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Managing moose, *Alces alces*, population in Finland: hunting virtual animals

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The moose population has been intensively managed in Finland since the beginning of 1970s. However, recent decline in population sizes observed in many parts of the country was unexpected. In this study, the development of the Finnish moose population in 1974–1994 was analysed with a simulation model where the crucial factor was the annual hunting. The simulation model was also used to generate predictions of the future population size. The simulations for three game management districts (Varsinais Suomi, Etelä Häme and Pohjois Savo) followed well the actual population data. In forecasts, the population size predictions began to become increasingly unreliable when the forecast horizon was extended to two or more years. The analysis revealed that a successful management strategy calls for information on spatial migration of the moose and more accurate population estimates.

1. Introduction

Moose (*Alces alces*) population sizes have been monitored in Finland since 1930. During the past 60 years, the population experienced drastic changes. In the 1950s, it increased steadily, but in the 1960s it began to decline, probably due to intense hunting, which was aimed at its productive part (Nygrén & Nygrén 1976, Nygrén 1987). Following the rapid decline of the population, the moose was totally protected in 1969–1971 in large parts of Finland. After these years the moose population has been managed carefully by selective harvesting, in order to regulate the size and structure of the population (Nygrén & Nygrén 1976, Nygrén 1984, Nygrén & Pesonen 1993). An exponential growth in the total population size was observed between 1970 and 1980, as documented both in the winter population size, and in the numbers of animals harvested (Fig. 1).

During the peak years in the late 70s the moose population grown up to more than 70 animals per 100 km^2 in western Finland (Nygrén & Nygrén 1977, Nygrén 1984). The damage to forests and crops increased rapidly (Nygrén & Pesonen 1993), and accordingly, new density grades were defined in 1980 as 40 animals per 100 km^2 (Nygrén & Pesonen 1993). The goal for the population management was to restrict the size of the winter population to minimise both moose-caused damages to forest stands, and traffic accidents, and to maximise calf production; and, thus, to gain the highest harvest potential (Nygrén & Pesonen 1993).

Hunting pressure and other limiting factors

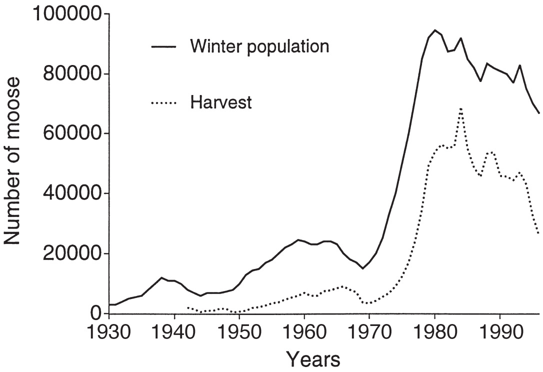

Fig. 1. The moose winter herd size and annual harvest in Finland in 1930–1995.

such as predation (e.g., Gasaway *et al.* 1983, Ballard *et al.* 1991) keeps the moose population size under the ecological carrying capacity (but *see* Boutin 1992). If these mortality factors are removed, the population starts to grow, and density dependent resource competition begins to regulate the population size (e.g., Van Ballenberghe & Ballard 1994). In Finland, the only significant regulator of the moose population size is hunting. Thus, the local moose populations should be able to be managed by changing hunting strategies. However, in the last few years the Finnish moose population has begun to decline against all presumptions. In spring 1995, the winter herd size was at its lowest in a period of 20 years (Nygrén 1996). This caused problems for the moose managers. Instead of decreasing population sizes, it would be necessary to get the population to increase again, or to maintain its size at a management-controlled level that would sustain uninterrupted hunting and also keep future annual harvest on high levels.

In this study, I developed a simulation model for the development of the Finnish moose population in the years 1974–1994. My aim was to develop understanding of what has happened to moose populations in different parts of Finland under the realised harvesting policies. In doing so, I made use of a structured model of a moose population subject to harvesting. The performance of the model was compared with extant data on the moose winter population size and annual harvest numbers.

2. Material and methods

The data are records of Finnish moose population numbers based on annual moose observations made by local hunters during the hunting season. Hunters also do snow-track censuses, which are modifications of Nordic census standard BIN D 1111 (Anon. 1979). These censuses and observations are organised by the Game Division of the Finnish Game and Fisheries Research Institute, FGFRI. The data, reported at the game management district level (altogether 15 in Finland; Fig. 2), are estimates of moose numbers per 100 km^2. They include records on the winter herd size, the number of calves per cow, sex ratio and the percentage of twin calves per female. The other sources of the data were Nygrén (1983) and Nygrén and Pesonen (1989), and hunting statistics from 1974 to 1994. The annual hunting quotas, harvest recommendations for the hunters, are calculated by the FGFRI by using the estimates of winter herd sizes and calf productions (Nygrén & Pesonen 1993).

For my current purposes the dynamics of the moose winter herd size (W) with harvesting is given as

$$W_{t+1} = W_t + C_t(F_t) - H_t(C_t, F_t, M_t),$$

where t is time in years, C_t is the annual number of calves born into the population, and H_t is the number of moose hunted annually. Both the winter herd and the annual harvest comprise calves, cows (F) and bulls (M). The calves mature in a year. The harvest is composed of the calves, cows and bulls killed by hunters. I assumed no other sources of mortality except hunting, because the number of moose killed by predators, diseases, traffic accidents (or by poachers) is considered very small compared to the number of animals in the harvest (Nygrén & Pesonen 1993). Even the calf mortality in winter is low since about 25%–40% of calves are hunted during their first autumn. I assumed that equal number of female and male calves are born. In reality this ratio is slightly biased towards males in Scandinavia, but it varies annually and locally. In Finland and Sweden, the percentage of male calves in calf harvest is 50%–55% (Hirvonen *et al.* 1994). In essence, the model is an econometric regression model for which the time series parameters are found by a first-order process (e.g., Maddala 1986, Pindyck & Rubinfeld 1991). Thus, when the 1974–1994 data are used in the simulation, I am dealing with a statistical regression model fitting. However, when using the model in predicting the future levels of the moose population I am using the autoregressive components in the assumed population dynamics (e.g., Chatfield 1984, Royama 1992).

The model was parameterised using 1974–1994 data on moose populations in three game management districts: Varsinais Suomi, Etelä Häme and Pohjois Savo (Fig. 2). These areas represent different parts of south and middle Finland where moose population is highest. The winter population size, calf production and harvesting data from these three districts were compared with forecasts of the simulation model. In the forecasting runs one or more of the last years were deleted from the parameterisation runs (i.e., simulations best fitted in real population size) and their population sizes were then predicted.

3. Results

In the game management district Varsinais Suomi the moose population size was highest (about 7 500 individuals) in 1978–1979 (Fig. 3A). After that, population size was purposefully reduced by hunting. Since 1983, the winter herd size has been about 4 000 individuals. The moose population in Etelä Häme declined as clearly as in Varsinais Suomi (Fig. 3D). In Pohjois Savo the peak of the population size was in 1979–1981. At that time, the winter herd size was about 7 500, but in the last few years it has been under 5 000 individuals (Fig. 3G). In all three game management districts there was approximately an equal number of cows and calves, whereas the number of bulls was about half of that of the cows and calves, except in 1974–1976, when the sex ratio was more equal. (Fig. 3B, E and H).

3.1. Simulations

In the simulation, the population size in Varsinais Suomi roughly matched the real situation. The population size continued to increase in the 1990s, when it actually declined. It means that emigration, overestimations of the ambient population size, or increased mortality (i.e., juvenile mortality) occurred in early 1990s. However, calf mortality should have been almost 80% during the last few years to match the reported population level with the data. However, such high mortality is impossible as compared with calf mortality in the whole country. Thus, overestimations of population size or emigration are more reasonable explanations for the mismatch between the data and the model. When a very small percentage of the winter herd (0.02% of cows) was allowed to emigrate annually, the simulation follows quite well the reported dynamics. This level of emigration was used with the fitted data (Fig. 3C). However, the winter herd sizes of cows, bulls and calves are smaller in the simulated data than in reported data (Fig. 3A, B and C).

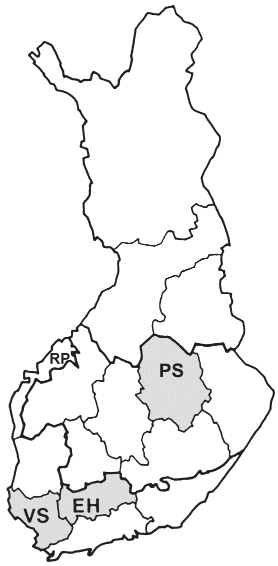

Fig. 2. The Game management districts in Finland. VS = Varsinais Suomi; EH = Etelä Häme; PS = Pohjois Savo; RP = Ruotsinkielinen Pohjanmaa.

In Etelä Häme, the simulated population began to decline after five years and went rapidly extinct. Because this was not observed in the data, the migration in the area must have been positive or the annual population size or calf production were underestimated. If some amount of annual immigration is added (under 1% of cows' and 3% of bulls' winter herd size; Fig. 3F), the simulation will, to some extent, follow the reported numbers (Fig. 3D, E and F).

The population size increased in the Pohjois Savo simulation more than in the data, similarly as in Varsinais Suomi. Here the increase did not coincide only with the last few years, but instead the size of the simulated population continued to grow as compared with the size of the reported one. To explain this phenomenon there must be an emigration or considerable population size overestimation in the actual data (3% of cows and bulls; Fig. 3I) or, alternatively, annual calf mortality must have been about 6%. The simulation with fitted data did not match the reported population size of the peak years (Fig. 3G, H and I). Also the decline in population size is not deep enough and the simulation overestimate winter herd sizes of the 1990s. Altogether the simulation of Pohjois Savo was not as accurate as in the other two districts.

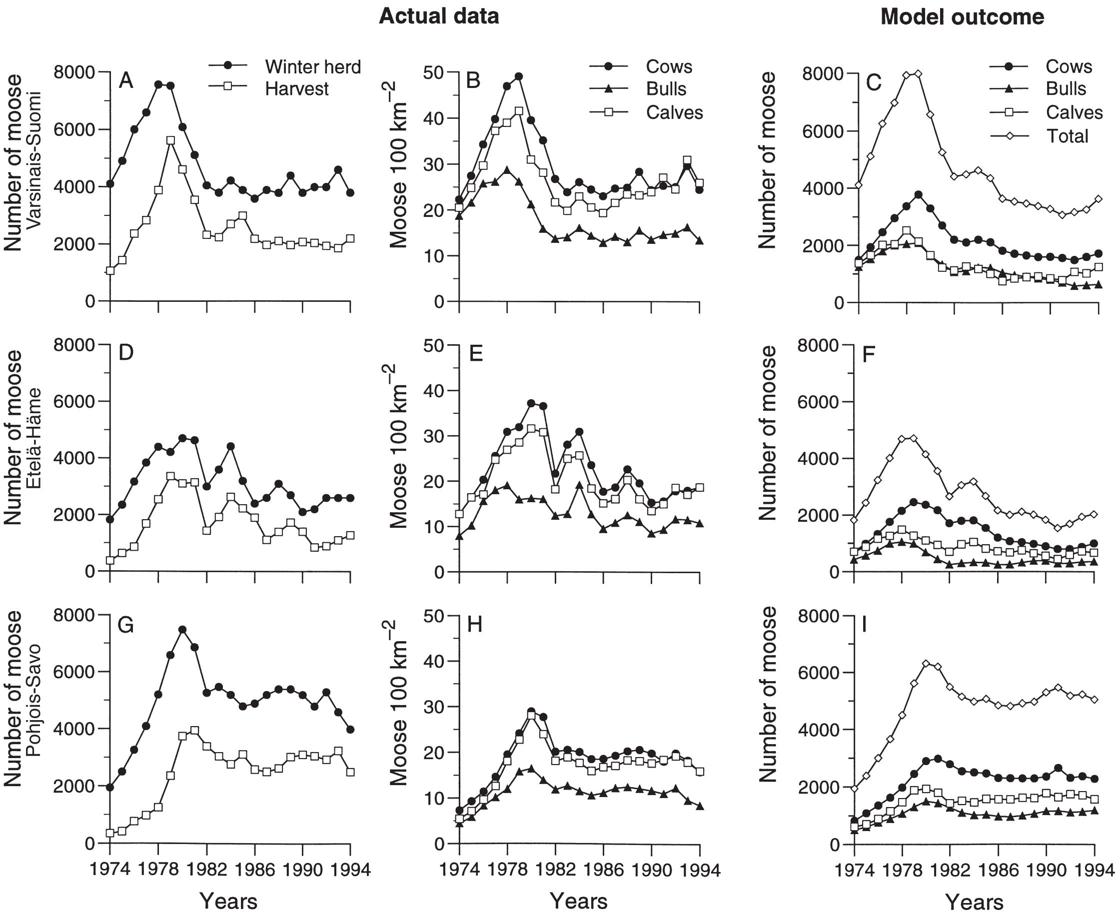

Fig. 3. The moose population of game management districts Varsinais Suomi, Etelä Häme and Pohjois Savo. The left-hand panels (A, D and G) give the annual winter population size and the number of harvested animals. The central panels (B, E and H) display population structure (the number of calves, cows, and bulls) in autumn before hunting season. The right-most panels (C, F and I) give the model fit.

3.2. Forecasting

The population size of the next year was forecasted by excluding the final year from the simulation best fitted in real population sizes. This gave a slight overestimation of the population size of Varsinais Suomi (Table 1). A forecast for two years fit better, and forecasts for three and four years were also close enough. If continued, forecasts for longer periods impaired accuracy.

In Etelä-Häme, a forecast for two years was precise, but also forecasts for one and three years were quite close to the real situation.

In Pohjois Savo the forecasts up to four years are overestimations (20%–30% more than reported population size). Continuing one more year would give a moose population size over ten thousand. Thus, the forecast will give a totally biased estimate.

4. Discussion

When only winter herd size, and birth and death rates as factors are considered, it is difficult to estimate the extant population sizes accurately. Problems arising in the population estimations are likely to be caused by moose migrations and dispersal over the borders of game management districts. Migrations between summer and winter areas are common (Pulliainen 1974, Cederlund *et al.* 1987, Sweanor & Sandegren 1989), although there can be both migratory and non-migratory moose in a population (Andersen 1991, Sweanor & Sandegren 1998). Movements of moose between different game management districts are not included in this analysis because there was not enough information available about the directions and expanse of movements in the Finnish moose population. For example, in Canada, Labonté *et al.* (1998) found out that yearling moose dispersed from less than 1 up to 100 km from their mother, but in Sweden dispersal distances were less than 4 km (Cederlund & Sand 1992).

Because hunting is regulated within a game management district, animals might migrate to regions where local population size has declined due to intensive hunting. In the 20 years studied here, the hunting pressure was very high in all the districts. The average annual harvest was up to 70% of winter population, and close to 45% of the estimated autumn population. In almost all the districts, the moose populations were hunted equally in relation to their winter population sizes. Only in Ruotsinkielinen Pohjanmaa (*see* Fig. 2) was harvesting more intense. There the number of harvested animals sometimes exceeded the winter herd size. However, population size in that district has not declined and the area might be one of those receiving relatively many immigrants. Nygrén and Pesonen (1993) suggested that moose annually migrate before the hunting season from central Finland to the coastal areas. The game management district of Ruotsinkielinen Pohjanmaa is on the west coast of Finland, and therefore, it is impossible for the moose to cross the other side of the district. Of the three districts used in the simulations Varsinais Suomi and Pohjois Savo were emigration areas, and Etelä Häme was the immigration area. Another plausible explanation might be local over- and underestimations of the population sizes.

The simulation model provided a relatively good fit to the moose population data of Varsinais Suomi game management district except for a growth rate during the last five years in the simulated data that was much larger than the reported data. One explanation might be the reduction in hunting pressure starting in the mid 1980s, although the calf production was still increasing. Thus, population size would have continued to grow. The moose population of Varsinais Suomi is considered to be quite stable, although local differences within the district are rather large (Nygrén 1996). The accurate forecasts for two years in this game management district support the idea of more or less stable population.

According to the simulation, Etelä Häme differs from the two other game management districts due to a high level of presumed immigration. Nygrén (1996) considers the population of Etelä Häme very mobile, thus, the net rate between immigration and emigration may change annually. More information about migration, particularly for Etelä Häme, is needed. Considering the present simulation, possible changes in migration rates and directions are problematic and the results of the simulation may vary greatly depending on the annual level of individuals in the population.

If the population size of Pohjois Savo was overestimated or emigration neglected, this could explain the rapid population increase observed in the simulation. This is because the calf production in this area has been high. According to Nygrén (1996), there has been slightly more immigration than emigration in Pohjois Savo but the changes of

Table 1. Result of predicting the future state of the moose population using the model. The tabulation is for the 1994 reported figures, for fitted parametres from the period 1974–1993 (= Forecast 1 year) and 1974–1992 (= forecast 2 year). The three game management districts Varsinais Suomi, Etelä Häme and Pohjois Savo are treated separately.

		Forecast		
	1994	1 year	2 years	3–4 years
Varsinais Suomi				
Calves	1 300	1 520	1 450	1 167
Cows	1 850	1 950	1 900	1 671
Bulls	640	770	710	439
Total	3 790	4 240	4 060	3 277
Etelä Häme				
Calves	850	760	920	1 061
Cows	1 200	1 090	1 190	1 229
Bulls	550	350	570	740
Total	2 600	2 200	2 680	3 030
Pohjois Savo				
Calves	1 310	1 430	1 840	1 659
Cows	1 940	2 130	2 450	2 274
Bulls	750	1 170	1 220	1 037
Total	4 000	4 730	5 510	4 970

migration rate are unknown. The population sizes in the fitted model of Pohjois Savo did not reach the levels of the actual population size.

Sylvén *et al.* (1987) made simulations of the moose population using population data of central Sweden. The hunting strategies had a major effect on the results of their simulation: considering the meat harvest, the maximal sustainable harvest is not possible, unless the population is highly productive. Also the initial population structure and state — increasing, stable, or decreasing — have a considerable effect on the population size (Sylvén *et al.* 1987).

Forecasting population sizes up to several years ahead is difficult. When the time span of the forecast increases, the results become increasingly unreliable (e.g., Lindström & Kokko 1996). Here the results began to deviate already after two years forecast window. Overestimation of the population size might potentially lead to drastic changes in moose numbers, if harvest quotas are calculated by using the inaccurate results. For sustainable management it would be very important to have a secure way to estimate expected population size for next few years ahead. This practise requires data accurate enough about the present population size and calls also for data to assess the significance of large-scale moose movements.

When deciding annual hunting quota, it is necessary to estimate correctly the number of available animals. If these estimates deviate from the actual population sizes, hunting may have a damaging effect on the moose population in the nearby future. In winter 1992–1993, the population size was overestimated (Nygrén & Pesonen 1994, 1995), and thus, the populations might have decreased due to overharvesting in 1994. This type of management error could, to some extent, explain differences between the simulated and the observed population sizes in Pohjois Savo and Varsinais Suomi management districts. The overestimated winter population size with effective calf production will give too high population estimation for the next year. Thus the estimations of the following years will also distort, if the real population size is not found out.

The moose population in Finland is expected to be managed to maintain its stability and productivity. In the present situation, even a small overharvesting might lead to difficulties and thus to total protection, or closed seasons, in some regions. Thus, reliable estimates of winter herd size and possible regional migrations of moose are important for developing reasonable long-term managing strategy. In all management districts except the intensively harvested Ruotsinkielinen Pohjanmaa, harvest rates were roughly similar as compared to winter herd sizes of the areas. However, these harvest rates might be too high to maintain stable populations. It would be of vital importance for viable management to find out, within reasonable error margins, the extant state and structure of moose populations in each game management district. One more source of uncertainty is the currently increasing number of bears and wolves in eastern Finland. It is currently difficult to predict, how strong an effect such predators will have on moose populations. To conclude, based on my analyses the Finnish moose population, as well as factors affecting its changes, the development of the population must be observed with special care in the near future.

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