

WINTER BROWSING ON PINE AND BIRCH IN RELATION TO MOOSE POPULATION DENSITY

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ABSTRACT: During a 10-year period we have studied the relationships between an enclosed moose (*Alces alces*) population of a known density (range 1.3-5.7 moose per km²) and browsing on Scots pine (*Pinus sylvestris*) and birch (*Betula* spp.). In this paper we focus on three aspects: 1) the percentage of pine stems browsed, 2) browsing induced mortality of pine and 3) stem-breakage of pine and birch (*Betula pendula*) by moose. These aspects were studied on permanently marked plots and stems in two different stand types (8-15 years and 16-40 years old respectively). There was a significant correlation between moose density and the number of browsed pines in the youngest stand type but not in the older stand type. Stem-breakage of the two tree species showed similar patterns over the years, although the frequency of breakage was considerably higher on birch than on pine. A sharp decline in stem-breakage of birch appeared some years before the moose density was decreased. Mortality of pine in the youngest stand type reached about two percent of the total number of stems. The highest accumulated mortality ($\approx 8\%$) over the ten year period was recorded on subdominant pines in the oldest stand type.

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Moose in Sweden have strong local influences on the vegetation (Bergström and Hjeljord 1987). High densities, mainly in winter concentration areas, but also elsewhere, are causing substantial problems for forest production (Lavsund 1987). The damage to young Scots pine stems, caused by moose browsing, often sets the practical limits for the moose density in areas with intensive forestry. In Sunnäs moose pen, with a known moose population size, various aspects of moose - vegetation relationships have been studied for a number of years. Dynamic aspects related to moose feeding patterns, forage production and utilization, forest damage and vegetation composition and structure have been dealt with (e.g. Bergström 1981, 1987, Danell *et al.* 1985, Danell and Bergström 1989, Vikberg and Bergström 1992). In this paper we highlight some of the aspects influencing the dynamic relationship of moose with forest trees.

Scots pine is a common winter food plant for moose, while the birch species (*Betula pendula* and *B. pubescens*) are used throughout the year (Cederlund *et al.* 1980, Bergström and

Hjeljord 1987). *Betula pendula* is the more preferred of the two birch species during winter (Danell *et al.* 1985).

PURPOSE

The study's purpose was to gain a better understanding of the relationships between moose density and a) browsing and browsing induced mortality, on young pine stems and b) stem-breakage through browsing on young pine and birch (*Betula pendula*).

METHODS

The study was carried out in the Sunnäs moose pen (61°06'N; 17°05'E). This enclosed area is 6.1 km² and situated within the southernmost part of the boreal forest. In the pen, Scots pine and Norway spruce (*Picea abies*) dominate the tree-layer while the two birch species are common mainly in the shrub-layer. The forest within the pen has been managed according to normal Swedish forestry practices including clear-cutting, planting and cleaning (the removal of surplus stems when trees are 1-2 m high). About 30 % of the pen area was young pine forest with a

stand age between 8 and 15 years in 1980 (below called ST1). Another 30 % consisted of stands, 16-40 years old (below called ST2). Thus, a high proportion of winter habitat for moose was available during the study within the Sunnäs moose pen.

The winter moose density during the study ranged between 1.3 and 5.7 moose per km² (Figure 1). The lower densities were comparable with densities in populations of free-ranging moose in the middle and southern parts of Sweden. Densities of 4-5 moose/km² and even more have been recorded in winter concentration areas in northern Sweden. The enclosed population was allowed to grow freely up to 1983, after which it was regulated by hunting.

In the two dominating types of pine stands, ST1 and ST2, 283 circular plots (each 20 m²) were laid out according to a two-stage stratified random design. The 283 plots and the pine stems (close to 1100) inside the plots were permanently marked. Pine browsing was defined as needle biomass removal of $\geq 10\%$ of the upper 6 whorls during the last winter (Delfin *et al.* 1981). Pine mortality, caused by moose browsing, was recorded in 1980 and 1984-89 after the winter browsing season. The pines killed by browsing were classified as main and secondary stems. The main stems

were usually the dominant ones on which the future forest production was to be based. Stem-breakage (defined as a broken stem (1-6 m high) with a diameter at point of breaking >15 mm) and the number of stems per plot were also recorded for pine and birch (*B. pendula*).

RESULTS

In the youngest forest stands (ST1) the number of pines browsed was strongly correlated with moose winter density (Figure 2; Spearman correlation coefficient (r_s)=0.94; $p<0.01$; $n=10$). Similar correlation analyses for the older stand type (ST2) showed no significance ($r_s=0.59$; $p<0.09$; $n=9$) although all points, except one (1988), fell fairly close to a straight line (Figure 2).

Figure 3 shows temporal changes in the number of broken stems when plotted against all years (1980-1989). Correlation analysis between these numbers and moose population densities showed that the number of broken pine stems in ST1 and ST2 was significantly correlated with moose density (ST1: $r_s=0.78$; $p<0.02$; $n=10$; ST2: $r_s=0.85$; $p<0.02$; $n=9$).

The number of pines killed by moose browsing varied between years. During the main increase of the moose population (1980-

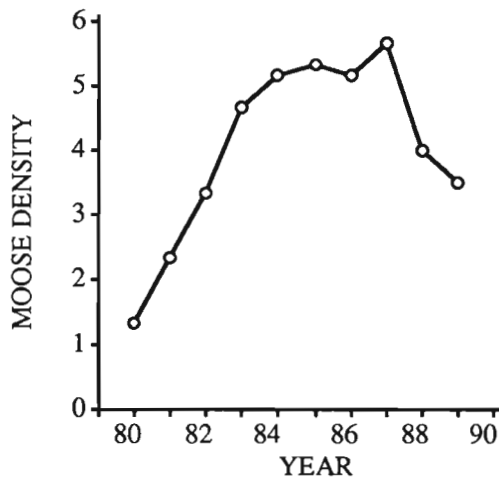


Fig. 1. Moose densities (moose/km²) in Sunnäs moose pen from 1980-89.

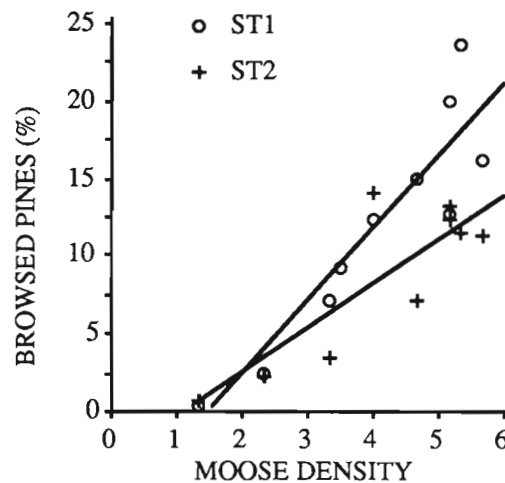


Fig. 2. Number of browsed pines (as the % of total marked pines) in two stand types in relation to moose density (moose/km²).

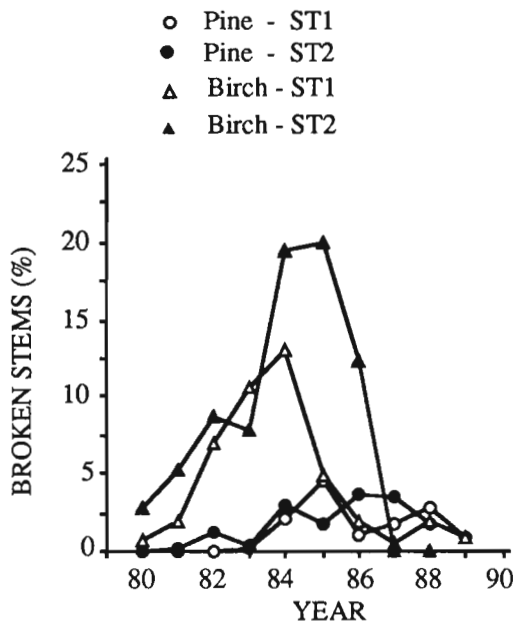


Fig. 3. Stem-breakage (% broken stems of total number of marked pines and birches) per year in two stand types in relation to time.

1984) very few pines were killed (Figure 4). After 4 to 6 years the number of killed main and secondary pine stems in ST1 increased. However, the most rapid increase of accumu-

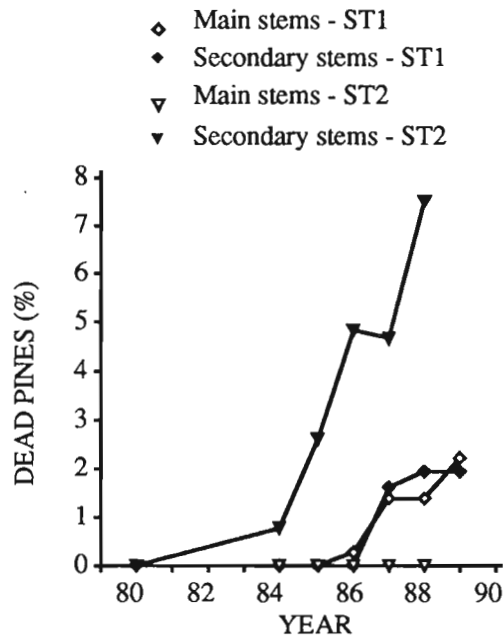


Fig. 4. Percentage of marked pines killed by moose winter browsing in two stand types accumulated over 10 years.

lated mortality was shown by secondary stems in ST2. No main stems in this stand type were killed by moose browsing. We tested moose density versus annual pine mortality and accumulated moose density versus accumulated mortality. No significant correlations were found ($p > 0.05$). The decline in accumulated pine mortality between some of the years is explained by the stand cleaning (see above) that took place in 1986 and 1987.

DISCUSSION

The browsing survey showed that a small proportion of the pine stems are browsed at low moose densities. However, each increase of one moose/km² resulted in roughly a 5% increase of browsed pine stems in ST1. The trend in number of browsed pine stems in ST2 indicated a slower increase than in ST1. The results indicated a potential to use number of browsed stems of a medium-preferred species to estimate browsing pressure or actual or relative moose densities. This potential was supported by Oldemeyer (1981, 1982) who showed a significant relationship between utilization of birch expressed as "percent plants browsed" and "percent of production browsed".

The frequency of stem-breakage of birch increased during the moose population growth but started to decline before the population decreased. This decline started when the trees were 2.5-3.5 m (Bergström unpubl.), a height when the most intensive breaking should occur (Lavsund and Jernelid 1988). A possible explanation to the decline in stem-breakage is that an annual frequency of birch stem-breakage of 10-14% will decrease the potential number of stems to break. If the annual figures are accumulated the percentage of birch stems broken reached 43% in ST1 and 76% in ST2 at the end of the study. When a birch has been browsed once, the moose often continue to browse on this birch the following winters (Bergström 1984, Danell *et al.* 1985), and few new breakable stems (diameter > 15 mm) are

produced on those rebrowsed individuals. Unfortunately we do not have any figures on the intensity of stem-breakage during the summer period. We know it occurs in connection with both leaf-stripping and twig biting.

Stem-breakage on pine also increased and declined during the study. However, the peak levels were considerably lower and the declines not that pronounced when compared with birch. The patterns, similar in both ST1 and ST2, were probably connected with the generally lower number of browsed pines. The accumulated numbers of broken pines after 10 years were 13 and 15 % respectively in ST1 and ST2. The low frequency of broken pines in the beginning of the study can be explained by the relatively low mean height (1 m). Lavsund and Jernelid (1988) have reported from winter concentration areas that moose start to break stems when they are about 1.5 m high. Rebrowsing of the same stems in subsequent winters does occur on pine (Löyttyniemi 1985, Vikberg and Bergström 1992).

Our study indicated that stem-breaking was not just a result of severe forage shortage but a common phenomenon of moose winter browsing. Telfer and Cairns (1978) reported on stem breakage from Elk Island National Park in Alberta. They concluded that another 10-27 % of available forage was added through stem breaking in forests and shrubland. We believe from observations in Sunnäs moose pen that stem-breaking resulted in a slower height growth of the trees. Moose in this way influence the height distribution of forage.

The mortality rate was different for pines of different age and dominance rank. As all pines in ST1 were of about the same height the difference in mortality between the two types of pine (main and secondary) was very small. In the older stand age class the main stems were considerably higher than secondary stems. The main stems were most often too high to be strongly influenced by moose

browsing while the subdominant, secondary stems were generally lower and weaker. The high mortality of secondary stems in ST2 was probably an effect of their low biomass, resulting in a higher sensitivity to browsing, in combination with competition from the more dominant main stems

The lack of correlation between moose density and pine mortality was probably due to the fact that many browse stems die only after repeated annual browsing and the tendency for moose to rebrowse the same stems year after year. The declining moose population continued to browse mainly on already browsed stems, thereby causing an increase in pine mortality even after a decrease in the moose population density.

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