lynx

The lynx, according to Sikku, does not tend to have strong stamina to run fast for longer periods of time. It does not prefer scavenging cadavers but does often return to newly slain pray. Preys preferred by lynx are roe deer, reindeer, hare and game bird. The lynx also does not utilize the whole animal, and especially it has problems to eat frozen meat during winter. The lynx is a stalker and closes in quietly before making its attack in a few leaps. Today there are up to 1 500 individuals in Sweden and probably more than 50% of them are within the reindeer herding area (Naturvårdsverket 2000c). An approximation of predation habits of lynx suggests that a lynx kills on average 40 roe deer per year outside the Swedish reindeer herding area, hence the number of reindeer should be less due to the larger body masses of reindeer (SOU 1999a).

Wolverine

The wolverine attack in longer runs, especially if the first attack doesn't succeed. Since it is not as good hunter as the lynx the wolverine often badly wounds the reindeer and therefore is considered as a "cruel" predator. It often prefers cadavers and remains of reindeer slain by lynx and also tends to store the remains for later feeding (Sikku 1999). The main prey of wolverine is reindeer, but also hare, red fox and game bird are parts of the diet. The number of wolverines in Sweden is around 270 individuals and mainly within the reindeer herding areas (Naturvårdsverket 2000b).

Brown bear

There are more than 1 000 brown bears in Sweden and the population has been growing with almost 16% per year until 1995 but today the increase is estimated to be 4% per year (Naturvårdsverket 2000a). The brown bear predation is most apparent during calving season after being in hibernated for several months during winter and in some herding districts the bear is considered to have a considerable effect on reindeer herding (Sikku 1999).

Golden eagle

Golden eagles predate on reindeer calves especially during the summer. There is a stable population in Norway consisting of around 1 000 nesting pairs (Gjershaug 1984; Gjershaug and Frydelund Steen 1998), and in Finland 350 nesting pairs (Ollila 1996). In the Swedish reindeer herding area there are around 630 golden eagle territories (SOU 1999a). The number of adult golden eagles in the reindeer herding area of Sweden is estimated to 1 700, including reproducing adults and wandering juveniles, during the months from May to August (SOU 1999b). An adult eagle needs 230 g of meat per day and according to investigations of prey remains in nests, less than 20% of the diets consists of reindeer during the summer months. Reindeer predated by golden eagles are probably lower during the winter months since the numbers of golden eagles are low due to seasonal migration and the reindeer calves are heavier. An adult eagle weighs 3.5 – 6 kg depending on sex, and according to experiments in Norway adult eagles have problems to vertically take-off with weights over one kg (Bergo 1990). This converge with the fact that golden eagles have problems to take-off when having one kg of meat in the crop (SOU 1999a). The percentage diseased and defect reindeer is claimed to be over-represented in reindeer slain by golden eagle (Franzén 1996). Some years the mortality of the reindeer calves is high because of bad weather during May and limited winter forage the winter before, which lowers the condition of the females. During such years the golden may eagle feed of the surplus of dead calves and the survivals are possibly chosen secondly.

Politics and economical compensation

Between 1999 and 2001 the Swedish government allocated 35 million SEK, e.g. 3.8 million €, per year as compensation for reindeer lost to predators. The allocation for 2003 is 50 million SEK, e.g. 5.4 million €, according to The Swedish Samí Parliament. Some reindeer herders claim that the predator populations have today reached levels where it is impossible to achieve economically sustainable reindeer herding. The reindeer move over large land areas and often in harsh terrain which makes it is difficult to look after the herd and protect them from predators. The effect of predators is not only the loss in meat for each slain reindeer, but also a dynamic loss of production capacity due to losses of reproductive females, and possible breeding programs may deteriorate.

The number of predator-killed reindeer in Sweden were in 1991, prior to the change of compensation program, estimated to around 16 000 calves and 6 000 adults per year (SOU 1999b), where wolverine and lynx were estimated to account for 90% of the kills, and bear together with eagles account for the remaining 10%. Each rejuvenation of wolverine and lynx is compensated with a fee corresponding 200 reindeer. The number of reindeer compensated for due to temporal, regular occurrences or rejuvenations of wolves, wolverines, lynx and brown bear and golden eagle are listed in table 2.

Table 2. Economical compensations for predator-killed reindeer.

	Economical compensation in number of reindeer		
Predator	**Rejuvenation**	**Regular occurrence**	**Temporal occurrence**
Wolf	500	50	50
Wolverine	200	50	0.2 per km^2
Lynx	200	50	0.2 per km^2
Brown bear & Golden eagle	0.2 per km^2	0.2 per km^2	0.2 per km^2

There is an agreement between the Swedish Environmental Protection Agency and the Swedish Samí Parliament of a maximum number of rejuvenations, and when the limits had been reached a decimation of the predator abundance is reconsidered. The herding districts claim today that the agreement has been violated.

Predators, such as lynx, wolverine and brown bear apparently have great inflict on reindeer production and should be accounted for when evaluating productivity, but predators such as wolves or golden eagle can be excluded due to rare occurrences in the reindeer herding areas or low predatory effect.

Parasites

As already mentioned, there are a number of different parasites that infect reindeer. The most severe parasites are warble flies (*Hypoderma tarandi*), nose bot flies (*Cephenemyia trompe*). Other significant external parasites are mosquitoes (*Culicidae*), and mange mites (*Sarcoptes scabiei*) (Oksanen 1999). However there are also several internal parasites such as brainworm (*Elaphostrongylus rangiferi*), gastro-intestinal nematodes (*Nematodirus tarandi, Nematodirella longissimespiculata, Capillaria* sp.*,* and *Trichuris* sp.), pinworms (*Skrjabinema tarandi*), abomasal nematodes (*Ostertagia* sp.), and lungworm (*Dictyocaulus eckerti*). Most of the nematode species have usually been regarded as rather harmless, except for brainworm and lungworm. Brainworm is blamed for severe outbreaks of meningoencephalitis after warm and rainy summers. In some animals the lungworm infection causes severe inflammations in the lungs and it is reason to believe that such inflammatory changes may influence winter survival (Josefsen *et al.* 2001)

Warble fly

Warble flies (*Hypoderma tarandi*), can influence the habitat use of the reindeer (White *et al.* 1981; Senft *et al.* 1987; Anderson and Nilsen 1998). A reindeer can have as many as 2 000 two and a half cm long, second and third stage larvae from warble fly in their skin. Heavy infections often cause considerable nutritional imbalance, allergic response, tissue and skin damage, and frequently severe secondary infections and immunosuppression (Karter *et al.* 1992). In late spring and early summer the larvae exits through the skin and fall to the ground to pupate.

Nose bot fly

Nose bot fly (*Cephenemyia trompe*) is a nasopharyngeal parasite and the larval stages feed on blood and cell fragments and at high infection levels may directly affect the health of the host (Nilssen and Haugerud 1995). The larvae are distributed in the nasal cavity, turbinates, sieve plates, and other irregular structures, often imbedded in mucosa. Third-instar larvae of *C. trompe* in late winter and early spring may cause inflammation, haemorrhage, and discomfort or respiratory distress during stress. In late spring and early summer the larvae of *C. trompe* and *H. tarandi* exits through the mouth and skin and fall to the ground and pupates (Nilssen and Haugerud 1994). After metamorphosis the adult insects mate and the fertilized females search for suitable hosts, which in turn elicits intense defence behaviour in reindeer (Espmark 1968; Helle and Aspi 1983; Karter and Folstad 1989)

Insect harassment effects

Insect harassment is influenced by weather conditions (Helle and Tarvianen 1984; Helle and Kojola 1994; Mörschel and Klein 1997; Reimers 1997; Mörschel 1999). Temperature seems to have a positive correlation to insect harassment (Helle and Tarvianen 1984; Anderson *et al.* 1994; Helle and Kojola 1994; Mörschel and Klein 1997; Mörschel 1999; Colman 2000) with a threshold below which no insects activity have been reported. Wind velocity seems to be negatively correlated to insects harassment (Anderson *et al.* 1994; Mörschel and Klein 1997; Mörschel 1999) where a upper limit over which no insect activity has been reported. Mating behaviour of oestrid flies has been reported by Anderson *et al.* (1994) to depend on sunshine, but Mörschel and Klein (1997) didn't find any significant effect by cloud cover on insect activity or caribou movements. Colman (2000), on the other hand, found that the level of parasitic fly harassment was moderate to severe when cloud cover was below 40%.

The insect activity reduces effective summer grazing time for the reindeer and therefore has a negative effect on their body condition (Downes *et al.* 1986; Mörschel and Klein 1997; Hagemoen and Reimers 1999) and the animal might be forced to seek higher altitudes where the wind velocity is higher and the temperature is lower. At these altitudes forage is often more scarce. In some reindeer districts the reindeer herders claim that the reindeer movement are increased because of the harassment. The increased movement may have impact on the reindeer seasonal natural weight gain (Helle and Tarvianen 1984), and hence causing production losses. Local or regional variation of reindeer parasite abundance in Sweden has not yet been investigated.

Constraints caused by other land use

The reindeer industry interacts with several other forms of land use, such as hydroelectric power complexes and dams, buildings, forestry, mining, agriculture, hunting, tourism and recreation. Conflicts exist between reindeer herding and other land user groups since the competing industries are expanding together with increased presence of humans, at the cost of reindeer foraging areas. The competing land use debars reindeer from their natural grazing lands and hinders their migrations. The competing industries affect the reindeer herding on different scales, both spatial and temporal. Some industries affect the reindeer seasonally such as tourism and hunting, while others are affecting permanently, such as mining and hydro power plants. Mining are local in the spatial scale, in contrast to hydroelectric power plants which can affect the reindeer industry in a large spatial scale due to destruction on large land areas and prevention of migration because of fragmentation. The industries that affect grazing, such as forestry and agriculture, does not necessarily take away areas from the reindeer but severely decreases forages quality, abundance, and access to the grounds. There are hence different grades of effect by industries and other human activities on reindeer production, and these differences should be formalized and ranked into indices scaling both in time and space.

Hydroelectric power plants

The main issue to the reindeer herders during the 1950ies and 60ies was primarily the extensive expansion of the hydro-electrical industry. The river valleys are important to the husbandry due to their richer primary production, and are used for migration routes and resting grazing areas. The lowlands close to the rivers have usually less snow during winter and become snow-free early in spring. Solid ice on rivers and lakes are useful to reindeer migrations.

The water regulation dammed up important grazing areas and the weak ices followed by the regulations made the migrations more difficult. On top of all the water regulations affected the fishery negatively (Lundmark 1998).

Hydro-electrical power plants requires extensive power lines to transport its energy to the inhabited areas. The wild reindeer of Norway tend to avoid areas with power lines and the effect could be observed up to 2.5 km away from power lines (Nelleman *et al.* 2001; Nellemann *et al.* 2002). Available forage in terms of lichen cover seems to decline 15-30 times with distance from power lines and is lowest in undisturbed areas with the highest density of grazing animals. Areas within 5 km of resorts, roads and power lines in combination were avoided in spite of valuable pastures. According to Flydahl and Reimers (2002), there are data indicating that reindeer habituate to power lines shortly after their construction when not accompanied by other human activity. Factors that may influence whether animals cross under power lines or not are the topographical location of the line, its location in forested vs. open terrain, the location in relation to grazing, calving and rutting areas, time of year, presence or absence of harassing insects, climatic factors that lead to corona and wind noise from the line, and the age, sex, physical and psychological condition of the animals as well as their earlier experiences.

No physiological effect due to the electromagnetic fields surrounding a power line has not been found, probably because reindeer move around extensively (Reimers *et al.* 2000b).

Forestry

When forestry began to extend clear-cut areas, the reindeer husbandry became severely affected. In the clear-cut areas the snow turns compact which makes it harder for the reindeer to reach the forage. The lichen cover is also affected by the harvesting machines and by the following ground scarification, which today is not as radical as it was earlier. Grasses and trees in rejuvenating areas with dense stands compete with the lichens which are important winter forage for the reindeer. The cuttings also leave tree residuals on the ground and these make it more difficult for the reindeer to reach the valuable forage (Eriksson *et al.* 1987; Eriksson and Raunistola 1990; Helle *et al.* 1990; Lundmark 1998; Danell 1999). In the early stages of the rejuvenation, the area is not suited for grazing and after some time when trees has reached some height the forest is fairly dense and avoided therefore by the reindeer. The lichens get affected by increased shading and does not grow well.

Arboreal lichens have always been important forage for the reindeer during periods with difficult snow conditions. The lichens vanish in clear-cut areas and increased the need for complementary feeding of the reindeer during harsh conditions. Selective harvest of merchantable trees and snags removed 30-55% of available lichens in British Columbia (Armleder and Stevenson 1996). Although live biomass of arboreal lichen on remaining trees increased in partial-cut forests (Rominger *et al.* 1994), but the total number of trees per hectare and thereby the overall availability of lichen biomass decreased. After clear-cutting, natural lichen regeneration only occurred within 350 m of mature forest with high lichen abundance (Stevenson 1990).

Forest fertilizers containing ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$) have a toxic effect on reindeer and other mammals since the nitrate ion NO_3^- converts through nitrite (NO_2^-) which is very toxic, into ammonia (NH_3). Åhman and Åhman (1984) found that fertilizers with ammonium nitrate or urea caused nitrate accumulation in forage plants but not exceeding toxic levels for reindeer. Fertilizers reduce the standing crop of *Cladina spp*. (Eriksson and Raunistola 1993). Forest fertilization with ammonium nitrate markedly reduces pasture utilization during the first winter after treatment and fertilization with urea has an even greater negative effect, that persists for at least two winters (Nordkvist and Erne 1983). In the year of 2000 a total area of 24 300 ha was fertilized in Sweden whereas about 12 000 ha in the reindeer husbandry area. About 1 000 ha was fertilized within the small scale private forestry. Forest fertilization have decreased to one seventh since 1980 (Skogsstyrelsen 2002), as shown in figure 5.

In The Forestry Act (SFS 1979:429) the forestry is obliged to show consideration towards the reindeer husbandry and its representatives more often consult the reindeer herders regarding clear-cuts. But the effects of the clear-cuts during the 1970s and 80s are still affecting the reindeer husbandry. Another factor is the increasing amount of small gravel roads used by the forestry. During the years 1990-2001 the new built forest roads have increased with 24 000 km which means that every year about 2 000 km of new forest road is constructed in Sweden as shown in figure 6. About half of the forested area in Sweden is situated in the reindeer husbandry area (Skogsstyrelsen 2002).

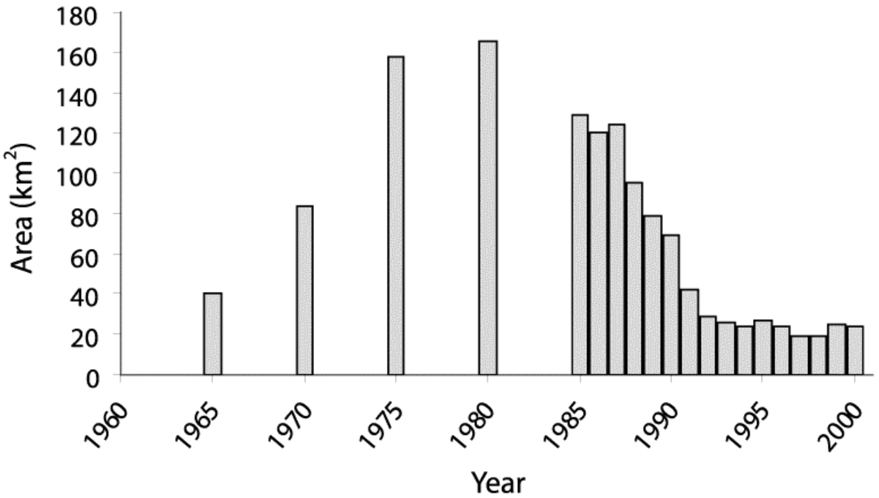

Figure 5. Area of fertilized forest in Sweden from 1965 to 2000.

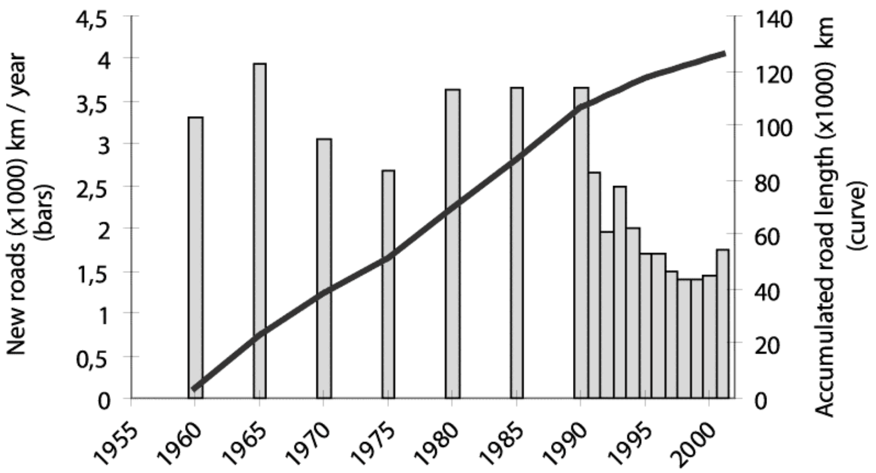

Figure 6. Forest roads constructed in Sweden the last 50 years.

The scale of impact should be mentioned here as well; a single low trafficked forest road might not affect the reindeer herding in a great aspect, but several smaller roads in a valuable grazing area probably cause greater effects. Small clear-cuts in extensively used grazing areas might as well be of minor importance, but a large clear-cut or several small clear-cuts in a valuable area may be of similar importance.

The largest effects on reindeer herding by forestry are loss of habitat, decreased quality of winter ranges, and fragmentation due to roads and clear-cut areas. All these effects could be mitigated through collaboration between the forestry industry and the reindeer herders by letting the herders utilize areas in a greater extent before a clear-cut is done. In this manner the loss of grazing land is lowered since the previously grazed areas in the district get time to regenerate.

Tourism

Tourism is to the Samí people both positive and negative. The positive side is that it makes it possible for small villages to maintain social and commercial services of which the Samí people are dependant as well. To some extent tourism also creates additional income to the Samí community in connection to reindeer husbandry and therefore support the industry.

However, tourism can be a factor of disturbance as well. This applies to stationary resorts, ski tracks and slopes, as well as hiking trails, tents and humans appearing in the terrain. Exposure to recreational activities may result in vigilance, avoidance behaviour and redistribution of reindeer. Stress lesions have been observed due to external stress factors (Rehbinder 1990). Tyler (1990) found that reindeer on Svalbard that were experimentally approached by snow-mobiles on average first reacted at a distance of 640 m, were disturbed at a distance of 410 m, fled at a distance of 80 m, and travelled 160 m in 22 seconds after the disturbance. Single disturbance events had negligible effects on the daily energy budgets of reindeer. Disturbances on wild and undomesticated reindeer in Norway by humans on foot or skis has been documented by Reimers, Colman *et al*. (2000a) and they found that the shortest distances for reaction in reindeer caused by human approach was 173 m, disturbance distance was 90 m, flight distance 38 m and following running distance was 221 m. Another difficulty appears during winter when snow-mobiles and roads make trails for the reindeer that is easy to walk upon compared to natural deep snow, and therefore scatters the herds and make them harder to control, and time consuming to recollect.

Helle and Särkelä (1993) examined semi-domesticated reindeer habitat choice close to a concentration of tourists in the area. The tourist frequency were divided in three zones where zone 1, at a distance of 0-5 km from the tourist resort, had a yearly tourist frequency density of 1 000 000 visitors, of which 110 000 were over-night guests. Zone 2, at a distance of 5-10 km from the resort, had a yearly tourist frequency of 46 000-80 000 visitors and zone 3, at a distance of 10-15 km from the resort, had 500 visitors which used the only hut that existed in this zone. Zone 1 had the infrastructure of electrified trails used by hikers, skiers and snow-mobiles. At a distance of at least 10 km from the resort the abundance of reindeer was similar as in the control areas whereas during summer the males showed less vigilance than the female reindeer. Helle and Särkelä claim that the losses to the reindeer husbandry due to tourists resorts was small compared to the gain of the tourist industry, but to minimize the loss to the reindeer husbandry, a better planning is called for.

Tourism is not regulated by any legal acts like reindeer husbandry, and reindeer herders have difficulties to find support for objections to any given decision regarding tourism. Recreational use of snow-mobiles has been a serious disturbance the last decades. A negative effect occurs when use of snow mobiles coincides with calving and it has been reported that the whole calving grounds has been abandoned due to intense use of snow mobiles (Lundmark 1998). How severe the impact of tourism is on the reindeer industry is unclear since the forms of tourism is diverse. However the impact of tourism could be lowered through restrictions of tourist during calving season and use of snow mobiles.

Traffic, roads and railroads

During the last century, the number of roads and railroads has increased. Especially gravel roads constructed by forestry companies have increased seven-fold since 1960 (Skogsstyrelsen 2002). This excessive road net has been constructed on the cost of reindeer pastures, particularly in winter grazing areas. Effects of transportation corridors on reindeer/caribou may be influenced by adjacent infrastructures, vehicle types involved, frequency of traffic, purpose of road use, habitat surrounding the roads, visual attributes of roads, habituation, sex and age of reindeer and season of use (Wolfe *et al.* 2000). Heavy traffic may accentuate the reaction of reindeer to roads and railways, impede crossings and serve as barriers. This may result in substantial mortality from collisions, and increase vigilance behaviour that may reduce foraging efficiency. Between 1 000 and 1 800 reindeer get killed every year in Sweden from traffic accidents (Vägverket 2001). In Finland between the years of 1974 and 1983 on average 2 300 reindeer per year were killed in accidents with road and railroad traffic, which were 1.6% per year of the total number of reindeer in Finland (Nieminen and Leppäluoto 1985). Of these 2 300 reindeer about 15% were yearly killed by train accidents.

Female caribou has been shown to avoid roads, especially during calving seasons (Dau and Cameron 1986), while non-maternal adults showed little or no correlation with distance from roads. Dau and Cameron suggest that a local displacement of maternal caribou occurs in response to roads and associated human activity. According to Vistnes and Nellemann (2001) roads may increase potential avoidance, thereby increasing the use of remaining undisturbed grazing grounds. Reimers (2001) claims that roads itself is no hinder to reindeer where no deep ditches or other limiting constructions are present, but the traffic is the hindering factor. Therefore roads with low traffic density are of little importance to reindeer migrations.

Caribou reactions due to provocation by snow mobiles were different between years in the study of Mahoney *et al.* (2001), probably due to varying snow depth. In years of deep snow the caribou's critical distance of response was significantly lower than in years with less snow. Upon exposure of snow mobiles, caribou were displaced 60 to 237 m from their initial location and groups with calves allowed the snow mobiles to move closer. This behaviour should not be considered to remain in undisturbed areas since the effect of habituation could be seen and the caribou got used to snow mobiles after exposure. An example of this is the vehicle traffic in Denali National Park in Alaska where no effects of increased traffic could be seen in distribution and abundance of caribou, grizzly bears (*Ursus arctos*) or dall sheep (*Ovis dalli*) (Burson *et al.* 2000; Yost and Wright 2001). Brown, Hall *et al.* (2000) made experiments on administration of road salt to hinder caribou from gathering on roads and limit the collisions with animals. Their work illustrates that when the salt needs is high enough, the vigilance to roads and traffic is reduced.

Red deer (*Cervus elaphus*) has been observed by several scientist to retract from open roads and therefore not being able to optimise its grazing pattern (e.g. Rowland *et al.* 2000).

Military disturbances

The Swedish Defence Forces have at times been disturbing the reindeer husbandry, especially due to over-flights by different kinds of aircrafts and use of terrain vehicles. The reindeer react differently to military disturbances depending on the season, degree of habituation, type of disturbance (aircraft, ground units etc), type of aircraft, altitude, airspeed, weather conditions, frequency of over flights, and the sex and age composition of reindeer/caribou groups (Wolfe *et al.* 2000). Caribou reacted to small fixed-wing and helicopter over-flights most strongly during calving (late May to early June), post-calving (early June to late June) and winter. Habituated caribou show less reaction to aircrafts and females with calves and larger groups were more likely to respond to over-flights than were other sex and age classes or smaller groups. Caribou subjected to over-flights in late winter interrupted resting bouts and consequently engaged in a greater number of resting bouts than caribou not subjected to over flights. Increased movement and activity during post-calving was seen, especially in females with calves (Maier *et al.* 1998). The noise exposure varied between 46 to 147 dBA, and more than 70% of the over-flights resulted in sound exposure levels between 85 – 100 dBA.

An energetic model on caribou predicted that the weight of autumn body fat would decline between 0.07-0.64 kg in a year if caribou were exposed to 10-40 consecutive days of single disturbance events by low-altitude jet over flights during post-calving (Luick *et al.* 1996). The highest frequency of exposure was predicted to reduce the probability of pregnancy the following year by 4-5% under normal or poor conditions, and severe insect harassment might worsen this effect. These numbers should be lower in reindeer due to less body weight (less energy spending to movement) and probably a higher habituation to disturbances in semi-domesticated reindeer compared to wild caribou.

Several reports (Miller and Gunn 1981; Harrington and Veitch 1991; 1992; Reimers 2001) indicate that low-flying jet fighters and helicopters do inflict reactions on reindeer and caribou and highest reactions was achieved when the strong sound of the aircrafts was combined with the visual impression of the aircrafts. Some change in activity cycles and distribution was seen but habituation and quick recovery of physical implications was also registered. Reimers (2001) found that semi-domesticated reindeer did not react very much during a military training event in Halkavarre Skytefelt in Finnmark, Norway, where the reindeer were over-flown by helicopters and jet aircrafts several times and with cannon fires and seismic activity close by. When humans on foot where closing in, the reactions of the reindeer increased compared to mechanical activities. Mild short-term effects were registered and long-term effects were so far unclear. Habituation occurs but probably the effects are higher during winter when reindeer movements are reduced and their energy balance is negative.

Military structures can also compete in land use. When a regiment was established in Arvidsjaur, Sweden the reindeer herders lost 7 000 ha due to the state using a paragraph in the Reindeer Pasture Act, which give the state right to withdraw the Reindeer husbandry right in an area (Lundmark 1998).

Disturbances from human activities

Human activities in reindeer herding areas that affect behaviour and habitat choice should be considered as disturbances. Human activities in the reindeer herding area are often connected to infrastructure, such as roads, tracks, power lines and residence areas, and decreased abundance of reindeer close to these structures has been shown in several reports (Miller and Gunn 1981; Dau and Cameron 1986; Tyler 1990; Harrington 1996; Bradshaw *et al.* 1998; Cumming and Hyer 1998; Maier *et al.* 1998; Danell 1999; Sporan *et al.* 1999; Aastrup 2000; Colman *et al.* 2000; Nellemann *et al.* 2000; Reimers *et al.* 2000a; Dyer *et al.* 2001; Mahoney *et al.* 2001; Nellemann *et al.* 2001; Vistnes and Nellemann 2001; Flydal and Reimers 2002). Sources of disturbances can be over-flights by airplanes and helicopters, passing snow-mobiles, humans on skis etc. The latter types of disturbances are much harder to estimate and locate geographically compared to infrastructure which has a fixed position.

All disturbances affect the reindeer on different scales, both spatially and temporally, and a suggestion of characterizing these is shown in Figure 7.

Disturbance from human activities may reduce grazing time and increase migration and evasive manoeuvres, which in turn cost energy. Reduction of time for recovery and grazing time may cause weight loss and calf mortality even if the forage is abundant and of good quality. The extent of the disturbance have therefore to be considered. Disturbances can be on a regional scale and of a linear structure or on a local scale and only a point source. Disturbances can be repeating over time or happen rarely, and may also have a fragmenting effect on the herding area. Reindeer seem to habituate differently to different objects, and cars on roads does not seem to have such a scaring effect compared to a snow mobile that shows up in an unexpected place, or visible human beings (Reimers 2001).

During the winter the reindeer gather in the winter grazing areas in the woodlands, which today is the bottle neck for the reindeer husbandry. The availability of winter forage determines how large herd one can support. If the reindeer are affected by disturbances during this time they may stop cratering for food and spread over large areas, particularly during late winter and when harsh weather conditions makes the forage difficult to reach. The availability of the forage may also be affected. Disturbances during winter can therefore affect the total herd size the following summer and the production in general (Nellemann *et al.* 2000). In the mountain reindeer herding districts, spring migration usually begins in April and in May they reach the calving grounds in the highlands. During calving the reindeer are particularly sensitive to disturbances. After calving the herd migrates to alpine areas where they graze from June through August. During this time the calves are marked before the herd is moved to the autumn grazing lands. The gathering preceding the autumn migration demands an extensive labour. Disturbances which scatter herds, may lead to that gatherings has to be redone. During autumn and early winter merely all slaughtering occur (Lundmark 1998).

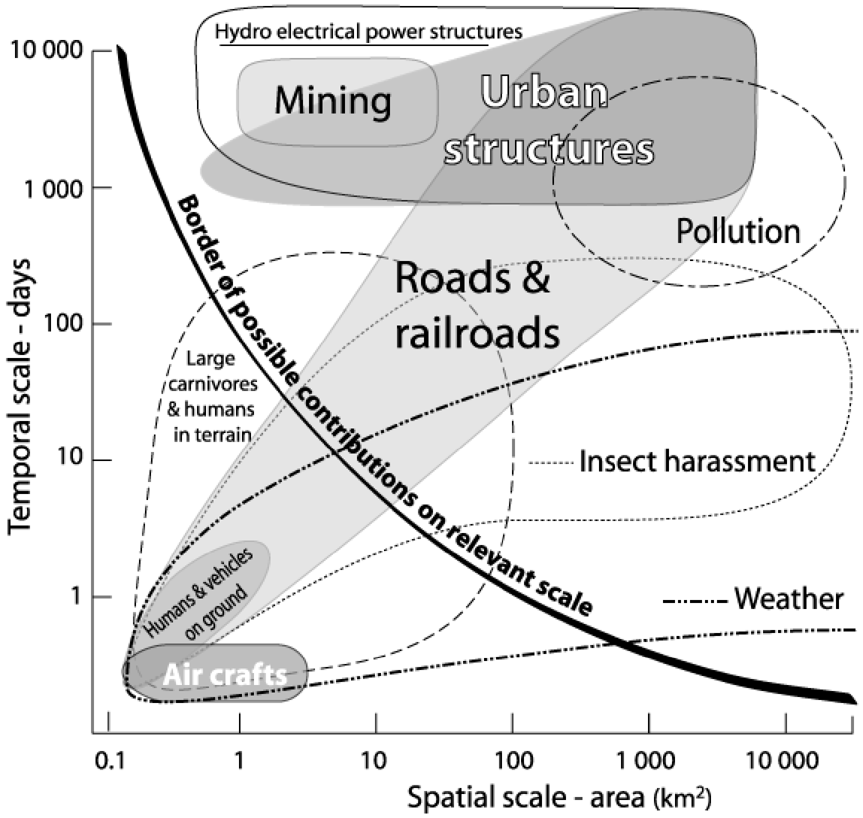

Figure 7. Suggested scales of spatial and temporal impacts of disturbances due to human activities, infrastructure, predators, insects and climate on reindeer.

Consequences of human activities

Fragmentation

The reindeer grazing areas become fragmented by linear structures such as roads, railroads, power lines and trails, but also by other structures such as dams, clear-cuts, industries and urban areas. This fragmentation has caused not only loss of grazing areas but also problems regarding migration and use of nearby pastures (Nelleman *et al.* 2001; Vistnes *et al.* 2002). This is a result of human activities and infrastructure, as well as effects from different use of natural resources. Local disturbances as well as linear structures affect reindeer industry, especially when the local disturbances are abundant both in time and space. Several local disturbances may together form a virtual linear disturbance which act as a limiting border. Local structures are also connected to other disturbing structures such as roads, traffic and trails, which might increase the fragmenting effect on reindeer herding.

The wild reindeer population in Norway is one of the last wild reindeer populations in north-western Europe and inhabit the most disturbed grazing lands in the circumpolar north. Fragmentation of the original continuous range by infrastructure and settlements has resulted in 26 separate subpopulations of wild reindeer, with little or no migration between them. In 17% of this area, where the human development was highest, only 1.1% of the reindeer were encountered (Vistnes *et al.* 2001). Density of reindeer increased with the distance to tourist resorts as well (Nellemann *et al.* 2000), and the available lichen biomass was 4-5 times higher within 5 km from the resort compared with areas further than 15 km from the resort. The loss of available grazing areas therefore has lead to overgrazing in undisturbed areas.

The number of forest roads in Sweden increase constantly, leading to more fragmented grazing areas. An index of fragmentation could be used in investigating the negative effect of infra-structure calculated from GIS-based information of infrastructure and grazing areas. One difficulty is to estimate the impact of different linear structures on reindeer movement, migration and habitat choice. Certainly the effect is substantial, but validation of linear structures also should comprise the value of habitat in which the structure is placed.

Habituation

Reimers (2001), found by comparing results from Greenland, Svalbard and Norway, that habituation occurs where human activities repeatedly occurs. His conclusions to explain these results are: The reindeer in some areas on Svalbard have little experience of human activities and assume vigilant behaviour to protect themselves. Other reindeer are used to mining industry and human activities and the little reaction to human activities were found. The cause of this behaviour change is, according to Reimers, that the reindeer don't connect any negative experiences with human activities. Differences are also found in areas where hunting occurs and tourist intensity vary. The hunting seems therefore to be inferior to the habituation to tourist activities.

Energetic costs

An example of the energetic costs for caribou due to disturbances, according to (Bradshaw *et al.* 1998), is 3.46 – 5.81 MJ. A caribou loses normally 10-15% of its autumn body mass during winter, and if disturbed 20-34 times (mean=27) the caribou would lose additional 2.5% of its body mass and therefore exceed 15% altogether. This has been recorded to happen not too seldom. In this case 2.5% is equal to 3.3 kg for a female on 132 kg, but since reindeer females in Sweden weigh around 70 kg this loss should be lower due to less energy spent when moving. The reindeer in Sweden is semi-domesticated and may become more easily habituated. Therefore the weight loss due to disturbance may be in relative terms lower. Still disturbances during sensitive parts of the year might play a role on production, and in severe cases during harsh conditions even on survival.

Environmental pollution

Pollutions affect the reindeer as every other living organism. Chemicals are spread into the ecosystems from sources of different kinds. The reindeer can be affected by these by ingesting or inhaling the chemicals found in forage and air. Luckily the air is rather unpolluted in the reindeer herding areas and could hereafter be left just mentioned, but fall-outs of airborne pollution are by rain and snow concentrated on the ground and also captured by herbs and lichens. Since lichens receive its nutrients from the precipitation, they get affected directly from the air and absorb pollutants mixed with rain. Herbs, on the other hand, absorb their nutrients and water from the ground and therefore become affected in a longer time frame and do not necessarily absorb pollutants that might be deposited on the ground. Large portions of the pollution leave the area through surface and ground water drainage, and become ultimately deposited in sediments or dissolved in free water bodies.

Amounts of heavy metals and other poisonous compounds have been traced in polar regions (Robillard *et al.* 2002), but as far as we can see today the effect on reindeer is of minor relevance, except the fall-out of caesium from the Chernobyl accident (Åhman *et al.* 1990; Åhman and Åhman 1994).

Chernobyl accident 1986

Large parts of the reindeer herding area in Sweden were contaminated with radioactive caesium from the Chernobyl accident in 1986, when the Soviet nuclear power plant suffered a severe failure. The main radio-nuclides deposited were ^{134}Cs and ^{137}Cs with physical half-lives of 2 and 30 years respectively. During the first year after the accident no food with activity concentrations exceeding 300 Bq/kg was allowed to be sold in Sweden. This caused that about 75% of all reindeer meat produced in Sweden during the autumn and winter 1986/87 was withdrawn from consumption because of too high caesium activities (Åhman *et al.* 1990). The reindeer herders were compensated by the Swedish Government for the costs and loss of income due to the Chernobyl fallout. In May 1997 the limit of activity concentrations was raised to 1 500 Bq/kg for reindeer, game and fresh-water fish. During the following two years about 25% of the slaughtered reindeer exceeded this limit, most of them in the southern half of the Swedish reindeer herding area. The highest radio-caesium activities were measured during winter when reindeer forage on lichens and moves in areas more severely suffered from the fallout. Due to the slow growth of lichen and way it absorbs nutrients from the atmosphere, the biological half-life of the radio-nucleotides in lichens is rather long (Tuominen and Jaakkola 1973). Since the reindeer utilize different areas during different seasons, the ecological half-life of caesium in their different ecosystems differ. The effective half-life of the activity concentration has been 3-4 years which is more rapid than expected (Åhman and Åhman 1994). To lower the activity concentration the reindeer herders in some contaminated areas feed the reindeer prior to slaughter, which also may improve carcass weights.

The Chernobyl accident has had a great impact on the reindeer industry in Sweden but regarding production figures the effect is marginal, since the slaughter or culling ratio was not altered and the animals have shown no effect of the radio-active fall-out. Its productivity consequences are therefore small.

Internal factors and husbandry effects

As internal factors I refer to the reindeer's physiological factors and factors under control of the reindeer herders. The body condition of the reindeer affect the reproductive success as well as the quality of the carcass.

The reindeer herders can control many factors such as where reindeer graze, any necessary or extra feeding, the herd structure, breeding programs, and pest and insect control through administration of endectocide. Some production techniques are done to achieve an immediate effect, such as feeding or movements of herds, while others have more long-term effects, such as breeding programs and parasite control agents. Even though the reindeer move and graze relatively freely, the herders try to optimise the migrations and use of grazing ranges, and keep the herds under observation, especially during the winter season. Feeding may sometimes be necessary due to difficult conditions, or just to increase the weight prior to slaughter. These measurements affect the production directly, both meat quantity and quality. Herd structure, including age class structure and male/female ratio, have a large impact on production (Lenvik 1990).

Physiological factors

Among wild and domestic reindeer, several reproductive traits are strongly correlated with maternal weight. Heavy females enjoy higher pregnancy rates, calve earlier, and give birth to heavier calves with a higher neonatal survival rate than lighter females do (Reimers 1997). Most studies indicate that both weaning weight of a calf and mature body weight correlate with its birth weight. Calf body weight and composition influence the rate of attainment of sexual maturity. Females that breed as calves suffer reduced growth and give birth to smaller calves, which suffer higher neonatal mortality and lower rates of post-natal growth. Significant is, when good animal condition is reached, the ground is prepared to achieve even better condition, and also the opposite. One can refer it to positive or negative vortex developments caused by lagged developments in the system..

Herding

Since reindeer herding is based on using the low-productive natural pastures over waste land areas in sub-arctic climate, migration between summer and winter grazing areas is often necessary. The distances between summer and winter grazing areas in different reindeer herding district differ greatly, up to 300 km, and may affect the time for efficient grazing during migration and cause loss of fat reserves due to long walking. The topography and condition of the areas used for migration might affect the condition of the herd as well as the time used for these migrations. The movement of the herds is done in different ways and today snow-mobiles and motorcycles are common tools. Some herding districts transport reindeer on trucks between summer and winter ranges due to deficient grazing opportunities in migration areas, caused by competing industries or over-grazing.

Feeding

Fundamentally, reindeer herding is converting pastures into harvested meat. The primary resource is therefore the forage, which is green plants, lichens and mushrooms. The reindeer is adapted to changing forage conditions and compositions, yet a rather demanding ruminant. Therefore the quality and composition of the forage is important. During the summer the reindeer gain weight and build up body depots which help the animals to survive during the harsh condition of the winter. However, due to weather, lack of forage, constraints in the environment and low animal condition, it has recently become quite common to feed the reindeer to maintain the number or gain slaughter weight.

According to (Åhman 2000) there are five typical scenarios where feeding might be beneficial;

- i) Emergency feeding, when there is lack of forage depending on snow depth or ice-crust formation, and feeding is necessary for survival.
- ii) Complementary feeding, which can be considered during the migration of reindeer or when an over-population of reindeer have been withheld and overgrazing has occurred.
- iii) Feeding of short duration, i.e. during gathering of herds, can be justified due to lack of time for foraging when handled and gathered.
- iv) Feeding of females during spring to give extra nutrients to pregnant females when forage still is sparse, which avoids large weight losses in females and increase calf survival and calf-weights.
- v) Feeding before slaughter, which help the reindeer to gain weight, improve the quality of carcass and also to lower any high levels of radioactive Caesium due to the Chernobyl accident.

Feeding apparently has impact on the production and might alter the number of reindeer possible to withheld in an area of certain condition. If investigations of survival vs. area conditions are made, feeding of type i) probably has large impact. Correspondingly, feeding type v) has large impact of meat quality and slaughter weights, and feeding type iv) has large impact on reproduction data. Consequently feeding is important to consider when productivity is judged.

Animal density and herd structure

The higher the reindeer density is on a given area, the more competition for the forage occurs and the productivity per animal is decreased, as shown in Figure 8. At high densities every reindeer suffer from competition of forage and decreased forage quality, and at low densities the utilization of grazing areas is not optimal (Dahle *et al.* 1999). If we look at the economical aspects of different densities, higher densities means more animals to handle and thereby higher running costs. Therefore the net profit has its optimum at a somewhat lower density than the production maximum (Figure 9)

By altering the reindeer herd composition of sex and age, consequences on the production is achieved (Lenvik 1990). When planning for the future it might be tempting to retain to many reindeer which increases grazing pressure followed by a decrease in forage abundance and quality, and in turn leads to weight losses and lowered fecundity in the herd, and the ratio of stillborn calves may increase together with decrease of the calf survival and calf weight in the autumn.

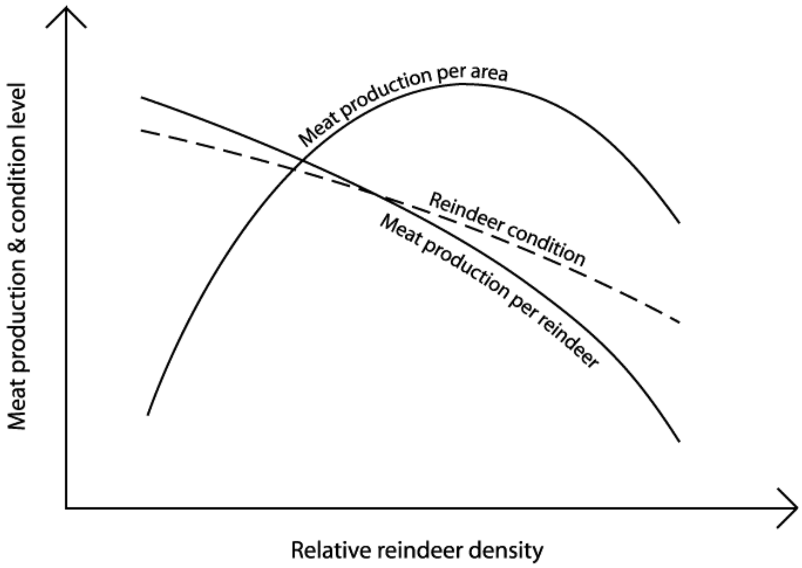

Figure 8. Density dependence in reindeer production per animal and area due to lack of forage and/or decreased forage quality (Dahle *et al.* 1999).

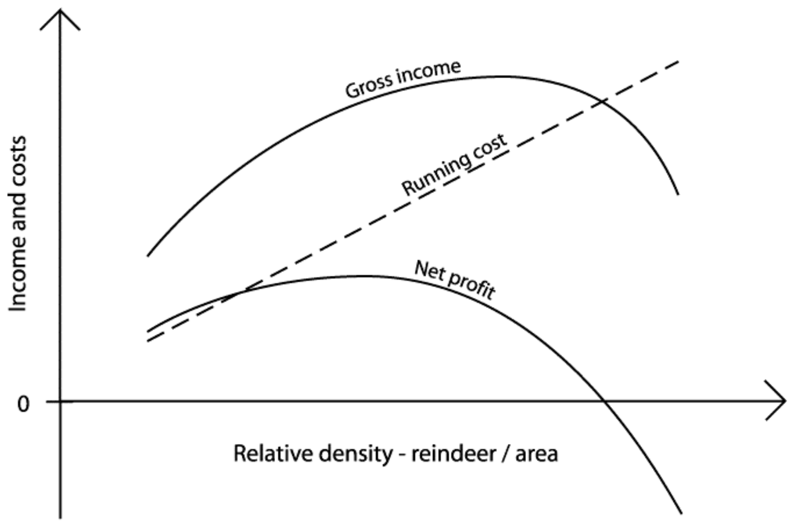

Figure 9. Economic optima with the running costs included and excluded, which shows that the optimum density with the costs included are somewhat lower than with the running costs excluded (Dahle *et al.* 1999).

Hence, if a female with calf totally gains more weight during the summer than an adult male reindeer, it is more advantageous to keep as few males and as many females as possible. If the opposite is the case an optimal balance is reached at a higher portion of males in the herd. A preferable minimum male/female ratio should be around 1/20. Another effect of slaughter the calves in the autumn instead of older animals is that the number of individuals can be held low during winter when the forage often is the limiting factor, and also the mortality during winter is higher for calves than for adults. The age structure of the herd also affects production. According to Lenvik (1990), the calf average weight in autumn is increased by 1.13 kg for each extra year of the mother, up to the age of five. High average weight and a female age of 4 – 8 years in the herd are positive factors of the survival, weight and condition of calves. According to Rönnegård *et al.* (2002) Calf masses are affected by both the mother's mass and her age, and mothers aged 2 – 4 years had calves that weighed less than calves of older mothers.

When culling calves and adults at slaughter, a selection towards heavier and more fast-growing animals can be achieved and by this method increase carcass weights. Experiments on selection programs has been done (Rönnegård and Danell 2002) where results in an increase in calf weights of approximately 2 kg after two generations of selection could be achieved and therefore clearly have an impact on reindeer production. Selection programs are a potential technique but it is not known for how long one can increase weight through selection, since the environment cannot be improved simultaneously to support the enhanced genetic capacity.

Parasite control

Due to several occurring internal and external parasites on reindeer, it is common to subcutaneously or orally administrate endectocides to reindeer. The most common endectocide is ivermectin, which is efficient against warbles, throat bots and gastro-intestinal nematodes (Oksanen 1999). The method of administration of the endectocide treatment is crucial to its efficacy where oral administration seems inefficient compared to subcutaneous injections. Some areas have more severe parasitic problems than other areas and the use of parasite control is more common. It is therefore necessary to consider the effects of endectocide to the reindeer production, when comparing productivity measures.

Synthesis

The intention of this essay is not to rank factors affecting reindeer production, but rather comment on their importance and sort out factors that are not relevant or not possible to achieve information about. I will try to identify a set of conceivable indicators of conditions for productivity. These indices are to be set on the appropriate scale for their impact on productivity, and in future studies be compared with each other and against production figures. Data availability regarding the factors will also be mentioned. The ultimate aim is to reveal indices per reindeer herding district to achieve structured and simplified data to be used in multivariate characterization of productivity patterns in the Swedish reindeer herding area.

Since forage affect reindeer survival and production all factors that affect forage are potentially of substance. Factors affecting the reindeer productivity often affect several different criteria which in turn affect the production, such as the weather's impacts on both forage and insects, which both in turn affect reindeer productivity. The very same factor, such as wind, might be positive in one way and negative in another. One example showing this is the negative effect of wind on making the winter conditions more harsh by increasing the chill effect and packing snow. Wind, on the other hand, is positive during summer since it becomes relieving against insect harassment. One way of sorting the factors out are by giving each factor a describing label or index of its effect on the system. Another way, which I also will try to use is by dividing the year into seasons and denominate the positive and negative factor which occurs and are related to each season. An simplified overview of the factors divided into seasons are shown in Figure 10.

The availability of data is an essential factor in the context. The factors discussed are compiled in Table 4 together with remarks on availability of data.

Topography is well documented and data such as altitude maps and geological and hydrological data is abundant. Area, distances, ruggedness, slope indices such as aspect and steepness, water ways, shelter from wind and sun etc. can be derived from digital altitude maps. These factors affect forage and probably insect harassment, as well as reachable areas for grazing and limitations in migration. Relevant indices per reindeer herding district could be utilizable grazing area (i.e. total district area minus impediments), average altitude, ruggedness, proportion of land above tree line, topological fragmentation (due to ridges, waterways and other obstacles). Ruggedness for example, can be derived from a grid-based topography map, where every pixel corresponds to 50 × 50 meters in reality and the equidistance is 1 meter.

Since climate and weather change in time, time series can be used to examine their effects on reindeer production. To divide climate and weather I assume climate to be long-term levels and trends in seasonal temperature, rainfall, wind as well as season length and effects due to mentioned factors. Weather, on the other hand, is regarded as fluctuations in a shorter temporal scale, such as a rainy summer, rain or thaw and frost sequences causing ice-crust formation. Therefore the weather factors are many and the challenge is sorting out special events that might be of concern and collect relevant conditions in Table 2. As mentioned earlier in this report calf losses has been observed to increase with low spring temperatures and late winter snow depth (Ropstad *et al.* 2001). Lee *et al.* (2000) showed that wet and warm winters the year before the rut decreased the number of surviving calves the following year, and in contrast warmer autumns prior to their birth increased the number of calves. These weather parameters can also be used to derive indicators of insect abundance and hence harassment in the Swedish reindeer herding area. When ice-crust is formed, and also during other harsh forage conditions as deep snow reindeer have problem reaching their forage.

Predators have a large impact on reindeer production. The main predators in the Swedish herding area are lynx and wolverine, but reindeer are affected of the other large carnivores in the reindeer herding area. Inventory maps and economical compensation reports are covering predatory abundance and mass slaughter incidents and could be used as information for example for a main large carnivore index, including all predators on reindeer. This predatory index could be the sum of the effect of all large carnivores.

Parasites are, as mentioned, probably of great importance to reindeer production. Since the relevant parasites are abundant all over the reindeer herding area of Sweden, weather data can be of use to understand the spatial abundance of harassing insects. Warm and calm days during summer increase insect harassment (Mörschel and Klein 1997; Mörschel 1999) and cloud cover seems to be negative correlated to insect harassment (Colman 2000). This data can be used to produce digital suitability maps for specified insects on a large scale and also to produce data on possible impact of insect harassment during a longer period of time.

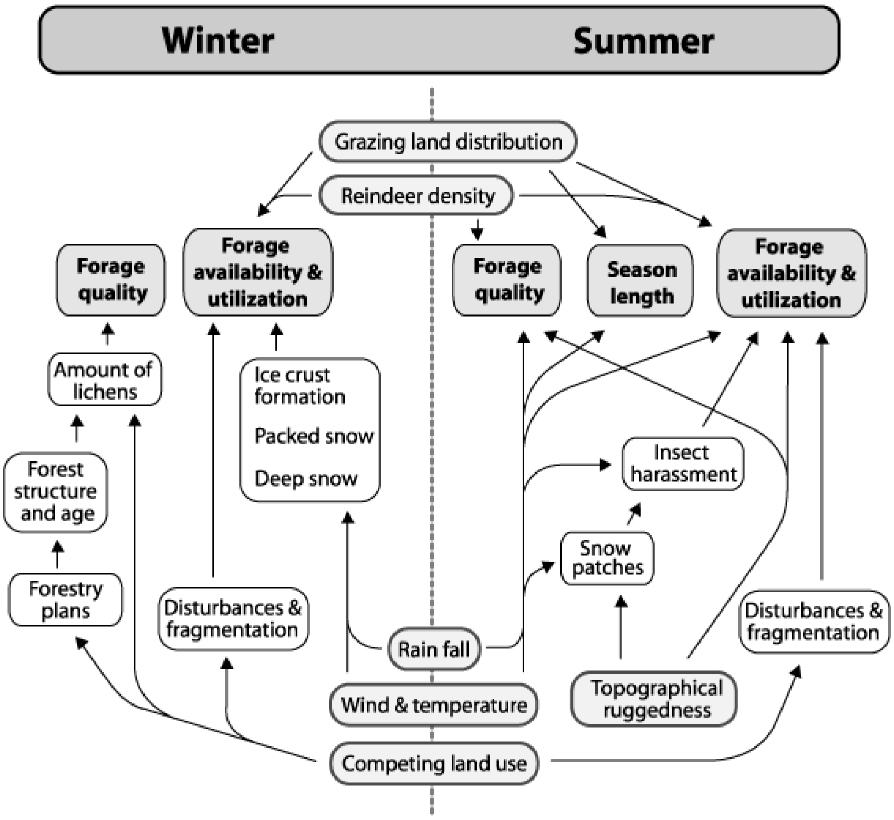

Figure 10. A simplified overview on factors' effects and the conditions needed for reindeer production divided into seasons of summer and winter.

Several indices has been used to model the severity of insects harassments (Skogland 1984; Mörschel 1999; Weladji *et al.* 2003) where temperature, wind speed and cloud cover are the parameters usually used. These indices could be used to model the insect harassment in the total Swedish reindeer herding area. Also the effect of endectocide treatments should be regarded and therefore an investigation of the herders utilization of such chemicals are of importance.

Disturbances are generated, as mentioned, from various sources, and the scale is of importance. Disturbances are on local scale, but relevant is the abundance of local disturbances, and whether the disturbance is constant or temporary. A power line is fixed in its location and permanent compared to a snow-mobile, but the reindeer ability to habituation concerning the type of disturbance is also a factor. If the disturbance renders the effect of fragmentation it should likely be regarded as more severe than non-fragmenting disturbances, and if the disturbance is seasonal it has to be examined whether the reindeer inhabit the actual habitat during the disturbance. An extensive investigation of ranking the sources of disturbance is necessary and should be of priority to be able to characterize the disturbance patterns.

Table 3: Weather and topographical factors and their effect on reindeer production

Weather condition	Positive (+) / negative (-)
Warm summer temperature (heat stress, high cellulose content in plants, short and early wilt period, increased insect harassment)	-
Low summer temperature (low cellulose content in herbs, prolonged wilt period)	+
Dry summers (lower plant production)	-
Windy summer days (decreased insect harassment)	+
Cloud cover (decreased insect harassment)	+
Warm autumn temperature (prolonged growth season)	+
Extreme snow depth during winter (foraging difficulties)	-
Wet winters (foraging difficulties)	- (one year lag)
Warm winters (foraging difficulties)	- (one year lag)
Ice-crust formation (foraging difficulties)	-
Late winter snow depth (foraging difficulties)	-
Snow patches in spring (prolonged fresh plant period, insect harassment relief)	+
Low spring temperature (decreased growth season)	-
Growth season length	+
Ruggedness (increased snow patch density, forage quality, shelter, temperature regulation)	+

Environmental factors, such as pollutions, are not severe enough to be considered in relation to productivity patterns. The Chernobyl accident, due to its small effect on production figures, should not be counted for. Other pollutions are of minor importance today in the reindeer herding districts, such as forest fertilizers, heavy metals, and other chemical compounds. But these pollutions could increase to a significant level in the future and should therefore not be considered irrelevant in a longer time perspective. Noise pollutions are, as mentioned, a relevant disturbance and the sources of this kind of pollution should be specified and included in the study. It could be included as a fragmenting effect of infrastructure such as roads and power-lines.

Fragmentation is probably the major consequence by all sorts of disturbances and an index of fragmentation is likely of large relevance. There are several factors that can give raise to fragmentation and all these factors should be included into one concluding fragmentation index and be examined for effects on reindeer productivity. The problem is here to find a relevant index which include as much fragmenting information as possible but is as general as necessary. Statistically it could be made through measurements from random scattered points to nearest fragmenting source, and by this achieve a mean fragmenting effect on every investigated area. The difficulty is though to validate the fragmenting sources in a relevant way, and need for subjective validation might be accounted for.

The reindeer physical condition coupled with density on the range is a measure on the condition of the land and is therefore a factor which reflects productivity. This information could be retrieved through investigations of meat quality and weight gains on individual reindeer.

Reindeer migration distances which is an energy cost and may affect grazing time, can be estimated through distance measurements of each reindeer herding district with the help of GIS. Data on whether migrations are performed on foot or by lorries has to be collected through interviews of inquiries.

Feeding is an most relevant factor regarding production and meat quality and should be counted for. No data exist on this and must be collected from the herders themselves through interviews or inquiries.

Herd structure, breeding programs and parasite control of each herding district are other factors on which information is deficient. Therefore inquiries are to be used in these cases as well.

In conclusion; reindeer production is depending upon many factors of different level of impact. By extending the geographical scale, the numbers of factors affecting the reindeer becomes apparent. Making an investigation of this scale on such amount of factors demands a lot predefining and generalisation of data into usable indices. Ecological and husbandry knowledge is necessary to make these definitions and generalisations in a relevant scientific manner. Due to the scale of the investigation many factors can be as well as has to be concluded into simplified indices since the number of herding districts in the comparisons are limited, i.e. $n = 51$, and the degrees of freedom in the statistical analyses therefore are limited.

Primarily analyses on topography, seasonal range areas and weather will be done to find the underlying patterns which affects prerequisites of the reindeer production. This primary survey will be divided into seasonal periods of interests to identify the certain weather conditions and topographical features together with the help of ecological knowledge. Secondly the fragmenting parameters will be taken into the investigation, i.e. competing industries, infrastructure and disturbances. Thirdly the herders' measures will be taken into account, such as herd structure, culling strategies and feeding as well as administration of parasite control agents.

There are of course limitations in such a study where the intention is comparing merely all factors affecting a biological system such as reindeer ecology. On the other hand the potential of the study is extensive due to its scale and large coverage of factors with the help of GIS and multivariate analyses. To make an investigation of this extent this approach seems suitable and the results may give new insights of range ecology and reindeer production.

Table 4. List of factors on reindeer production considered relevant.

Factor		Data available	Data origin
Climate			
	- Temperature	Y	SMHI database
	- Wind	Y	- " -
	- Rain fall / Snow depth	Y	- " -
	- Growing season length	Y	- " -
	- North Atlantic Oscillation (NAO)	Y	- " -
Topography			
	- Altitude	Y	Metria maps
	- Ruggedness	Y	- " -
	- Water bodies	Y	- " -
	- Limiting ridges	Y	- " -
	- Grazing land areas	Y	- " -
	- Summer / winter ranges	Y	- " -
Infra structure & Competing land use			
	- Roads	Y	Metria maps
	- Railroads	Y	- " -
	- Hydroelectrical dams & power lines	Y	- " -
	- Urban areas / airports	Y	- " -
	- Tourist resorts	Y	- " -
	- Agriculture	Y	- " -
	- Peat harvesting & mining	Y	- " -
	- Forestry	Yet to come	CORINT (Swedish groundcover data)
Large carnivores			
	- Wolf	Y	Inventory data, länsstyrelsen
	- Wolverine	Y	- " -
	- Lynx	Y	- " -
	- Brown bear	Y	- " -
	- Golden eagle	Y	- " -
Insect abundance			
	- Nose bot fly / Warble fly	N	Suitability maps SMHI & Metria data
	- Parasite control	N	Herder inquiry
Herd data			
	- Migration distances	N	Herder inquiry
	- Transport ways	N	- " -
	- Herd structure – gender/age/size	N	- " -
	- Emergency feeding etc	N	- " -
Slaughter strategies			
	- Calf culling	Y	Jordbruksverket
	- Culling percentage	Y	- " -
	- Breeding programs	N	Herder inquiry
Animal conditions			
	- Slaughter weights	Y	Jordbruksverket
	- Fat content	Y	- " -

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References

Aastrup, P. (2000). "Responses of West Greenland caribou to the approach of humans on foot." Polar Research **19**(1): 83-90.

Ackerman, S. A. and J. A. Knox (2003). Meteorology - Understanding the atmosphere, Thomson Brooks/Cole. ISBN: 0-534-37199-X

Anderson, J. R. and A. C. Nilsen (1998). "Do reindeer aggregate on snow patches to reduce harassment by parasitic flies or to thermoregulate." Rangifer **18**(1): 3-17.

Anderson, J. R., A. C. Nilssen, *et al.* (1994). "Mating behavior and thermoregulation of the reindeer warble fly, Hypoderma tarandi L. (Diptera: Oestridae)." Journal of Insect Behavior **7**(5): 679-706.

Armleder, H. M. and S. K. Stevenson (1996). "Using Alternative Silvicultural Systems to Integrate Mountain Caribou and Timber Management in British Columbia." Rangifer **Special Issue No. 9**: 141-148.

Bergo, G. (1990). Ørneskador på småfe og hjortedjur, NINA**:** 36 sid.

Bradshaw, C. J. A., S. Boutin, *et al.* (1998). "Energetic implications of disturbance caused by petroleum exploration to woodland caribou." Canadian Journal of Zoology **76**(7): 1319-1324.

Brown, W. K., W. K. Hall, *et al.* (2000). "Repellency of three compounds to caribou." Wildlife Society Bulletin **28**(2): 365-371.

Burson, S. L., J. L. Belant, *et al.* (2000). "The effect of vehicle traffic on wildlife in Denali National Park." Arctic **53**(2): 146-151.

Colman, J., P. Jordhøy, *et al.* (2000). "Fragmentation, overgrazing and anthropogenic disturbance in Norwegian reindeer ranges." Rangifer **Special Issue No. 12**: 103.

Colman, J. E. (2000). Behaviour patterns of wild reindeer in relation to sheep and parasitic flies. Faculty of Mathematics and Natural Sciences. Oslo, University of Oslo.

Crête, M. and S. Payette (1990). "Climatic changes and caribou abundance in northern Québec over the last century." Rangifer **Special Issue No. 3**: 159-165.

Crittenden, P. D. (2000). "Aspects of the ecology of mat-forming lichens." Rangifer **20**(2-3): 127-139.

Cumming, H. G. and B. T. Hyer (1998). "Experimental log hauling through a traditional caribou winterin area." Rangifer **Special Issue No. 10**: 241-258.

Dahle, H. K., Ö. Danell, *et al.* (1999). Reindrift i Nordvest-Europa i 1998 - biologiske muligheter og begrensninger. Köbenhavn, Nordiskt Ministerråd**:** 116 sid.

Danell, Ö. (1999). "Skogsbrukets effekter på renbetet är oftast negativa." Boazodiehtu **2**: 4-7.

Danell, Ö. (2000). "Status, directions and priorities of reindeer husbandry research in Sweden." Polar Research **19**(1): 111-115.

Danell, Ö. and E. Gaare (1999). Renhjordens produktionspotential och betesutnyttjande. Reindrift i Nordvest-Europa 1998 - biologiske muligheter og begrensninger. København, Nordiskt Ministerråd**:** 73-86.

Dau, J. R. and R. D. Cameron (1986). "Effects of a road system on caribou distribution during calving." Rangifer **Special Issue No. 1**: 95-101.

Downes, C. M., J. B. Theberge, *et al.* (1986). "The influence of insects on the distribution, microhabitat choice, and behaviour of the Burwash caribou herd." Canadian Journal of Zoology **64**: 622-629.

Dyer, S. J., J. P. O'Neill, *et al.* (2001). "Avoidance of industrial development by woodland caribou." Journal of Wildlife Management **65**(3): 531-542.

Eriksson, O. and T. Raunistola (1990). "Impact of soil scarification on reindeer pastures." Rangifer **Special Issue No. 3**: 99-106.

Eriksson, O. and T. Raunistola (1993). "Impact of forest fertilizers on winter pastures of semi-domesticated reindeer." Rangifer **13**(4): 203-214.

Eriksson, O., M. Sandewall, *et al.* (1987). "Virkesproduktionens inverkan på renskötselns lavbete - En metodstudie (A model for analyzing influence of timber production in lichens for reindeer grazing)." Rangifer **7**(2): 15-32.

Espmark, Y. (1968). "Observations of defence reactions to oestrid flies by semidomestic forest reindeer (*Rangifer tarandus* L.) in Swedish Lapland." Zoologische Beiträge **14**(1-2): 155-167.
Flydal, K. and E. Reimers (2002). Lokale effekter av kraftledninger og vindmøller. Rapport fra REIN-prosjektet, Norges Forskningsråd**:** 11-19.
Franzén, R. (1996). "Kungsörnen som predator på ren." Kungsörnen **1996**: 2-11.
Gjershaug, J. O. (1984). Hekkeøkologi hos kongeørn *Aquila chrysaetos* i Møre og Romsdal., Universitetet i Oslo.
Gjershaug, J. O. and O. Frydelund Steen (1998). "Kungsörnens status i Norge." Kungsörnen **1998**: 2-8.
Gunn, A. and T. Skogland (1997). "Responses of caribou and reindeer to global warming." Ecological Studies; Global change and Arctic terrestrial ecosystems **124**: 189-200.
Gustavsson, K., E. Persson*, et al.* (1989). Rennäringen - En presentation för skogsfolk. Jönköping, Skogsstyrelsen. ISBN 91-85748-77-3
Hagemoen, R. I. M. and E. Reimers (1999). "Reindeer summer activity pattern in relation to temperature and insect harassment." Rangifer **Report No. 4**: 85.
Hagemoen, R. I. M. and E. Reimers (2002). "Reindeer summer activity pattern in realtion to weather and insect harassment." Journal of Animal Ecology **71**(4): 883-892.
Harrington, F. H. (1996). "Human impacts on George River Caribou: An Overview." Rangifer **Special Issue No. 9**: 277-278.
Harrington, F. H. and A. M. Veitch (1991). "Short-term impacts of low-level jet fighter training in Labrador." Arctic **44**(4): 318-327.
Harrington, F. H. and A. M. Veitch (1992). "Calving success of woodland caribou exposed to low-level jet fighter overflights." Arctic **45**(3): 213-218.
Helle, T. and J. Aspi (1983). "Does herd formation reduce insect harassment among reindeer? A field experiment with animal traps." Acta Zoologica Fennica **175**: 129-131.
Helle, T., J. Aspi*, et al.* (1990). "The effects of stand characteristics on reindeer lichens and range use by semi-domesticated reindeer." Rangifer **Special Issue No. 3**: 107-114.
Helle, T. and I. Kojola (1994). "Body mass variation in semidomesticated reindeer." Canadian Journal of Zoology **72**(4): 681-688.
Helle, T. and M. Särkelä (1993). "The Effects of Outdoor Recreation on Range Use by Semi-domesticated Reindeer." Scandinavian Journal of Forest Research **8**: 123-133.
Helle, T. and L. Tarvianen (1984). "Effects of insect harassment on weight gain and survival in reindeer calves." Rangifer **4**(1): 24-27.
Ihl, C. and D. R. Klein (2001). "Habitat and diet selection by muskoxen and reindeer in western Alaska." Journal of Wildlife Management **65**(4): 964-972.
Johnson, C. J., K. L. Parker*, et al.* (2001). "Foraging across a variable landscape: Behavioral decisions made by woodland caribou at multiple spatial scales." Oecologia (Berlin) **127**(4): 590-602.
Josefsen, T. D., T. Mørk*, et al.* (2001). "Lungworm infection in reindeer." Rangifer **Report No. 5**: 52.
Karter, A. J. and I. Folstad (1989). "Defence behaviour of reindeer in response to flying parasitic Diptera." Rangifer **9**(1): 14-16.
Karter, A. J., I. Folstad*, et al.* (1992). "Abiotic factors influencing embryonic development, egg hatching, and larval orientation in the reindeer warble fly, *Hypoderma tarandi*." Medical and Veterinary Entomology **6**(4): 355-362.
Klein, D. R. (1990). "Variation in quality of caribou and reindeer forage plants associated with season, plant part, and phenology." Rangifer **Special Issue No. 3**: 123-130.
Leader-Williams, N. (1988). Reindeer on South Georgia: the ecology of an introduced population. Cambridge, Cambridge University Press.
Lee, S. E., M. C. Press*, et al.* (2000). "Regional effects of climate change on reindeer: a case study of the Muotkatunturi region in Finnish Lapland." Polar Research **19**(1): 99-105.
Lenvik, D. (1990). "Flokkstrukturering - tiltak for lønnsom og ressurstilpasset reindrift." Rangifer **Special Issue No. 4**: 21-35.

Luick, B. R., J. A. Kitchens*, et al.* (1996). "Modeling energy and reproductive costs in caribou exposed to low flying military jet aircraft." Rangifer **Special Issue No. 9**: 209-212.
Lundmark, L. (1998). Så länge vi har marker. Stockholm, Rabén Prisma. 91-518-3453-7
Mahoney, S. P., K. Mawhinney*, et al.* (2001). "Caribou reactions to provocation by snowmachines in Newfoundland." Rangifer **21**(1): 35-43.
Maier, J. A. K., S. M. Murphy*, et al.* (1998). "Responses of caribou to overflights by low-altitude jet aircraft." Journal of Wildlife Management **62**(2): 752-766.
Miller, F. L. and A. Gunn (1981). "Play by Peary caribou calves before, during, and after helicopter harassment." Canadian Journal of Zoology **59**: 823-827.
Mysterud, A., N. G. Yoccoz*, et al.* (2000). "Relationships between sex ratio, climate and density in red deer: The importance of spatial scale." Journal of Animal Ecology **69**(6): 959-974.
Mörschel, F. M. (1999). "Use of climatic data to model the presence of Oestrid flies in caribou herds." Journal of Wildlife Management **63**(2): 588-593.
Mörschel, F. M. and D. R. Klein (1997). "Effects of weather and parasitic insects on behaviour and group dynamics of caribou of the Delta Herd, Alaska." Canadian Journal of Zoology **75**: 1659-1670.
Naturvårdsverket (2000a) Åtgärdsprogram för bevarande av Björn (*Ursus arctos*). Naturvårdsverket. *Åtgärdsprogram nr* **20.** Stockholm
Naturvårdsverket (2000b) Åtgärdsprogram för bevarande av Järv (*Gulo gulo*). Naturvårdsverket. *Åtgärdsprogram nr* **21.** Stockholm
Naturvårdsverket (2000c) Åtgärdsprogram för bevarande av Lodjur (*Lynx lynx*). Naturvårdsverket. *Åtgärdsprogram nr* **22.** Stockholm
Nelleman, C., I. Vistnes*, et al.* (2001). "Winter distribution of wild reindeer in relation to power lines, roads and resorts." Biological Conservation **101**(3): 351-360.
Nellemann, C., P. Jordhøy*, et al.* (2000). "Cumulative impacts of tourist resorts on wild reindeer (Rangifer tarandus tarandus) during winter." Arctic **53**(1): 9-17.
Nellemann, C., I. Vistnes*, et al.* (2001). "Winter distribution of wild reindeer in relation to power lines, roads and resorts." Biological Conservation **101**(3): 351-360.
Nellemann, C., I. Vistnes*, et al.* (2002). Regionale effekter av kraftledninger. Rapport fra REIN-prosjektet, Norges forskningsråd**:** 21-44.
Nieminen, M. (1994). Poro - Ruumiinrakenne ja elintoiminat. Rovaniemi. ISBN 951-8914-53-2
Nieminen, M. and J. Leppäluoto (1985). "Renarnas trafikdödlighet i Finland under åren 1974 - 1983 (Traffic deaths of reindeer in Finland during 1974-83)." Rangifer **5**(2): 53-58.
Nilssen, A. C. and R. E. Haugerud (1994). "The timing and departure rate of the larvae of the warble fly *Hypoderma (=Oedemagena) tarandi* (L.) and the nose bot fly *Cephenemyia trompe* (Modeer) (Diptera: Oestridae) from reindeer." Rangifer **14**(3): 113-122.
Nilssen, A. C. and R. E. Haugerud (1995). "Epizootiology of the reindeer nose bot fly, Cephenemyia trompe (Modeer) (Diptera: Oestridae), in reindeer, Rangifer tarandus (L.), in Norway." Canadian Journal of Zoology **73**(6): 1024-1036.
Nilsson, A. (2003). Adaptation of Semi-domesticated Reindeer to Emergency Feeding. Reindeer Husbandry Unit, Department of Animal Breeding. Uppsala, Swedish University of Agricultural Sciences. **Agraria 399**.
Nordkvist, M. and K. Erne (1983). "The toxicity of forest fertilizers (ammonium nitrate) to reindeer." Acta Zoologica Fennica **175**: 101-105.
Oksanen, A. (1999). "Endectocide treatment of the reindeer." Rangifer **19** (Special Issue No. 11): 217 p.
Ollila, T. (1996). "Finlands kungsörnar 1990-1994." Kungsörnen **1996**: 12-17.
Ottersen, G., B. Planque*, et al.* (2001). "Ecological effects of the North Atlantic Oscillation." Oecologia (Berlin) **128**(1): 1-14.
Post, E. and N. C. Stenseth (1999). "Climatic variability, plant phenology, and northern ungulates." Ecology (Washington D C) **80**(4): 1322-1339.

Rehbinder, C. (1990). "Management stress in reindeer." Rangifer **Special Issue No. 3**: 267-288.
Reimers, E. (1997). "Rangifer population ecology: a Scandinavian perspective." Rangifer **17**(3): 105-118.
Reimers, E. (2001). Halkavarre skytefelt - Våpenflygning og militære øvelser - En litteraturoversikt og analyse av virkningen på rein og caribou av militær og annen menneskelig virksomhet. Oslo, Norges veterinærhøgskole/Universitetet i Oslo**:** 45 sid.
Reimers, E., J. Colman*, et al.* (2000a). "Fright response of reindeer in four geographical areas in Southern Norway after disturbance by humans on foot or skis." Rangifer **Special Issue No. 12**: 112.
Reimers, E., K. Flydal*, et al.* (2000b). "High voltage transmission lines and their affect on reindeer: a research programme in progress." Polar Research **19**(1): 75-82.
Renbeteskommissionen (2001) Betänkande / avgivet av Svensk-norska renbeteskommissionen av 1997. S.-n. renbeteskommissionen, Utrikesdepartementet. Helsingfors
Robillard, S., G. Beauchamp*, et al.* (2002). "Levels of cadmium, lead, mercury and 137caesium in caribou (*Rangifer tarandus*) tissues from Northern Québec." Arctic **55**(1): 1-9.
Rominger, E. M., L. Allen-Johnson*, et al.* (1994). "Arboreal lichen in uncut and partially cut subalpine fir stands in woodland caribou habitat, northern Idaho and southeastern British Columbia." Forest Ecology and Management **70**(1-3): 195-202.
Ropstad, E., S. D. Albon*, et al.* (2001). "Reproductive success of reindeer associated with climate variability." Rangifer **Report No 5.**: 77.
Rowland, M. M., M. J. Wisdom*, et al.* (2000). "Elk distribution and modeling in relation to roads." Journal of Wildlife Management **64**(3): 672-684.
Rönnegård, L. and Ö. Danell (2002). "Selection response in a reindeer herd." In press.
Rönnegård, L., P. Forslund*, et al.* (2002). "Life-time patterns in adult female weight, reproduction and offspring weight in semi-domesticated reindeer." Canadian Journal of Zoology **80**: 2047-2055.
SCB (1999). Svensk rennäring, Statistiska centralbyrån, Svenska Samernas Riksförbund, Jordbruksverket, Sveriges Lantbruksuniversitet. ISBN 91-618-1024-X
SCB (2001) Statistiska Centralbyrån *Siffror om rennäringen* http://www.rennaringsstatistik.scb.se/index.asp (Accessed 2003-04-14)
Senft, R. L., M. B. Coughenour*, et al.* (1987). "Large herbivore foraging and ecological hierarchies - Landscape ecology can enhance traditional foraging theory." Bioscience **37**: 789-799.
SFS (1971:437). Rennäringslag. SFS nr:. **1971:437**.
SFS (1979:429). Skogsvårdslag. SFS nr:. **1979:429**.
Sikku, O. J. (1999). Traditionell samisk kunskap om rovdjur. Bilagor till sammanhållen rovdjurspolitik. Stockholm, Miljödepartementet. **SOU 1999:146:** 235-244.
Skogland, T. (1984). "Wild reindeer foraging-niche organization." Holarctic Ecology **7**(4): 345-379.
Skogsstyrelsen (2002). Skogsstatisktisk årsbok 2002 - Statistical Yearbook of Forestry 2002. Jönköping, Sweden, Skogsstyrelsen - National Board of Forestry, Sweden. ISBN 91-88462-52-8
Soppela, P., M. Nieminen*, et al.* (1986). "Thermoregulation in reindeer." Rangifer **Special Issue No. 1**: 273-278.
SOU (1999a) Bilagor till Sammanhållen rovdjurspolitik - slutbetänkande. Rovdjursutredningen, Miljödepartementet. *Statens offentliga utredningar SOU* **1999:146.** Stockholm
SOU (1999b) Sammanhållen rovdjurspolitik - slutbetänkande. Rovdjursutredningen, Miljödepartementet. *Statens offentliga utredningar SOU* **1999:146.** Stockholm
Sporan, N. R., K. Hedegart Flaata*, et al.* (1999). "Wild reindeer and human disturbance - a study of decreasing human disturbance and use of winter pastures." Rangifer **Report No. 4**: 99-100.
Stevenson, S. K. (1990). "Managing second-growth forests as caribou habitat." Rangifer **Special Issue No. 3**: 139-144.

Syroechkovskii, E. E. (1995). Part II: Biology and Ecology of Reindeer. Wild Reindeer. D. R. Klein. Moscow, Science Publishers, Inc.**:** 107-173.

Tappeiner, U., G. Tappeiner*, et al.* (2001). "GIS-based modelling of spatial pattern of snow cover duration in an alpine area." Ecological Modelling **138**(1-3): 265-275.

Tuominen, Y. and T. Jaakkola (1973). Absorption and accumulation of mineral elements and radioactive nuclides. The Lichens. M. E. Hale. New York, London, Academic Press**:** 185-223.

Tyler, N. J. C. (1990). "Short-term behavioural responses of Svalbard reindeer to direct provocation by a snowmobile." Rangifer **Special Issue No. 4**: 18.

Warenberg, K., Ö. Danell*, et al.* (1997). Flora i renbetesland, Nordiskt Organ för Renforskning, A/S Landbruksforlaget. ISBN 82-529-2144-2

Weladji, R. B. (2001). "Use of climatic data to estimate the effect of insect harassment on summer weight gain in reindeer *(Rangifer tarandus)* calves." Rangifer **Report No. 5**: 96.

Weladji, R. B., O. Holand*, et al.* (2003). "Use of climatic data to assess the effect of oestrid harrassment on reindeer (*Rangifer tarandus*) calves autumn weight." in press.

Weladji, R. B., D. R. Klein*, et al.* (2002). "Comparative response of *Rangifer tarandus* and other northern ungulates to climatic variability." Rangifer **22**(1): 33-50.

White, R. G., F. L. Bunnell*, et al.* (1981). Ungulates on arctic ranges. Tundra ecosystems: a comparative analysis. J. J. Moore. **The Int. Bil. Progr. 25:** 397-485.

Vistnes, I. and C. Nellemann (2001). "Avoidance of cabins, roads, and power lines by reindeer during calving." Journal of Wildlife Management **65**(4): 915-925.

Vistnes, I., C. Nellemann*, et al.* (2001). "Wild reindeer: Impacts of progressive infrastructure development on distribution and range use." Polar Biology **24**(7): 531-537.

Vistnes, I., C. Nellemann*, et al.* (2002). "Infrastructure as barriers to wild reindeer migration." Rangifer **Report No. 6**: 109.

Wolfe, S. A., B. Griffith*, et al.* (2000). "Response of reindeer and caribou to human activities." Polar Research **19**(1): 63-73.

Vägverket (2001). Vägverkets Viltskadetabell 1993-2000, Vägverket**:** 2 sid.

Yost, A. C. and R. G. Wright (2001). "Moose, caribou, and grizzly bear distribution in relation to road traffic in Denali National Park, Alaska." Arctic **54**(1): 41-48.

Åhman, B. (2000). Utfodring av renar. Umeå, Sámiid Riikkasearvi/SSR.

Åhman, B. and G. Åhman (1994). "Radiocesium in Swedish reindeer after the Chernobyl fallout: seasonal variations and long-term decline." Health Physics **66**(5): 503-512.

Åhman, G. and B. Åhman (1984). "Skogsgödslingens inverkan på nitrat- och råproteininnehållet i några viktiga renbetesväxter (Effects of forest fertilization on nitrate and crude protein content in some important reindeer forage species)." Rangifer **4**(1): 43-53.

Åhman, G., B. Åhman*, et al.* (1990). "Consequences of the Chernobyl accident for reindeer husbandry in Sweden." Rangifer **Special Issue No. 3**: 83-88.

Åsbakk, K., R. E. Haugerud*, et al.* (2001). "Reindeer warble fly - *Hypoderma tarandi* - histological and immuno-histological properties of the 1st instar larvae." Rangifer **Report No. 5**: 106.