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Effect of plantation characteristics on moose browsing on Scots pine

Risto Heikkilä

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The effect of plantation characteristics on moose browsing intensity was studied in 82 Scots pine plantations in southern Finland. Moose browsing occurred most commonly in plantations established on relatively fertile soil, and the degree of damage was at highest in plantations with openings. A high amount of brush, especially aspen, increased the risk of damage. Furthermore, damage was intensified in plantations situated on hills, slopes or at a long distance from main roads or settlements.

Männyn istutustaimikoiden hirvituhoalttiuteen vaikuttavia tekijöitä tutkittiin 82 taimikossa Etelä-Suomessa. Yleisimmin hirven syönnöksiä tavattiin voimakkaasti heinittyneissä, kasvupaikaltaan rehevissä taimikoissa. Tuhoja esiintyi eniten aukkoisissa taimikoissa. Tuhot olivat sitä suurempia, mitä enemmän taimikossa oli muiden puulajien kuin koivun muodostamaa vesaikkoa. Tuhoja esiintyi keskimääräistä enemmän taimikoissa, jotka sijaitsivat rinteissä, korkeissa maastokohdissa tai etäällä teistä ja asumuksista.

Keywords: *Pinus sylvestris, Alces alces*, browsing damage, plantation characteristics, feeding behaviour.
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Author's address: The Finnish Forest Research Institute, PL 18, SF-01301 Vantaa, Finland.

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1. Introduction

Amount and quality of the food available for moose in forest tree plantations is mainly determined by the goals of wood production. Scots pine (*Pinus sylvestris*) plantations differ from each other as a result of the variation in the growing sites, the surroundings and in the silvicultural measures applied. This evidently also affects the feeding behaviour of moose and the damage they cause. The properties of plantations can be regulated in accordance with the expected risk of damage.

In studies on the areal pattern of moose damage, silvicultural measures have been found to have an effect on the extent of damage in pine plantations (Yli-Vakkuri 1956, Westman 1958, Löyttyniemi and Piisilä 1983, Lääperi and Löyttyniemi 1988).

The feeding behaviour of the moose is regulated by the amount and quality of the available food. According to Belovsky (1981, 1986), the availability and energy contents of the food plant are the major factors as regards the optimal use of energy. When presented with alternative food sources, the moose has been found to prefer well-growing pine plants (Niemelä and Danell 1988, Niemelä, Hagman and Lehtilä 1989). When the amount of available food increased, the feeding concentrated on the twigs with best quality (Vivås and Saether 1987). Certain tree species, e.g. rowan (*Sorbus aucuparia*) and aspen (*Populus tremula*), that commonly occur in pine plantations, are reported to be preferred by moose to pine and birches (*Betula pendula* and *B. pubescens*) (Bergström and Hjeljord 1987).

Moose are less active in the winter than during other seasons and this obviously affects the optimal use of food and energy. The use of feeding areas in wintertime differs from that in the summer. During the winter the animals congregate in narrower forest areas that provide food (Lykke 1964, Ahlén 1975, Matchett 1985).

The purpose of the present study was to find out the dependence of moose damage on the characteristics of pine plantations in order to evaluate possibilities of reducing the susceptibility of plantations.

2. Material and methods

The field data were collected in summer 1987 by surveying pine plantations established by planting. The study was done in four rural municipalities in southern Finland: Orimattila, Sysmä, Padasjoki and Lammi (61° 30' N – 60° 40' N, 24° 30'E – 26° 00'E). The data consisted of all plantations reported from the district forestry board as having been seriously damaged during the previous winter. A compensation was paid for the land owners because of the damage occurred. The comparative data consisted of the plantations of the same age (seven years) situated as close as possible to the damaged ones. There was no opinion of the degree of damage in these plantations when starting the study. Thus the data consisted of a series of plantations with damage of varying intensity. Altogether 82 plantations were studied. The average size of plantations was 1.6 ha.

The plantations, all potential sites for moose browsing at the same time, were assumed to represent winter ranges of about the same average density of animals. The average moose winter density per 1000 ha in the study area was during the five- and three-year periods preceding the investigation as follows (Nygrén, T., Finnish Game and Fisheries Research Institute, unpublished data) :

	5 years	3 years
Orimattila	5.4	3.5
Lammi	4.0	3.8
Padasjoki	5.4	4.9
Sysmä	5.1	4.5
Average	5.0	4.2

Most of the damage had obviously occurred during the three-year period. It was impossible to determine the exact moose density on each local forest area. It had obviously been locally even significantly greater than average owing to the gathering of moose to winter ranges. It was thus concluded that the plantations were situated in areas where a higher than average degree of damage could be expected. Because the comparative data were collected in the nearest plantations of the same age, it is obvious that all plantations were equally exposed to moose damage.

Each plantation was inspected by dividing it in 3 to 8 parts of equal size, depending on the area. Thus it was possible to collect the data accurately in relation to the variation in different parts of the plantations. The classifications were made at first for each small part and counted to represent the whole plantation A map was made of each plantation, on which characteristics of the surroundings and plantations were marked after which their proportions were counted. Measurings were made using 28 m^2 sample plots with the distance of 15–30 m. Only plants over 50 cm high were inspected, because they can be assumed to represent the main part of the food available for the moose in the winter. The following classifications were used when inspecting the plantations and their surroundings:

Characteristics of plantations:

Area of plantation, ha.

Topography of plantation: 1 = even, 2 = uneven, hilly 3 = slope.

Plantation: 1 = on forest land, 2 = on abandoned field.

Height of the plants of different tree species.

Severity of moose damage on pine plants: 0 = no browsing or very slight, 1 = abundant browsing (20–40% of plants), degree of damage light, 2 = browsing more abundant (40–60% of plants), average degree of damage, 3 = browsing most abundant (>60% of plants), high degree of damage.

Edge effect (damage concentrated at the edge of the plantation): 0 = no effect, 1 = slight, 2 = great.

Amount of openings: 0 = none, 1 = a few, 2 = moderate, 3 = great.

Amount of brush trees: 1 = small, 2 = moderate (coverage smaller than that of pine), 3 = coverage the same as that of pine, 4 = great, 5 = very great.

Proportion of brush tree species out of total amount of the brush (%).

Browsing degree on tree species other than pine (%).

Amount of grassy vegetation: 1 = small, coverage of tall species negligible, 2 = moderate, 3 = great, 4 = very great (a lot of tall species).

Cleaning of plantation: 1 = done, 2 = not done

Characteristics of surroundings:

Topography of surroundings: plantation 1 = at lower level than the surroundings, 2 = at the same level, 3 = at higher level.

Surrounding forest: tree species, development class: 1 = young plantation or regeneration area, 2 = young thinning stand, 3 = old thinning stand, 4 = mature thinning stand or mature stand.

Distance to nearest main road, settlement etc: 0–200 m, 200–400 m, 400–600 m, >600 m.

The severity of moose damage on pine plants was evaluated using both the proportion of browsed plants and the degree of damage on the basis of the browsed twig biomass. The occurrence of openings was classified according to the total amount of open areas, where planted pine plants had been died as very young. The openings were chosen as variable because it was considered to be of importance as regards the behaviour of the moose.

Because of the relatively small variation between the forest site types in pine plantations it was decided to divide the sites more accurately using the ground vegetation. The amount of grassy vegetation was determined taking into account the overall abundance and distribution of typical, especially tall species indicating the variation in site type quality (Kujala 1979).

Relationships between different variables and the intensity of moose damage were analysed with a stepwise logistic regression model. If needed, for example because of the small frequency of the variables, the classes were combined. The dependence between the damage and the combined effects of different factors was analysed using a loglinear model.

3. Results

The distribution of plantations in the classes of different characteristics is presented in Table 1. Young plantations or regeneration areas represented on average 13 % of the surrounding forests of plantations, young thinning stands 30 % , old thinning stands 37 % and mature thinning stands or mature forests 20 %. Pine forests other than young plantations represented 18 % out of the total, spruce forests 55 % and deciduous, mainly birch forests 14 %, respectively.

The amount of grassy vegetation and openings were found to have the greatest effect on the occurrence of the damage. In

Table 1. Distribution of plantations according to their characteristics (classifications see p. 343).

Characteristic	Classes 0	1	2	3	4	5
	No. of plantations					
Topography		25	30	27		
-"- of surroundings		7	44	31		
Forest/abandoned field		4	78			
Degree of damage	23	28	21	10		
Edge effect	59	17	6			
Openings	24	29	15	14		
Amount of brush		15	24	23	14	6
Amount of grasses		12	25	36	9	
Cleaning	68	14				
Distance to roads etc.	6	8	11	57		

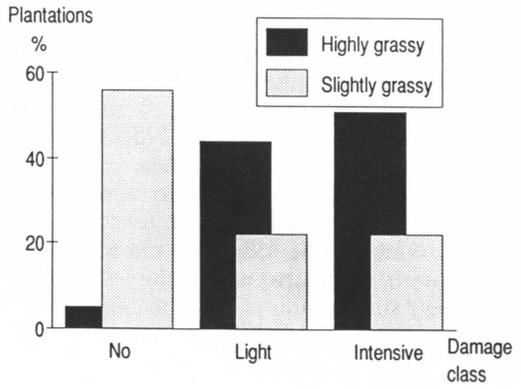

Figure 1. The intensity of damage in different classes of the grassy vegetation. Combined classes: damage 2+3, grassy 1+2, 3+4. N = 82.

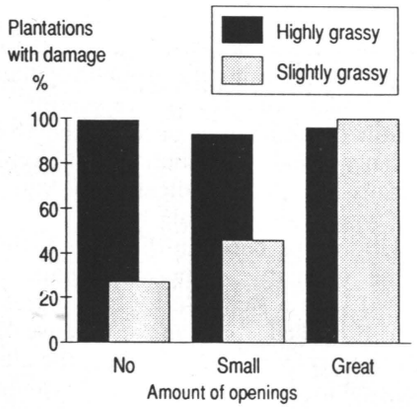

Figure 2. The occurrence of damage in relation to the amount of openings and grassy vegetation. Combined classes as in Figure 1 except openings 2+3. N = 82.

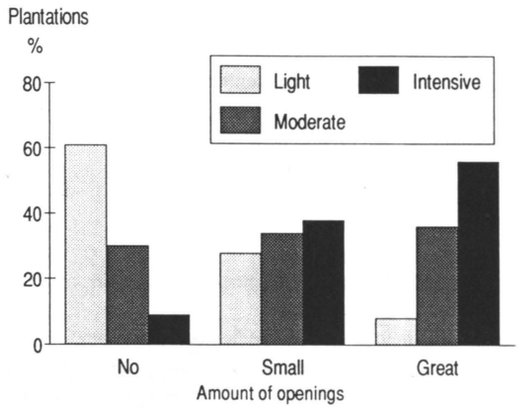

Figure 3. The intensity of damage in relation to the occurrence of openings. Combined classes: damage 2+3, openings 2+3. N = 82.

plantations with a large amount of grassy vegetation, indicating good soil fertility, the overall occurrence of moose browsing was very common. On drier, slightly grassy sites the occurrence of damage was more dependent on the number of openings (Figs. 1 and 2). These factors explained most significantly the degree of damage in the final models when analysing the data using linear regression (p. 00–00).

Browsing was significantly dependent on the amount of openings in the plantations (Fig. 3). In the greatest opening class the 14 plantations represented densities of pine plants under 1560/ha and thus the openings could be counted to cover at least 20 % of the area. An increasing amount of grasses also correlated with the increasing number of openings in the plantations, the two factors thus having a cumulative effect on damage. It was not possible to determine the cause for the openings. Obviously some of the small

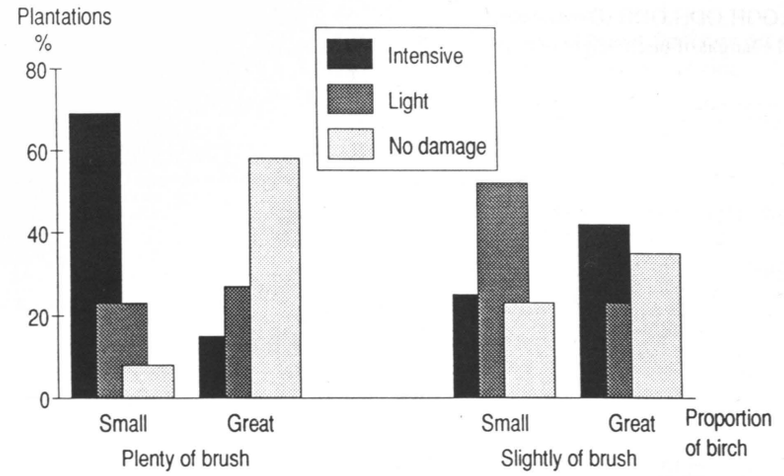

Figure 4. The effect of the amount of the brush and the proportion of the birch (<> 75 %) on the intensity of damage in plantations on an average. Combined classes: brush 1+2+3 and 4+5. N = 82.

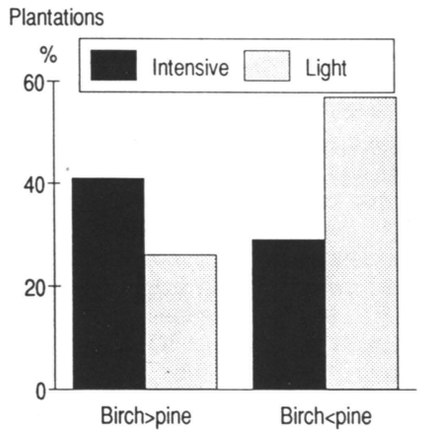

Figure 5. The effect of the pine/birch height relationship on the intensity of damage. N = 82.

transplants had died soon after planting.

The most common deciduous tree was the birch (*Betula* sp) (64 %). Other commonly occurred species were rowan (17 %) and aspen (8%). Willows (*Salix* spp), gray alder (*Alnus incana*) and juniper (*Juniperus communis*) were relatively rare in the plantations. The total amount of deciduous brush did not explain the occurrence of the damage. The intensity of the damage on pines was dependent on the proportion of birch in the deciduous tree vegetation (Fig. 4). When the proportion of birch was over 75 % the degree of damage was light, even if the plantations contained a lot of brush. Thus, when the coverage of the birch was the same or even greater than that of pine, the damage on pine did not increase significantly. However, when birches were taller than pines, the occurrence of intensive damage was common. Plantations with the birch smaller than the pine contained a remarkably high amount of light damage (Fig. 5). Following models were found to explain the relationships between brush and damage:

Model: PBH,DBH,DPH,DPB (D=damage, P=proportion of birch, B=amount of brush, H=height of birch/pine).

	Df.	Likelihood-ratio Chi-square	probability
H,DPB.	11	21.43	0.029
Diff. due to delet. BP.	1	3.89	0.049
BH,PB,DB,DP.	12	24.97	0.015
Diff. due to delet. DPB	2	7.43	0.024

Best model found is D,P,B,H,DPB. The amount of brush being large and proportion of birch <75%, degree of damage is high.

Model: DGH,OGH,ODH,ODG (D=damage, G=grasses, H=height of birch/height of pine).

	Df.	Likelihood-ratio Chi-square	probability
DH,DG,OG.	23	32.51	0.090
Diff. due to delet. OD.	4	9.89	0.042
DH,DG,OD.	21	29.59	0.101
Diff. due to delet. OG.	2	6.97	0.031
DH,OG,OD.	21	38.21	0.012
Diff. due to delet. DG.	2	15.59	0.001
H,DG,OG,OD.	21	29.41	0.105
Diff. due to delet. DH.	2	6.79	0.034

Best model found is D,H,G,O,DH,DG,OG. Degree of damage is explained by grasses, openings and relationship between the height of birch and height of pine with combined effects.

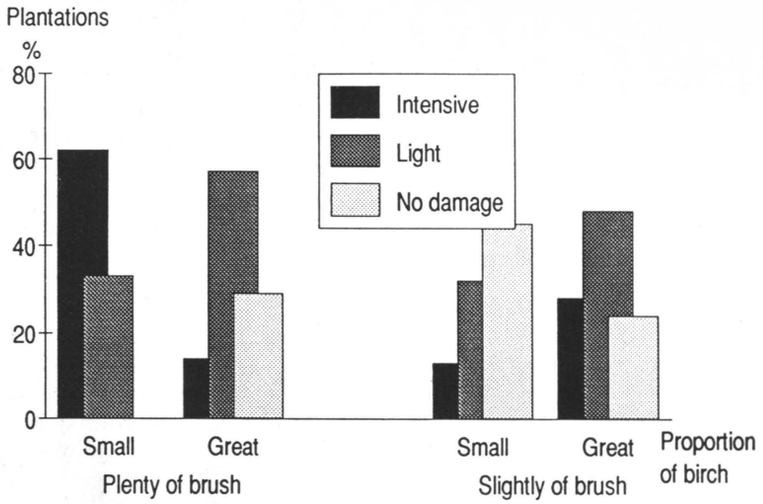

Figure 6. The effect of the amount of the brush and proportion of the birch (<>75 %) on the degree of damage in fully stocked plantations. Combined classes as in Figure 4. N = 53.

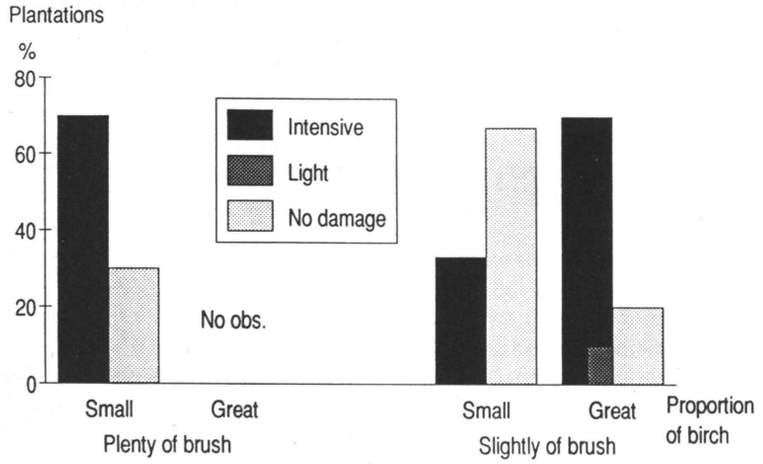

Figure 7. The effect of the amount of the brush and proportion of the birch (<> 75%) on the degree of damage in plantations with openings. Combined classes as in Figure 4. N = 29.

In fully stocked plantations without openings (ca. 2000 plants/ha) the damage caused by the moose was also most intensive in those ones with the highest proportion of deciduous tree species other than birch (Fig. 6). Intensive damage occurred in plantations with a large number of openings regardless of whether the amount of brush was small or not (Fig. 7).

The average proportion of brush tree species, aspen, rowan, and willows, was 20 % in plantations with no damage and 31 % in the other ones. When the occurrence of aspen increased, also the degree of damage on pine plants increased (Pearson Chisquare 4.59, Df. 1, $p < 0.05$). Occurrence of rowan was more even in both plantations and no difference was found by that species alone.

The average browsing degree of all brush tree species was high, especially in plantations suffering from serious damage (Table 2). The browsing degree of rowan and aspen was commonly over 60 % in plantations with serious damage. On an average, the degree of browsing over 60 % occurred for rowan in 72 % and for aspen in 68 % of plantations, were these tree species were found. Also the average height of those tree species was relatively low as a result of the browsing (aspen 86±14 cm, rowan 100±8 cm, willows 49±9 cm) as compared with the pine (208±17 cm).

In plantations where silvicultural cleaning was made the degree of damage was smaller than in the uncleaned ones (Pearson Chisquare 4.03, Df 1, $p < 0.05$) (Fig. 8). In all 10 plantations with most intensive degree of damage cleaning was not done. Because cleaned plantations contain small amount of aspen and rowan, the result also supports the idea that the moose chooses its feeding habitat accordingly with the preferred tree species. However, when the amount of grassy vegetation was high, damage was severe despite cleaning. Because the plantations were only seven years old, the time period from the cleaning was evidently too short for the new sprouts to grow up intensively.

The topography of the terrain affected the occurrence of damage, that being most common in plantations situated on hills or slopes. The amount of openings in the plantations, combined with the topography,

Table 2. Moose browsing degree on deciduous plants in different damage classes of pine.

Degree of browsing	Degree of damage on pine 0+1 Birch	Rowan	Aspen	2+3 Birch	Rowan	Aspen
	% of plantations					
0–60 %	46	28	26	25	0	6
61–100 %	8	36	37	21	36	31
In total	54	64	63	46	36	37

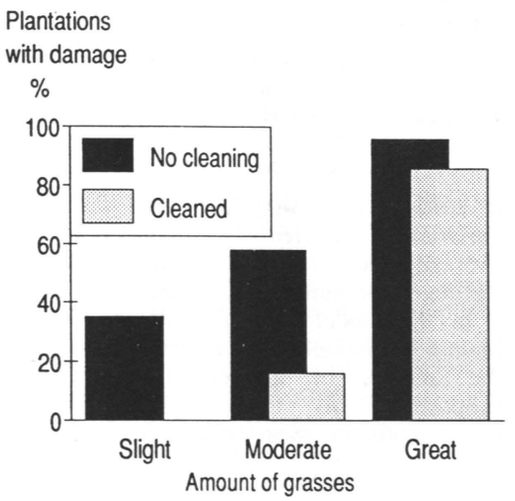

Figure 8. The effect of the cleaning on the occurence of damage in different classes of the grassy vegetation. Combined classes: grasses 3+4. N = 82.

strongly increased the damage in both hilly and slopy plantations (Fig. 9). The proportion of spruce (*Picea abies*) forest around the plantations averaged for the seriously damaged plantations 57 % and for slightly or not at all damaged ones 52 %, respectively. A proportion of less than 50% had no effect on the degree of damage. The number of cases where the proportion of spruce forest was higher, was too small to make any comparisons. Any concentration of the damage at the edges of plantations was not found.

Disturbing factors such as main roads and settlements reduced the occurrence of damage when the distance to the plantations was under 200 m. The effect was only slight

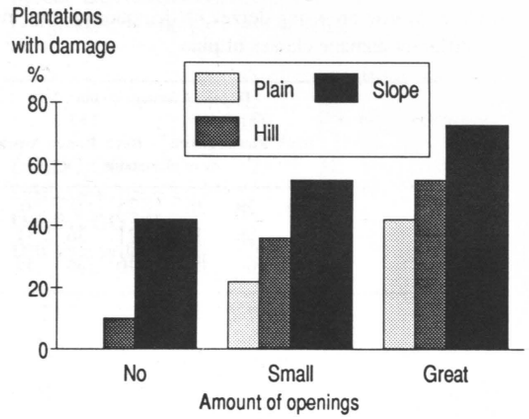

Figure 9. The effect of the plantation topography on the occurence of the intensive damage in different classes of openings. N = 82.

at a distance of 400 m. There was little variation in the area of the plantations (on average under 2 ha), and no correlation with the degree of damage was found.

In the model consisting of the factors having an overall effect on moose damage, the amount of grasses, openings and proportion of the birch explained significantly the occurrence of the damage:

Summary of stepwise results:

Step no:		Df	Logt likelihood	Improvement Chi-sq.	P-val.	Goodness of fit Chi-sq.	P-val.
0			−48.660			49.240	0.000
1	Grasses	2	−33.129	31.062	0.000	18.178	0.020
2	Openings	1	−30.340	5.577	0.018	12.601	0.082
3	Prop.of birch	1	−28.139	4.404	0.036	8.197	0.224

Hosmer-Lemeshow test: Goodness of fit Chi-sq.= 12.767, Df.= 7, P-value = 0.078.

In cases with most intensive damage the amount of openings and plantation topography had the strongest effect:

Summary of stepwise results:

Step no:		Df	Log likelihood	Improvement Chi-sq.	P-val.	Goodness of fit Chi-sq.	P-val.
0			−56.838	39.734	0.0011		
1	Openings	3	−48.240	17.196	0.001	22.538	0.068
2	Topography	1	−45.526	5.428	0.020	17.110	0.194

Hosmer-Lemeshow test: Goodness of fit Chi-sq. = 3.864, Df. = 6, P-value = 0.695.

4. Discussion

A high coverage of grassy vegetation, indicating better soil fertility (Kujala 1979), seems to significantly explain the overall susceptibility of pine plantations to damage caused by moose. High soil fertility makes the food material easier to digest, resulting in the reduced proportion of difficully digestible resin compounds owing to the low C/N ratio (Freeland and Janzen 1974, Bryant and Kuropat 1980, Bryant, Chapin and Klein 1983).

In food preference experiments moose have been shown to consume more biomass of well-growing plants compared with poorly growing ones (Niemelä and Danell 1988). Fertilized plantations have been damaged to a greater extent than unfertilized ones (Laine and Mannerkoski 1980, Löyttyniemi 1981). Moose damage was more commonly found in plantations with good soil fertility than in those with poor soil fertility (Rautiainen and Räsänen 1980, Heikurainen 1982).

A high coverage of grasses inhibits seedling growth through shading and increases the risk of vole damage. This leads to the appearance of openings (Hansson and Hansson 1980, Rautiainen and Räsänen 1980). The damage caused by moose is reported to be less serious in dense than in sparse plantations (Westman 1958, Padaiga 1986). The susceptibility of patchy plantations to moose damage might increase due to the fact that moose stay longer in such habitats. As feeding sites, sparse plantations are not so resistant against moose browsing as the dense ones. Vivås and Saether (1987) have shown that moose consume thicker parts of the twigs in sparse birch plantations as opposed to the dense ones. The thin parts of the twigs are more easily digestible by the moose (Hjeljord, Sundstoel and Haagenrud 1982).

The moose can be expected to attempt to optimize the use of energy in relation to time (Pyke, Pulliam and Charnov 1977, Owen-Smith and Novellie 1982, Engen and Stenseth 1984, Belovsky 1984). In that sense the most digestible component of the available food is chosen. Consequently, the use of pine would become less, the greater the amount of preferred deciduous trees available. The costs needed for changing the feeding site are also to take into account.

The results of the present study show that the amount and composition of the brush tree vegetation affects the use of pine plantations as feeding sites by the moose. The occurrence of preferred tree species as available food thus also increases the use of less preferred pine, evidently increasing the value of habitat suitability. The proportion of aspen has also previously been reported to correlate with the damage to pine (Lääperi and Löyttyniemi 1988). In food preference experiments, pines grouped with aspen have been more intensively browsed than those with gray alder or only pine (Danell unpublished data). The preferred brush tree species were browsed to a great extent, evidently owing to their suitability as an easily digestible food source (Hjeljord, Sundstoel and Haagenrud 1982, Salonen 1982).

The total amount of available food, rather than the occurrence of preferred tree species, seems to effect the habitat use of moose during the winter (Pierce and Peak 1984). Plantations dominated by aspen and pine have also been shown to be browsed more than average, depending on the severity of the winter (Peek, Ulrich and Mackie 1976).

The sporadic occurrence of preferred deciduous trees, due to natural reason or as a result of cleaning, seems to affect the choise of feeding habitat by the moose. If cleaning is postponed or not at all done the plantations would be more equal. This might reduce the concentration of moose at attractive sites. However, the composition of the plantations is evidently not the only reason for the gathering of moose in plantations in the winter and for the patchy use of the food available. Owing to their tendency to move to winter ranges and to change their movement activity as a consequence of variations in snow depth (Coady 1974) gathering can be expected at feeding habitats.

If the supply of preferred food available is great in a forest area, the damage in pine plantations will be relatively low (Padaiga 1986, Örd and Tönisson 1986). Taking into account the attractive effect of preferred brush trees, it is however recommended that the amount of suitable food be increased, especially outside the plantations.

Silvicultural cleaning also reduces the food resources available at least for the first years after it is done. This should probably be taken into account in highly consumed winter ranges. In order to keep the total supply of available food at high level in plantations, the density of the plantations should be increased using mainly pine. According to the results birch can be used to a great extent, if the competition with pine could be avoided. Rowan, which commonly forms low growing units, could possibly be suitable as alternative food resource for the moose in pine plantations. Total destruction of the brush vegetation for longer periods leads to a reduction in the amount of brush available for the moose after the pines have passed the risky period.

According to Repo and Löyttyniemi (1985) the pine plantations surrounded by spruce forest are vulnerable to moose damage. In present study the proportion of spruce forest up to 50 % around the plantations did not increase the risk. Probably a pine plantation should be more completely surrounded by spruce forest in order to have any effect.

5. Conclusions

The results of the present study show the characteristics of pine plantations to affect the intensity of the damage caused by moose browsing. Consequently, in order to avoid the most serious damage, the main results can be taken into account in planning silvicultural measures as well as in predicting the feeding habitats.

The damage could obviously be reduced using plantation management which corresponds the use of food resources by the moose. Planting of the pine on fertile soil leads to an uncertain initial development, resulting an increased risk of severe damage. Evidently, an increase in growing density will make the effect of the browsing less severe.

The composition of broad-leaved tree species can be taken into account when cleaning the pine plantations since it affects the feeding habitat of the moose. By reducing the amount of preferred trees, especially aspen, occurring sporadically in pine plantations, the attractive effect will be diminished. The total removal of preferred tree species may, however, also reduce the amount of food available in permanently utilized winter ranges and thus increase the use of the pine. It would probably be advantageous to use rowan as alternative food at least if no compensative food resource is available outside plantations. It was not possible to demonstrate this in the present study.

Both pine and birch are important tree species as the winter food of the moose. Pine plantations can be grown together with a moderate proportion of brush trees consisting mainly of the birch, without any serious risk of damage. Obviously the birch vegetation also means an alternative food for the moose. Thus it would be better to postpone the removal of birch undergrowth in such plantations, if it does not disturb growing of the pine.

Plantations situated on slopes or small hills seem to be preferred by moose, as well as those lying outside the disturbance of human activities, which should be taken into account when predicting the risk of damage.

References

Ahlén, I. 1975. Winter habitats of moose and deer in relation to land use in Scandinavia. Viltrevy 9(3): 1–192.

Belovsky, G.E. 1981. Food plant selection by a generalist herbivore: the moose. Ecology 62: 1020–1030.

— 1984. Herbivore optimal foraging: a comparative test of three models. The American Naturalist 124: 97–115.

— 1986. Generalist herbivore foraging and its role in competitive interactions. American Zoologist 26: 51–69.

Bergström, R. & Hjeljord, O. 1987. Moose and vegetation interactions in Northwestern Europe and Poland. Swedish Wildlife Research, suppl. 1: 213–228.

Bryant, J.P., Chapin III, F.S. & Klein, D.R. 1983. Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory. Oikos 40: 357–368.

— & Kuropat, P.J. 1980. Selection of winter forage by subarctic browsing vertebrates: the role of plant chemistry. Annual Review of Ecology and Systematics 11: 261–285.

Coady, J.W. 1974. Influence of snow on behaviour of moose. Le Naturaliste Canadien 101: 417–436.

Engen, S. & Stenseth, N-E. 1984. A general version of optimal foraging theory: the effect of simultaneous encounters. Theoretical Population Biology 26: 192–204.

Freeland, W.J. & Janzen, D.H. 1974. Strategies in herbivory by mammals: the role of plant secondary compounds. The American Naturalist 108: 269–289.

Hansson, L. & Hansson, T-B. 1980. Smgnagarskador i svensk skogsbruk under 1970-talet. Summary: Small rodent damage in Swedish forestry during 1971-79. Sveriges Lantbruksuniversitet, Insitutionen fr viltekologi. Rapport 1: 1–63.

Heikurainen, L. 1982. Ojitusalueiden taimistojen kehityksestä vuosina 1964–68 toimeenpannun suometsäkilpailun koealojen valossa. Summary: Development of seedling stands on drained peatlands. Silva Fennica 16: 287–321.

Hjeljord, O., Sundstoel, E. & Haagenrud, H. 1982. The nutritional value of browse to moose. Journal of Wildlife Management 46(2) 333–343.

Laine, J. & Mannerkoski, H. 1980. Lannoituksen vaikutus mäntytaimikoiden kasvuun ja hirvituhoihin karuilla ojitetuilla soilla. Acta Forestalia Fennica 166: 1–45.

Kujala, V. 1979. Suomen metsätyypit. Abstract: Forest types of Finland. Communicationes Instituti Forestalis Fenniae 92(8): 1–45.

Lykke, J. 1964. Elg og skog. Elgskadeundersoekelser i Verdal. Medd. Statens Viltundersoekelser 2 ser. 17: 1–57.

Lääperi, A. & Löyttyniemi, K. 1988. Hirvituhot vuosina 1973–1982 perustetuissa männyn vijelytaimikoissa Uudenmaan-Hämeen metsälautakunnan alueella. Summary: Moose (Alces alces) damage in pine plantations established during 1973–1982 in the Uusimaa-Häme Forestry Board District. Folia Forestalia 719: 1–13.

Löyttyniemi, K. 1981. Typpilannoituksen ja neulasten ravinnepitoisuuden vaikutus hirven mäntyravinnon valintaan. Summary: Nitrogen fertilization and nutrient contents in Scots pine in relation to the browsing preference by moose (Alces alces). Folia Forestalia 487: 1–14.

— & Piisilä, N. 1983. Hirvivahingot männyn viljelytaimikoissa Uudenmaan-Hämeen piirimetsälautakunnan alueella. Summary: Moose (Alces alces) damage in young pine plantations in the Forestry Board District Uusimaa – Häme. Folia Forestalia 553: 1–23.

Matchett, M.R. 1985. Moose habitat relationships in the Yaak river drainage, northwestern Montana. University of Montana. 229 p.

Niemelä, P. & Danell, K. 1988. Comparison of moose browsing on Scots pine (Pinus sylvestris) and lodgepole pine (Pinus contorta). Journal of Applied Ecology 25: 761–775.

— Hagman, M. & Lehtilä, K. 1989. Relationship between Pinus sylvestris L. origin and browsing preference by moose in Finland. Scandinavian Journal of Forest Research 4: 239–246.

Owen-Smith, N. & Novellie, P. 1982. What should a clever ungulate eat? The American Naturalist 119(2): 151–178.

Padaiga, V. 1986. Kompleksnie meroprijatija po ohrane lesnyi nasazhdenii ot povrezhdenii losjami. Summary: Measures to counteract elk-damage to stands. Metsanduslikud uurimused XXI: 26–38.

Pierce, J.D. & Peek, J.M. 1984. Moose habitat use and selection patterns in north-central Idaho. Journal of Wildlife Management 48(4): 1335–1343.

Peek, J.M., Ulrich, D.L., & Mackie, R.J. 1976. Moose habitat selection and relationships to management in northeastern Minnesota. Wildlife Monographs 48: 1–65.

Pyke, G.H., Pulliam, H.R. & Charnov, E.L. 1977. Optimal foraging: a selective review of theory and tests. The Quarterly Review of Biology 52.2: 137–154.

Rautiainen, O. & Räsänen, P.K. 1980. Männyn ja kuusen viljelytaimikoiden kehitys Itä-Savossa 1968–1976. Summary: Development of Scots pine and Norway spruce plantations in Itä-Savo in 1968–1976. Folia Forestalia 426: 1–24.

Repo, S. & Löyttyniemi, K. 1985. Lähiympäristön vaikutus männyn viljelytaimikon hirvivahinkoalttiuteen. Summary: The effect of immediate environment on moose (Alces alces) damage in young scots pine plantations. Folia Forestalia 626: 1–14.

Salonen, J. 1982. Hirven talviravinnon ravintoarvo. Summary: Nutritional value of moose winter browsing plants. Suomen Riista 29: 40–45.

Westman, H. 1958. Älgens skadegörelse på ungskogen. Summary: The damage caused by elk to young stands. Kungliga Skogshögskolans skrifter 28: 1–148.

Vivås, H. & Saether, B-E. 1987. Interactions between a generalist herbivore, the moose *Alces alces*, and its food resources: an experimental study of winter foraging behaviour in relation to browse availability. Journal of Animal Ecology 56: 509–520.

Yli-Vakkuri, P. 1956. Männyn kylvötaimistojen hirvivahingoista Pohjanmaalla. Summary: Moose damage in seedling stands of pine in Ostrobotnia. Silva Fennica 88(3): 1–17.

Örd, A. & Tönisson, J. 1986. Povrezhdenie losem sosnovyi molodnjakov v Estonskij SSR i vozmozhnosti imenshenija povrezhdenija. Summary: Elk-damage to young pine stands in the Estonian SSR. Possibilities of decreasing this damage. Metsanduslikud uurimused XXI: 7–25.

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