THINNING RESIDUES AS A SOURCE OF BROWSE FOR MOOSE IN MANAGED FORESTS IN FINLAND

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ABSTRACT: Moose (*Alces alces*) browsing causes considerable damage in young Scots pine (*Pinus sylvestris*) stands in Finland. In this study, we examined the possibility of increasing moose browse in managed forests by providing cutting residues (i.e., the tops of different tree species) from commercial thinnings made in early or midwinter. The study was carried out in 24 thinned stands in southern and central Finland during 1993-98. Moose browsing on cut tree tops was measured on circular plots, as well as at feeding sites with salt (Na^+) stones and on plots where the cut tree tops were raised up from the ground. The biomass of tree tops consumed in the thinned stands was even greater than that measured in young pine stands. The biomass consumption was increased by propping the tree tops against standing trees or rocks. Placing salt stones to attract moose had no effect on browsing on the pine tops raised up at the feeding sites. The phenolic acid concentrations were generally higher in the cut pine tops than in the side twigs of standing trees or in young pines, indicating that the high consumption by moose was not explained by low phenolic acid concentrations. According to the fecal pellet groups, 19-23 moose days/ha were spent in the thinned stands. We estimate that a 10 ha cutting area would provide food during 2 winter months for moose at a density of 1 animal/km^2. We conclude that more accessible winter food can be provided by timing the cuttings in early and midwinter.

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The effects of moose (*Alces alces*) on forest stands and tree species composition depend on the size of moose populations. During the winter moose populations concentrate in specific forest areas that are often relatively large and in which the winter food supply is high. The availability of food also varies spatially and is related to natural factors as well as forest management. In general, increasing the amount of food results in higher moose densities. In Finland, habitat carrying capacity calculations have generally been based on the availability of young Scots pine (*Pinus sylvestris*) stands (Löyttyniemi and Lääperi 1988). Relationships between the effects of selective browsing, the size of the moose populations, and food resources have been studied in managed forests (Heikkilä and Härkönen 1993). The effects of moose on forestry, as well as the consequences of food resources, have been emphasized in several studies carried out in Fennoscandia (Lavsund 1987). In Finland, the effects of these factors on forest ecosystems have been taken into account in local areas with higher than average moose densities (Heikkilä and Härkönen 1998).

In Finland, a high proportion of the forest land is dominated by Scots pine, and the forest landscape as well as natural moose habitats are managed for timber production. Investigations in young stands, as well as the results of the national forest inventories, have shown that there are certain relationships between damage and the size of moose populations (Löyttyniemi and Piisilä 1983). The availability of pine, together with that of deciduous trees, especially birch (*Betula* spp.) species, is important for moose during the critical winter months. It has been shown that a shortage of browse is a factor that makes the economically important young stands especially vulnerable to browse damage in terms of stem breakage.

Advanced young pine stands (Heikkilä and Mikkonen 1992, Heikkilä and Härkönen 1998), peatland compartments with deciduous browse (Heikkilä and Härkönen 1993), forest edges with dense undergrowth (Histøl and Hjeljord 1993), and freshly cut areas (Heikkilä *et al.* 1996), are considered to be an alternative to young seedling and sapling stands. In this respect, the value of thinned stands as a source of browse for moose has not been determined.

The aim of this study is to find ways of increasing browse for moose in managed forests by increasing the accessibility of thinning residues. Year-round cutting and thinning activities provide food sources, but their availability could be increased through appropriate scheduling of the thinning operation. This could eventually lead to a decrease in browsing damage on young Scots pines.

METHODS

Browse Production

Our experiments were mainly conducted in thinned pole stands (20-25 years). Moose browsing on cutting residues (i.e., the tops of different tree species) after commercial thinning was investigated in 1994-95 in four Scots pine dominated stands at Ruokolahti (61°30'N, 28°80'E), southern Finland, and in 1996-97 in 13 stands at Lakomäki (62°54'N, 25°38'E), central Finland. At Lakomäki 5 birch-dominated stands were also included. In addition, 1 clearcut area was investigated in 1993 at Lapinjärvi (60°30'N, 26°00'E). At Parkano (62°00'N, 23°15'E) in 1992-93, as well as at Lakomäki in 1997-98, the effect of raising the tree tops up from the ground was studied in 1 pine stand. All these study areas supported high moose densities, (1-2 animals/km^2) in several thousand ha of forest, the average density for larger areas being 0.3-0.5/km^2.

The experimental areas were commercially thinned or clearcut in early or midwinter (Nov-Feb). Moose browsing after thinning was measured on 279 50 m^2 circular plots spaced 20 m apart, using the systematic line-plot method (Lääperi and Löyttyniemi 1988). Each tree top lying inside the plots was investigated, but branches outside the plot were omitted. All the bites made by moose were counted and measured to the nearest millimeter. The bites were converted into consumed dry-weight biomass according to Härkönen *et al.* (1998). The density of the pine stands after thinning was determined by counting the number of living trees, and the number of thinned pine stems by counting the stumps. Fecal pellet groups on the plot were counted. On the clearcut area at Lapinjärvi the sample consisted of tree tops of different tree species. The aim was to compare the biomass consumed per tree, and therefore all the tree tops found in the sampled area were included.

Raising Tops

At Lakomäki in 1997-98, the experiment consisted of 12 50 x 50 m square plots. On 6 of the plots the pine tops were propped up against living trees or rocks in order to improve browse accessibility for moose during the winter. At Parkano, there were 20 feeding sites with 10 cut pine tops raised up, and the 10 nearest tops lying on the ground examined for comparison. The pine tops lying on the ground were partly covered by 30-50 cm of snow.

Providing Salt

Salt stones have been used to direct moose feeding towards advanced young pine stands (Heikkilä and Härkönen 1998). The effect of salt stones on browse consumption in thinned pine stands was estimated at Ruokolahti, where 12 feeding sites were established on 2-3 February, 1995, by providing 10 pine tops on 6 sites with salt stone and 10 pine tops on 6 sites without salt. The tops were positioned so as to remain above the snow surface within the reach of moose. The distance between adjacent feeding sites was at least 200 m. The distance between adjacent tops in the individual feeding sites was at least 3 m. Salt stones were placed on posts (pines ca 20 cm diameter) at a height of 2 m. We checked the feeding sites on 20 February, 1995, in order to find out whether the moose started feeding earlier on the salted sites. The available dry biomass per top was estimated by summing up the dry biomass removed and the dry biomass remaining. The feeding sites were terminated on 24 April, 1995, before any of the sites had became totally depleted of twigs available to moose.

Phenolic Acids

Food quality in terms of secondary compounds affects moose winter browsing (Bryant and Kuropat 1980). To analyse the effect of phenolic acids on moose feeding on pine twigs, shoot samples were taken at Lakomäki in winter 1998 from the freshly cut tops of thinned pines, from ca 2-m-high young pines, and from the side twigs of 4-5-m-high pines (n = 30 for each). The diameter of the sampled twigs was based on moose bite size (Heikkilä and Härkönen 1993, 1998). The samples were collected from a number of sites in the study area. The analysed chemical compounds were cinnamon acid, 4-hydroxid bentsoe acid, vanillin acid, 2,5-dihydroxid bentsoe acid, 3,4-dihydroxid bentsoe acid, p-kumarin acid, gallus acid, and ferulic acid. The analyses were made using the GC-MSD (HP 5973 MSD) method described in Hoffman and Petranetz (1972) and Hoffman and Yang (1972).

Statistical Analysis

Statistical analyses on the results from the feeding site experiments were performed using the Mann-Whitney U-test. One-way analysis of variance with Bonferroni statistics was used for other comparisons. The values are expressed as means ± SE.

RESULTS

There were only 4 different tree species in the study stands (Fig. 1a). The density of aspen (*Populus tremula*) was negligible after thinning operations. Scots pine, Norway spruce (*Picea abies*), birch, and aspen tops were available for moose after the thinning operations (Fig. 1b). The cut tops of Norway spruce were not browsed by moose (Fig. 1c and 1d). Moose had mainly browsed on the pine tops. The total stand density after thinning, the density of moose fecal pellet groups, the total number of twigs browsed by moose, and the twig biomass consumed by moose did not differ between the experiments (Table 1). There was a statistically significant difference in the total number of stems removed in thinning between the experiments.

On the clearcut area at Lapinjärvi in 1993, moose had browsed 213 ± 30 pine twigs, 296 ± 19 silver birch (*B. pendula*) twigs, 51 ± 8 aspen twigs, and 72 ± 8 sallow (*Salix caprea*) twigs per tree top. The mean bite diameters were respectively 4.3 ± 0.1 mm, 3.6 ± 0.1 mm, 7.6 ± 0.5 mm, and 6.0 ± 0.2 mm. The biomass consumed per tree top was highest on pine (1.36 kg) and lowest on sallow (0.53 kg). The respective

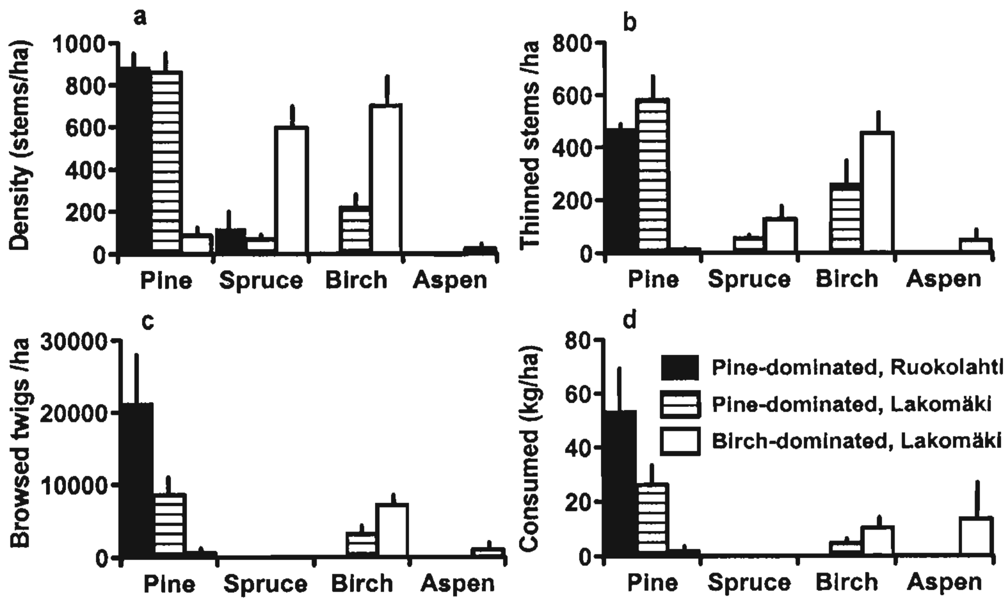

Fig. 1. Density of different tree species after thinning (a), number of thinned stems (b), number of browsed twigs (c), and twig biomass consumed by moose (d) in pine-dominated stands (n = 4) at Ruokolahti, in pine-dominated stands at Lakomäki (n = 13), and birch-dominated stands (n = 5) at Lakomäki in spring 1997. Means are given with their standard errors.

values for silver birch and aspen were 0.96 kg and 0.73 kg.

Moose had browsed significantly more of the raised up pine tops compared to those lying on the ground (Fig. 2). The difference was about fourfold at both sites. The mean bite diameters were 3.5 ± 0.1 mm on raised vs. 3.4 ± 0.1 mm on tops lying on the ground at Parkano, and respectively 3.6 ± 0.1 mm vs. 3.5 ± 0.2 mm at Lakomäki. The differences were not statistically significant (P = 0.57 and P = 0.52, respectively). At Lakomäki, the number of fecal pellet groups was significantly higher on the plots where the tops had been raised up than on the plots where the tops were lying on the ground

Table 1. Total stand density after thinning, number of stems removed in thinning, density of moose fecal pellet groups, number of twigs browsed by moose, and twig biomass consumed in Scots pine dominated stands at Ruokolahti, Scots pine dominated stands at Lakomäki, and birch-dominated stands at Lakomäki. Means with the same letter do not differ significantly (ANOVA with Bonferroni corrections, $P > 0.05$).

Variable	Ruokolahti Pine $n = 4$	Lakomäki Pine $n = 13$	Lakomäki Birch $n = 5$	F	P
Total stand density (/ha)	1,002^{a}	1,217^{a}	1,406^{a}	2.38	0.120
Stems removed (/ha)	473^{a}	891^{b}	640^{ab}	4.23	0.030
Pellet groups (/ha)	316^{a}	261^{a}	98^{a}	3.43	0.053
Number of twigs (/ha)	21,310^{a}	11,697^{a}	8,773^{a}	2.49	0.110
Biomass consumed (kg/ha)	53.7^{a}	30.8^{a}	25.5^{a}	1.37	0.279

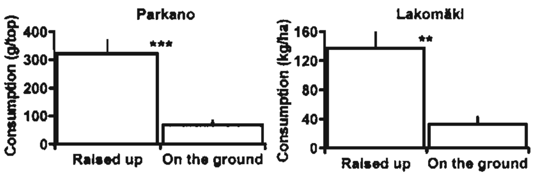

Fig. 2. Browse consumption on raised-up pine tops vs. pine tops lying on the ground at Parkano in winter 1992-93 and at Lakomäki in winter 1997-98. Means are given with their standard errors. $^{**}P<0.01$, $^{***}P<0.001$.

(470 ± 47 vs. 159 ± 58/ha, $P = 0.01$).

In the feeding experiment with salt attraction at Ruokolahti, the moose did not use the pine tops with salt stone more than those without (Table 2). Neither did they start feeding earlier on the salted sites, because 5 of the sites without salt stone and 4 of the sites with salt stone were found by moose during the first 20 days. The available dry biomass per pine top averaged 685 ± 112 g.

The phenolic acid concentrations were generally higher in the cut pine tree tops than in the living young pine trees (Table 3). In most cases the concentrations were also significantly higher in cut tree tops than in the side twigs of 4-5-m-high young advanced pines. The total phenolic acid content of the twigs was also higher in the cut pine tree tops than in the young pine trees or side twigs of young advanced pines.

DISCUSSION

In thinned stands there is no longer any risk of stem breakage because the height of the trees is more than 4 m (*cf.*, Heikkilä and Mikkonen 1992). In this study, we assumed that thinned stands with thinning residues can be important as a source of browse for moose. If the residence time of moose and moose browsing are directed at these stands, the risk of damage in young stands might be reduced. The importance of cut pines for moose has been emphasized in previous studies. Jernelid and Lavsund (1984) and Lääperi (1990) suggested that feeding stations should be established on moose winter ranges in order to diminish browsing damage. This method presupposes the transportation of tree tops to permanently maintained sites. The present results indicate that moose can intensively browse the cutting residues lying on the ground after thinnings made in early winter. Thus, special transportation is not needed. The biomass consumed from tree tops lying on the ground in the study areas was 26, 31, 33, and 54 kg/ha during a period of time shorter than 1 whole winter. These amounts are even larger than those measured in young pine stands (Heikkilä and Härkönen 1996, Härkönen 1998).

If cutting is carried out in early winter, the residues may become partly covered by snow. In cases where the tree tops had been propped up against standing trees or rocks, the consumed twig biomass was 4 times higher. Assuming that 600 pine tops/

Table 2. Number of moose bites, twig biomass consumed, mean bite diameter, and consumption rate per top between feeding sites with and without salt stone at Ruokolahti (Mann-Whitney *U*-test). Means are given with their standard errors.

Variable	Pine tops with salt stone $n = 6$	Pine tops without salt stone $n = 6$	*P*
Number of bites	125±30	104±20	0.522
Twig biomass consumed (g)	400±113	382±71	0.749
Mean bite diameter (mm)	3.5±0.1	3.5±0.1	0.827
Consumption rate (%)	67±16	65±11	0.512

Table 3. Concentration of phenolic acids (μg/kg) in Scots pine twigs of different feeding strata. Means with the same letter do not differ significantly (ANOVA with Bonferroni corrections, $P > 0.05$).

Phenolic acids	Young pine	Cut pine tops	Advanced pine	*F*	*P*
Cinnamon	12.7^{a}	16.7^{b}	14.6^{c}	15.58	0.000
4-hydroxid bentsoe	10.6^{a}	12.0^{a}	8.9^{a}	2.90	0.060
Vanillin	9.4^{a}	11.0^{b}	10.8^{ab}	3.30	0.041
2,5-dihydroxid bentsoe	4.0^{a}	4.6^{b}	4.3^{c}	25.75	0.000
3,4-dihydroxid bentsoe	6.9^{a}	8.0^{a}	7.0^{a}	1.23	0.297
P-kumarin	11.4^{a}	11.8^{a}	7.4^{b}	13.68	0.000
Gallus	6.2^{a}	7.3^{a}	7.1^{a}	3.03	0.053
Ferulic	9.1^{a}	14.0^{b}	8.3^{a}	12.26	0.000
Total	70.3^{a}	85.3^{b}	68.2^{a}	8.14	0.001

ha are available after thinning cutting, the theoretical consumption according to the available biomass per pine top (685 g), could reach 411 kg/ha. The actual consumption reached 230-240 kg/ha depending on the conditions in the different study areas. This means that an area of 10 ha would easily provide food during 2 winter months for ca 1 moose/km^2, which is often considered a relatively high population density in small-scale forest management areas in Finland. Because pine browse is most important for moose in mid- and late winter (Bergström and Hjeljord 1987), it would be beneficial to schedule the timing of cuttings in order to improve the availability of food above snow cover.

Several observations, as well as studies on radio-tracked moose (Heikkilä *et al.* 1996), have shown that moose like to remain feeding in freshly cut areas. Similarly, white-tailed deer (*Odocoileus virginianus*) feed intensively on cutting residues during winter (Salmi 1949). The fecal pellet group countings showed that 19-23 moose days/ha were spent in thinned stands, based on the 14 groups/day commonly used in Fennoscandia (Olsson *et al.* 1997).

Salt is commonly provided for moose in forest areas in Fennoscandia. Attempts have been made to direct moose feeding using salt stones as attractants in winter (Lääperi 1990, Heikkilä and Härkönen 1998). These studies indicate that pine is consumed in relatively large quantities in the vicinity of salt. It is not fully known whether this is due to the attractive effect of the Na^+ source and/or related to the functioning of the digestive tract. In North America, moose look for salt in spring and early summer to equilibrate their Na/K balance or to facilitate milk or antler production (Jordan 1987). In Finland, it has also been shown that moose consume salt in winter (Heikkilä and Härkönen 1998). In our study, the presence of salt stones had no effect on the browsing of pine tops raised up at feeding sites. However, there may not have been enough time for moose to find the newly established stones. Another explanation could be that the cut tree tops alone are attractive, and attraction cannot be increased further.

The results of the analysis of phenolic acid compounds indicate that these digestibility reducing compounds (Bryant and Kuropat 1980) did not influence moose selective feeding, and that their concentrations obviously do not decrease with age in young trees. However, we cannot exclude the possibility that some terpene compounds affect twig quality and selection by moose (Härkönen *et al.* 1997).

In conclusion, owing to the serious problems in high density moose areas, we recommend that more winter food be provided by carrying out thinnings in early and midwinter. Making this food more accessible in areas with high snow accumulation would be beneficial because moose often cause damage during the critical late winter months.

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