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Developing an ecologically and economically more stable semi-domestic reindeer management - a Finnish point of view

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Abstract: In arctic and sub-arctic regions semi-domestic reindeer management forms an important livelihood which should be able to provide enough income for herders. Reindeer management has natural limits of growth. Consequently it should be managed to optimise both the use of reindeer pastures and herder income. Reindeer pastures should be grazed at the economic carrying capacity level. This gives the maximum sustained harvest from reindeer stock and also the maximum sustained foraging from pastures. How is this to be accomplished? First, reliable knowledge about reindeer pastures in time and place is necessary: to estimate the quantity and quality of specific reindeer pastures within each management district, as well as the productive capacity and the changes in condition and productivity of those pastures. Secondly, data is needed on the accurate productivity of reindeer stock and the production costs for each management district. Thirdly, study the relationships between pasture resources and productivity of reindeer stock together with the effects of long-term reindeer densities on pasture condition and productivity. Finally, knowledge is needed about the effects of herd structure on reindeer stock productivity as well as the factors which restrict the use of reindeer pastures. Models based on adequate data could provide a useful tool for optimising the use of reindeer pastures and herder income. First the economic carrying capacity of reindeer pastures should be studied. Subsequently the economy of reindeer husbandry could be modelled with respect to reindeer stock density. Also the economy of reindeer husbandry based on different levels of feeding, and the effects of this husbandry practice on pastures, should be modelled. Models should be accurate and flexible enough to use when looking for solutions to practical questions and challenges in reindeer management.

Key words: *Rangifer tarandus*, range land management, carrying capacity, animal production, vegetation, stocking rate.

1. Background

An ecologically stable way to utilise natural resources in semi-domestic reindeer (*Rangifer t. tarandus*) management means primarily a stable way to use reindeer pastures. In arctic and sub-arctic regions, semi-domestic reindeer management forms an important livelihood which today must provide increasing incomes for reindeer herders. However, traditional reindeer management has natural limits to growth. Therefore the use of reindeer pastures and the profit of management should optimised at the same time.

Finnish semi-domesticated reindeer management has gone through several changes during the past decades. By introducing supplementary feeding during the 1970's, animal condition was improved. Also expansive treatment against parasites during 1980's can be supposed to have had the same effect (see Heggstad *et al.*, 1986). There followed a reduced mortality rate and an increased reproduction rate in reindeer stocks. Improved reproduction rates also resulted from increased calf slaughtering, which reduced the post-calving reproduction costs of females in winter. However, calf slaughtering increased the stock productivity most by reducing the mortality rate and changing the stock structure (Helle & Kojola, 1993; Kojola & Helle, 1993a; Kumpula *et al.*, 1998a).

As the result of a new management strategy and favourable winters, the stock of Finnish semi-domesticated reindeer made a continuous increase beginning in the 1980's (Fig. 1). Previous to this increase, reindeer numbers oscillated at relatively low levels. It is probable that natural control systems involving population density, known from wild reindeer populations (see Klein, 1968; Reimers, 1983; Skogland, 1983; 1985), also applied earlier to the semi-domesticated reindeer stock in Finland.

In northern Finland, supplementary feeding had been marginal before the 1990's. There followed, however, serious reindeer losses during the 1990's, which caused increased reindeer feeding also in this area. Pasture inventories indicated that the condition of winter pastures had deteriorated markedly from the early 1980's to the beginning of the 1990's (Mattila, 1996). Further, that the condition of winter pastures in the mid 1990's was poor or only satisfactory in most of the northern management area (Kumpula *et al.*, 1997).

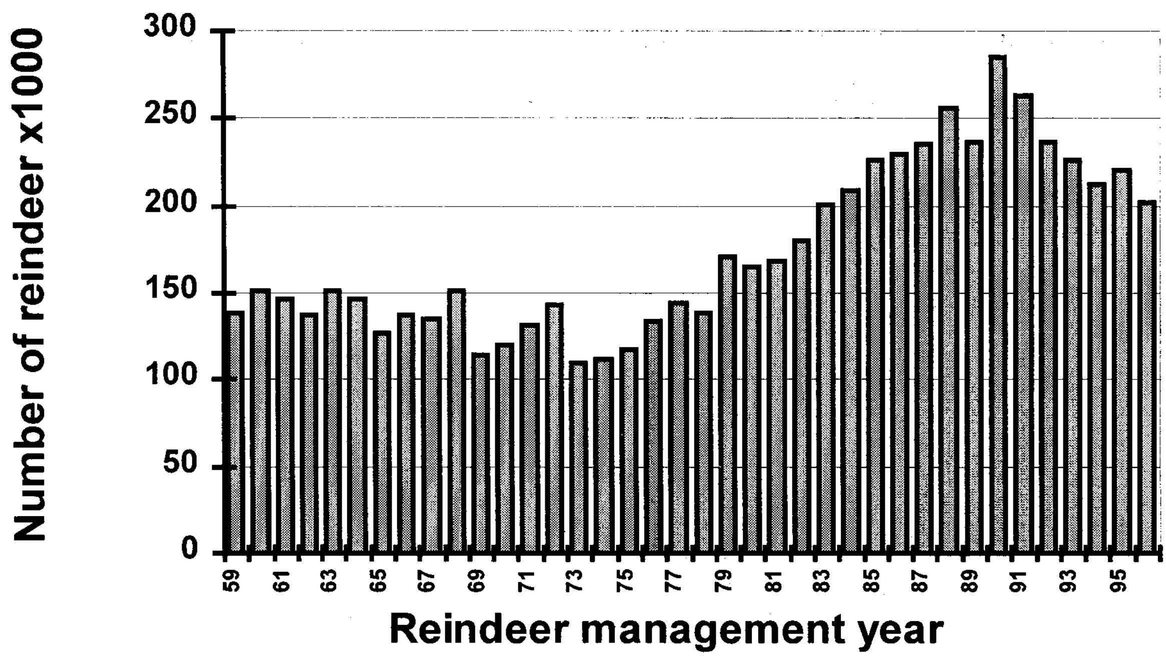

Fig. 1. Numbers of Finnish semi-domestic reindeer (age > one year) between 1959-96.

Supplementary feeding may be unavoidable in order to keep the present reindeer stock level and productivity in the northern area. The use of supplementary feeding as the only solution will make management increasingly dependent on it, since pastures lack sufficient time and opportunity to recover as earlier (Fig. 2). Increased feeding raises production costs for the herder, and consequently may decrease the net incomes even while increasing stock productivity.

Supplementary feeding at reindeer densities above the carrying capacities of the range may also cause more complex problems. The origin of these problems can be found when we compare the needs of today's reindeer management to expand, to the limited natural resources within which that expansion is meant to take place (Fig. 3). The conflict between these two aspects and the problems, which come into existence from it, will probably increase the need for economic support in reindeer husbandry. The status and image of reindeer husbandry will also be modified in this process. The overall result likely will be a strengthened controlling system imposed on reindeer management.

2. Carrying capacity concept

Developing sustainable pasture use is a basic tenant of the traditional management of free living semi-domesticated reindeer. Theoretically, to manage livestock range in an optimal manner, the animal number should be kept at a level resulting in the highest sustained yield in meat production. This level is called the economic carrying capacity of the range (Caughley, 1976; 1979; 1981). In wildlife management, the concept of the ecological carrying capacity of the range is probably more commonly used (see Caughley, 1976; Macnab, 1985; Messier *et al.*, 1988; Crete, 1989). It is understood as a certain balance between a herbivore population and its forage resources.

Caughley (1976; 1979; 1981) proposed a model depicting the relationship between large herbivores and their forage resources. When the population of herbivores grows, the forage biomass diminishes with increasing grazing, and its composition changes with time. Along the zero-isocline between the standing crop of herbivore and the standing crop of vegetation for a given system there are several vegetation-herbivore equilibria and more than one sustained animal yield. On the economic carrying capacity equilibrium, the standing crop of animals gives the maximum sustained annually harvested yield and sustains the standing crop of vegetation at a certain level.

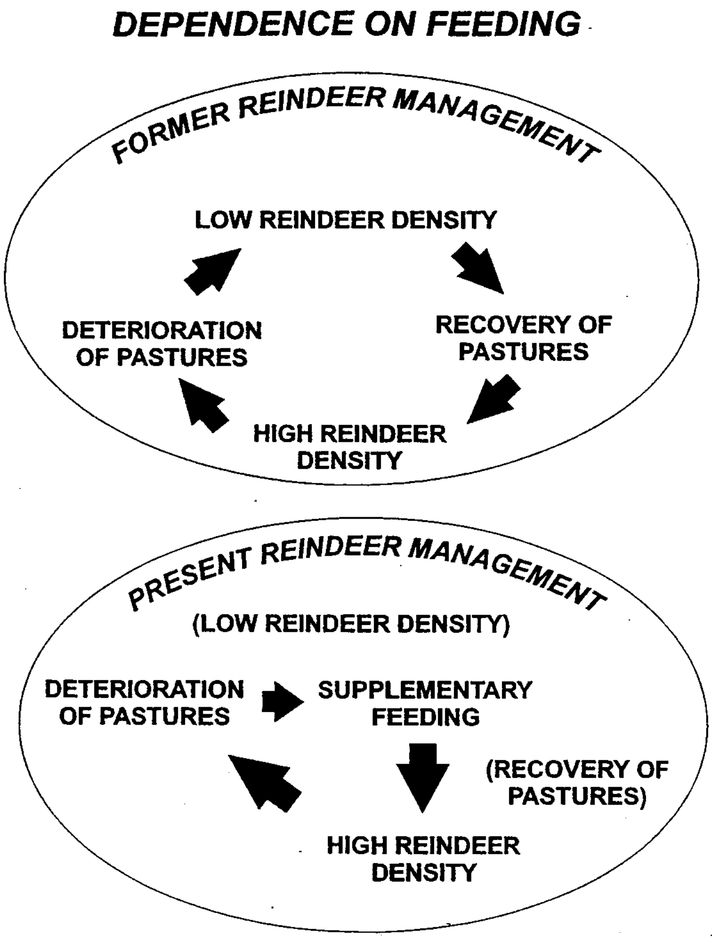

Fig. 2. Effect of supplemental feeding on the management of semi-domestic reindeer range.

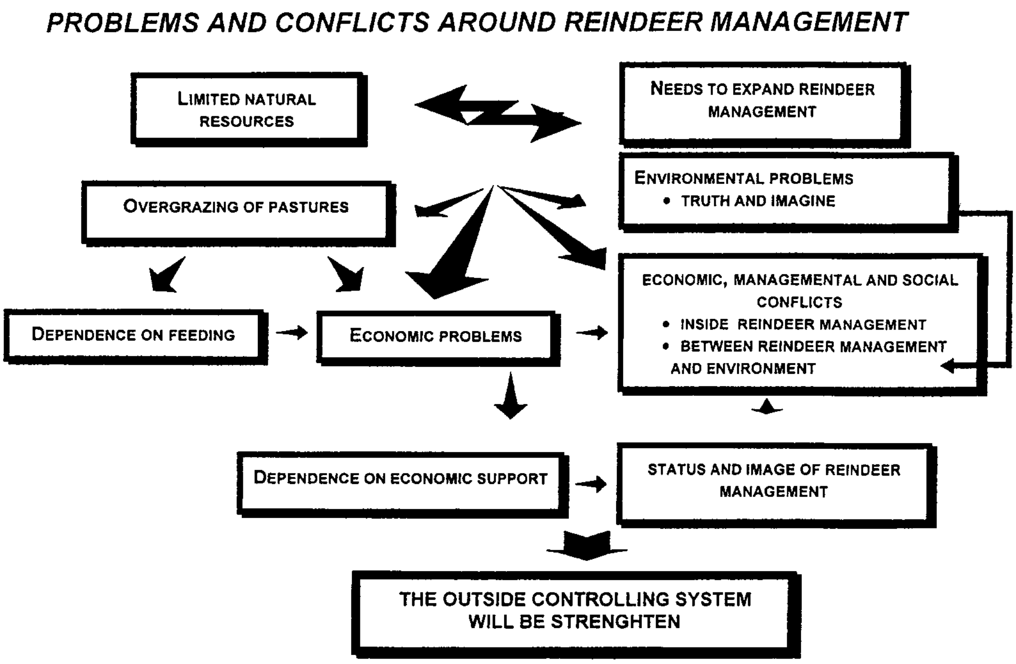

Fig. 3. Problems and conflicts in semi-domestic reindeer management today.

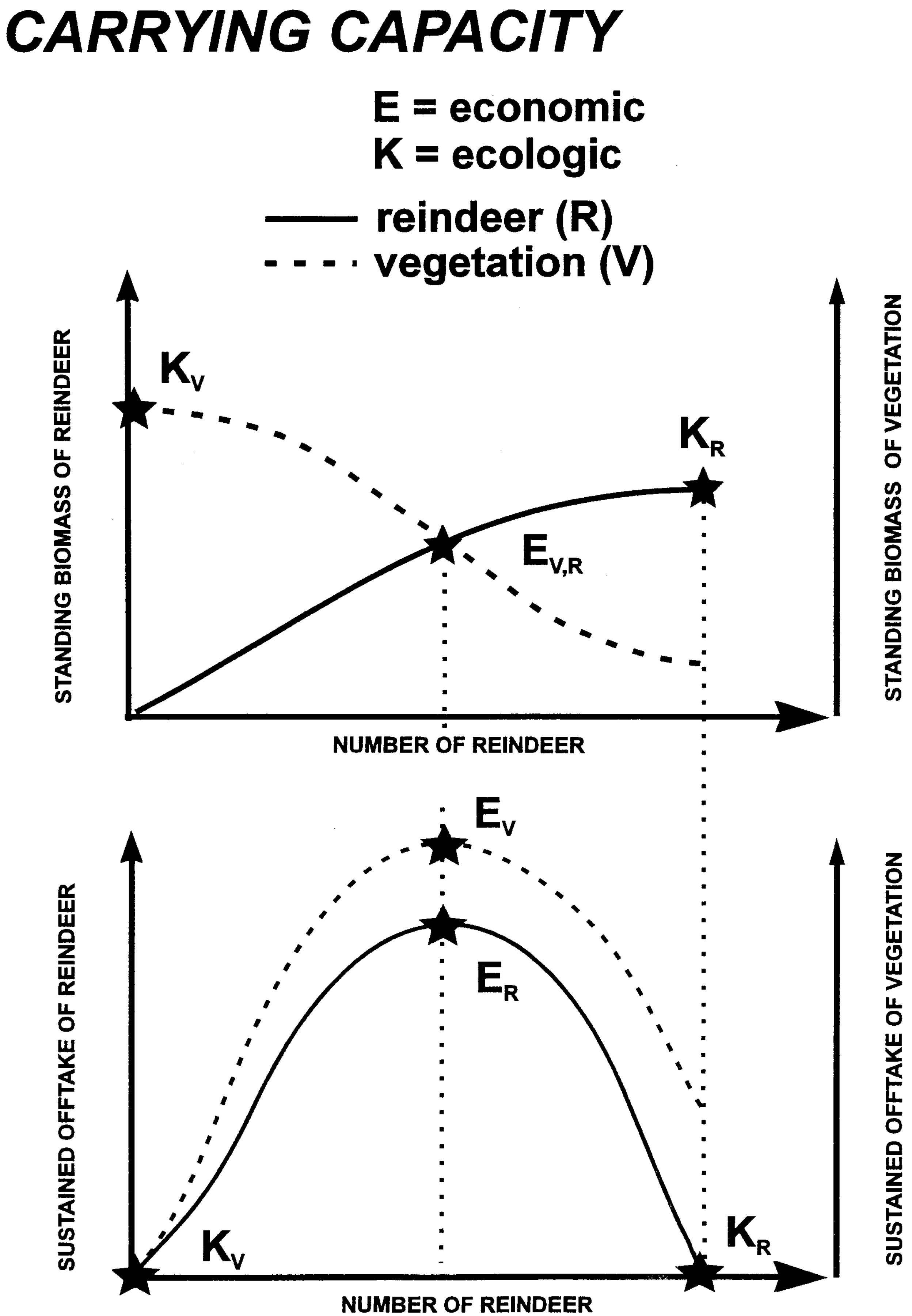

Fig. 4. The carrying capacity concept as a four dimensional measure of reindeer range.

There is a greater standing crop of herbivores and less standing crop of vegetation on the ecological carrying capacity equilibrium than on the economic equilibrium (Caughley, 1976; 1979; 1981). At the ecological equilibrium, the sustained animal population is adjusted at a certain maximum level only by the reproduction rate and natural mortality. Both of the latter are regulated by the shortage of food. In theory, it's not possible at this point to harvest from the population without decreasing the standing crop of animals. However, the theory also includes the fact that a standing crop of animals will tend to oscillate on both sides of the ecological carrying capacity equilibrium.

Carrying capacity of range is often viewed using only two fixed components, the first one being the biological needs of the animal and the second one the food availability and productivity of the range (Hobbs *et al.*, 1982; Potvin & Huot, 1983; McCall *et al.*, 1997). From this perspective, the nutritional needs of the animals are usually first determined carefully, followed by observations as to how well these needs are satisfied by the food availability/productivity of a certain range. Finally an evaluation is made of the maximum number of animals this range can support, without first considering how the number of animals in stock before the study affected the food availability/productivity of this range.

Caughley's model has been widely applied and used both in range land and wildlife management studies. Although Caughley views carrying capacity as a two dimensional measure, one for herbivore and the other for vegetation, the sustained productivity of vegetation in relation to long-term grazing is obscure or hidden in his model. This may explain why the sustained productivity of forage plants in a region is so often understood as fixed, being only dependent on vegetation types, temperature, humidity, topography and soil nutrients. Sustained heavy grazing, however, not only reduces the standing crop of forage plants, but also affects the sustained yield of new forage produced per year in a region (see Hobbs *et al.*, 1982; Potvin & Huot, 1983; Macnab, 1985; Crete, 1989; Hobbs & Hanley, 1990).

Although there are some studies in which the productivity of plants has been evaluated with respect to long-term grazing (Hoefs, 1984; Ouellet *et al.*, 1994) the carrying capacity of a range has rarely been viewed on the basis of the productivity of the vegetation. There are some recent works in which this aspect of carrying capacity is handled (McLeod, 1997). Therefore I present a draft of the carrying capacity concept which connects both the standing biomass and productivity of reindeer as herbivore and the standing biomass and productivity of plants as forage (Fig. 4). The ecological carrying capacity equilibrium of vegetation is the climax stage of vegetation without any grazing. On the economic carrying capacity equilibrium both the sustained productivity of vegetation and reindeer are at a maximum. This means an equilibrium reindeer biomass kept stable by harvesting or predation, to obtain the maximum sustained harvest of reindeer and the maximum harvest of vegetation as forage. The sustained animal production will only be at a maximum if the sustained forage plant production also is at a maximum. This is simply for the reason that it is impossible to form anything from nothing.

At the ecological carrying capacity equilibrium for reindeer there is no surplus production because of equal rates of reproduction and mortality. Theoretically, at the ecological carrying capacity equilibrium for a herbivore, there is less vegetation than at the economic carrying capacity equilibrium. The productivity of forage plants in the former state only supports the standing population of herbivores without giving any yield or harvest from the population. If a reindeer population is harvested or predated at this point, the plant and herbivore equilibrium will shift to the left.

The productivity of vegetation on reindeer range has to be assessed from the available «key» forage plants for reindeer on the most important pastures of each region. Among the «key» reindeer forage plants there are those, which compensate and supplement one another. At economic carrying capacity equilibrium, the quantity and quality of forage produced by these plants should be sustainable at a maximum. Reindeer lichens (*Cladina* spp.) are essential as reindeer winter food, but are not the only important food plants. Therefore, the economic carrying capacity of reindeer ranges should not aim solely at maximising the sustained productivity of reindeer lichens. Rather it is essential to keep lichen pastures productive »enough» and in good »enough» condition, while at the same time, hold the productivity of other forage plants permanently at a maximum. This »stage» of the lichens and other forage plants on reindeer pastures is probably dependent on the vegetation and forage plant communities on the total range. It is also affected strongly by weather, snow conditions and topography within this range.

3. Developmental work

3.1 Basic knowledge and data

Developing reindeer husbandry is a long-term process dependent on political, economical and biological goals and on co-operation between management, research and husbandry. This will be an ongoing process but certain basic elements must be faced if semi-domestic reindeer management is to become ecologically and economically stable.

The first basic element is knowledge and data about reindeer pastures for each management district. The quantity, quality, location and condition of main pasture types should be known. Also the use and composition as well as the productive capacity of pastures in relation to long-term grazing have to be evaluated. This knowledge will provide the basis for planning optimal grazing on those pastures.

What are needed, are repeated reindeer pasture inventories as well as more detailed studies on the productivity and use of the most important forage plants. Pasture inventory based on fieldwork and remote sensing (see Colpaert *et al.*, 1995) have been carried out in Finland since 1995. Similarly winter pastures have been monitored (Kumpula *et al.*, 1997), and the summer pastures will be monitored. The growth of some food plants in relation to long-term grazing is also being studied (Kumpula *et al.*, 1998b).

The second basic element is knowledge and data about reindeer management and husbandry at the district level. The annual statistics collected, primarily by reindeer husbandry, make it possible to view and infer many trends and exceptions. The more accurate the statistics are, the more valuable and useful these are for reindeer management and husbandry.

The annual statistics should include the exact number and category (sex, age) of reindeer slaughtered and left alive in winter stock in each district. Reliable figures allow calculation of the annual calf percent and mortality rate in the reindeer stock. Also the mean annual body and slaughter weight of the different categories of animals tells much about the circumstances of the previous season and long-term development of pasturage conditions. The data also allows reliable calculation of the annual meat production per management district.

The statistics should also include valuable information about the quantity of supplementary feeding and the management work performed in each district. A sufficient overview of the incomes and production costs of reindeer management, will make it possible to study the economics of reindeer management and husbandry. Since 1959, statistics on Finnish reindeer numbers have been collected by the Association of Finnish Reindeer Herding Co-operatives. Still, lot of developmental work is needed in order to obtain more detailed data, specifically in the area of economics. To date, Finnish reindeer management statistics have been used in several studies regarding the demography and productivity of reindeer in Finland (e.g. Helle *et al.*, 1990; Kumpula & Nieminen, 1992; Helle & Kojola, 1993; Kojola & Helle, 1993a; b; Kumpula *et al.*, 1998a).

3.2 Interactions to study

Many kinds of interactions between pasture resources and reindeer stock can be inferred from the statistics. Of primary interest is the effect of long-term reindeer densities on the condition and productive capacity of reindeer pastures in various vegetation zones and districts. Conversely, how the pasture quantity, condition and productivity effect the reproduction and productivity of reindeer. The present need to feed reindeer should also be better documented given present pasture quantity, quality and condition. It would also be useful to focus on what effect supplemental feeding has on reindeer productivity and pastures. The impact of herd structure on reindeer stock productivity is another obvious area for study. It is also important to be aware of possible additional factors involved in restricting and controlling the use of pastures on the level of vegetation zone and management district.

There exist several studies on wild and semi-domesticated reindeer populations where many of these interactions have been examined (Klein, 1968; Alendal & Byrkjedal, 1974; Gossow, 1974; Reimers, 1977; 1983; Skogland, 1983; 1985; 1986; Helle *et al.*, 1990; Kumpula & Nieminen, 1992; Cameron & Smith, 1993; Helle & Kojola, 1993; 1994; Kojola & Helle, 1993a; b; Kojola *et al.*, 1995). However, adopting these relationships directly in another area is not necessarily valid because of differences from one area to another in vegetation, pasture types, topography, weather and snow conditions. The differences in wild and semi-domestic reindeer management are too evident for applying the results of the one to the other.

Accurate data from the many aspects of reindeer husbandry is prerequisite to founding reliable relationships and predictions about pasture and stock in each reindeer district. This fact should not be forgotten when planning a follow-up strategy for pastures and management. However, to get absolute data specifically from reindeer pastures will never be possible. Therefore, using the best professional opinion, it has to be decided which methods can give the widest, the most accurate and the most useful data.

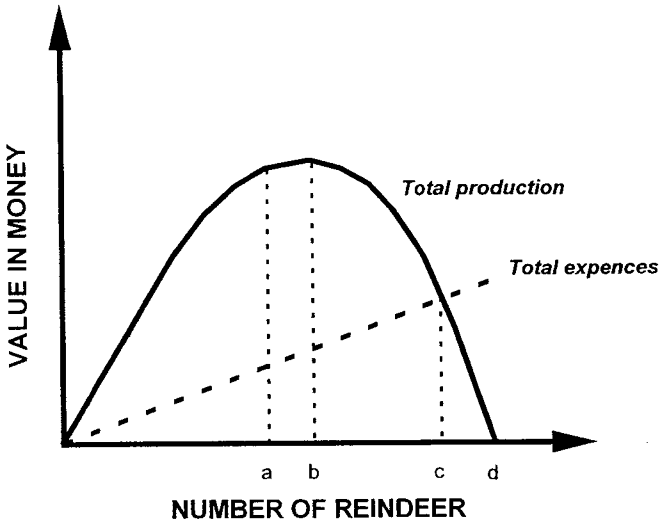

Fig. 5. A simplified diagram showing the economics of natural reindeer management given a limited range. The sustained maximal net incomes from reindeer meat are achieved at ***a*** and the maximal sustained gross incomes at ***b***. There are no net incomes at ***c***. At ***d*** there are no gross incomes, and a lot of expenses.

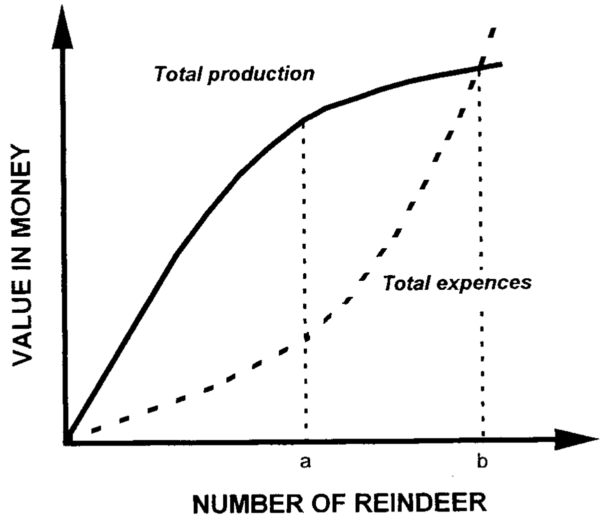

Fig. 6. A simplified diagram showing the economics of reindeer management given a limited range when based on feeding. The sustained maximal net incomes from reindeer meat are achieved at ***a***. There are no net incomes at ***b***. Keeping reindeer over this number makes reindeer management increasingly unprofitable.

3.3 Making and using models

Optimising the use of reindeer pastures is necessary in developing reindeer husbandry. Models, which evaluate the economic carrying capacity of specific reindeer management districts, would give valuable advice for planning the long-term optimal stocking of reindeer ranges. The dependencies and interactions in these models should be carefully built and studied. The models, however, should be flexible enough to admit local data.

The next step would be to form a sub-model to study the economics of reindeer husbandry with respect to reindeer density. This would enable the combination of incomes and management costs for various reindeer densities, investigating how to maximise the sustained net incomes (fig 5). Forming this sub-model would require exact studies of the economics of the present management.

Supplementary feeding of reindeer is the permanent management practise in Finland. A certain readiness to implement supplementary feeding in reindeer management is necessary to prevent starvation and animal losses during the occasional bad winter. There are also many Finnish management districts with very scanty winter pastures, but plenty of summer pastures. Sub-models taking this difference into consideration should be constructed to study the economics of a reindeer husbandry based on different levels of feeding (fig 6). This model should also incorporate a study of the long-term effects of feeding on reindeer pastures.

3.4 Testing and using the models in practice

Model predictions should first be tested and compared with reality by using a documented time series. If the developed models can supply accurate enough predictions, they should be included to those tools being used in the planning and development of semi-domestic reindeer management and husbandry at the district level.

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