BARK STRIPPING BY MOOSE IN COMMERCIAL FORESTS OF FENNOSCANDIA - A REVIEW

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ABSTRACT: The stripping of bark from young timber trees by wild cervids is of commercial concern in many parts of Fennoscandia. We review the occurrence of this habit in moose (*Alces alces*) in relation to region, forestry practices, site productivity, and quality of available forage in the vicinity of areas with bark stripping. The greatest commercial loss from bark stripping is seen in Scots pine (*Pinus sylvestris*), with lesser impacts on Norway spruce (*Picea abies*). In stands of young Scots pine subject to bark stripping, generally less than 5% of trees are affected each year. In central Sweden, the damage to pine is confined to sapling stands 1.5-4 m tall, but to the north older trees in 'thinning-stage stands' are also frequently barked. Bark stripping in central Sweden occurs primarily during spring, while in the north it occurs throughout the year with a higher frequency in mid- to late winter. Bark stripping of Norway spruce has previously occurred only to a small extent, but in the past decade it has increased in importance in parts of southern Fennoscandia. In these new occurrences there is an apparent association with areas of high acidification from anthropogenic sources. Various authors have suggested why cervids seek tree bark, particularly red deer (*Cervus elaphus*). For moose, however, no single hypothesis has been verified. Possible mechanisms inducing bark stripping are discussed here, including the role of nutrient deficiencies in moose. Finally, methods for reducing bark stripping damage by moose are discussed.

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Almost all forest land in Fennoscandia (i.e., Finland, Norway, and Sweden) is subject to silviculture, and cultivated forests are dominated by only 2 tree-sized conifers, Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). Pine dominates in the northern parts of Sweden and Finland, and in the eastern parts of Norway, while spruce dominates elsewhere (Lavsund 1987, Faber 1996). Together these 2 species account for approximately 90% of the commercially used trees, with the other ca. 10% comprised of deciduous trees, mainly birch (*Betula* spp.), and introduced lodgepole pine (*Pinus contorta*). Forestry has a very high commercial value since forest products are one of the main export articles, especially in Sweden and Finland, contributing 17% (Statistical Yearbook of Forestry 1996: 290) and 34% (Anon. 1996) of the export value for these two countries, respectively. In Norway forest products account for 3.5% of the total export for the country (Statistics Norway 1997).

In Fennoscandia, damages caused by moose (*Alces alces*) in commercial forests have been documented since the end of the 19th century (Fredenberg 1889, Bromée 1939, Axelsson 1990, Faber 1996). Browsing of young shoots is the most prevalent form of damage, with stem breakage and bark stripping of stems occurring to a lesser degree (Lavsund 1987). The greatest commercial losses attributed to bark stripping by moose are seen in Scots pine (Nygrén 1990, Faber 1996, Troms Skogselskap 1996), with lesser impacts on Norway spruce (Furulund 1977, Axelsson 1990, Pehrson and Faber 1993). The damages, including bark stripping, caused to the commercial tree species by moose in Fennoscandian countries are an important factor to consider during moose management discussions.

The purpose of this review is to summarize the literature concerning bark stripping by moose in commercial forests of Fennoscandia with regards to Scots pine and Norway spruce, as this type of forest damage is of concern for modern forestry throughout this region. Our objectives are to review: (1) patterns of occurrence of bark stripping, including geographic distribution; (2) relationships to stand characteristics; (3) plausible hypotheses explaining bark stripping by moose, especially concerning qualitative aspects of bark; and (4) measures to reduce damage, including alternate forestry practices.

OCCURRENCE OF BARK STRIPPING

Scots Pine

There are some regional differences in bark stripping by moose which have been observed in some studies, especially in Sweden. In southcentral Sweden, the damage to pine is confined to sapling stands 1.5-4 m tall, but to the north older trees in 'thinning-stage stands' are also frequently barked (Faber and Thorson 1996, Faber *et al.* 1996). Bark stripping in central Sweden occurs mainly during spring, while in the north it takes place throughout the year with a higher frequency in mid- to late winter (Bokeland 1983, Faber 1996).

In Norway however, bark stripping on pine occurs only to a very limited extent and little research has been done on this subject (Histøl and Hjeljord 1993, Troms Skogselskap 1996, O. Hjeljord, *pers. comm.*). In one area of southern Norway stripping of oak (*Quercus robur*) trees was recorded (Engeland and Pettersen 1994). In Finland pine saplings are stripped to some extent all over moose areas but at very low frequencies and few monitoring studies have been performed (R. Heikkilä and K. Nygrén, *pers. comm.*).

In Sweden, where stands of young Scots pine are subject to bark stripping, generally less than 5% of trees are affected each year (Faber 1996, Faber and Thorson 1996). A good portion of these damages are re-stripping. Although total bark stripping damages appear to be low on the landscape level, there is concern for measurable economic losses at the local scale. The spatial distribution of bark stripping varies with spatial scale. Thus in a typical forest landscape in coastal northern Sweden, bark stripping occurred quite regularly at the landscape level (100 km^2), but was more patchily distributed on the local (1 km^2) and stand (1-10 ha) scale. At the tree level less than 1% of the pine were bark stripped in this particular area (L. Edenius, *unpubl. data*). High incidence of bark stripping (>5% of pine stripped on an annual basis) is uncommon and confined to moose winter yards.

Norway Spruce

In the past decade, bark stripping of Norway spruce has increased in parts of southern Fennoscandia where this previously occurred only to a small extent (Axelsson 1990, Pehrson and Faber 1993). In these new occurrences there is an apparent association with areas of high acidification from anthropogenic sources (Brodin 1993, Pehrson and Faber 1993). Also, in the county of Älvsborg in southern Sweden, extensive bark stripping of Norway spruce, which in the past had been non-existent or sporadic, began occurring in the early 1980's. Then in 1985, in the same areas as the damage to spruce, moose were found dying of a previously unknown disease, a wasting syndrome (Rehbinder *et al.* 1991, Stéen *et al.* 1993), and more than 1,400 animals have since been found sick or dead in association with this syndrome. The question has been raised, and remains to be answered, if the two phenomena are related. Studies so far have not proven there to be any relationship (Axelsson 1990, Pehrson and Faber 1993).

In Norway stripping of spruce bark by moose has also been recorded (Furulund 1977). In Finland although local cases of stripping on mature spruce trees occur annually, the phenomenon is rare (R. Heikkilä and K. Nygrén, *pers. comm.*). However, little research has been done in either country concerning this problem (R. Heikkilä, O. Hjeljord, and K. Nygrén, *pers. comm.*). In the Republic of Estonia and other parts of the Baltic states, southeast of Fennoscandia, considerable damages to spruce have been recorded (Randveer and Heikkilä 1996, W. Faber, *pers. comm.*).

RELATIONSHIPS TO STAND CHARACTERISTICS

Research in Sweden has shown that frequency of bark stripping seems to be related to site productivity, stand size, and density of trees. Results of investigations at Grimsö Wildlife Research Area (GWRA) in southcentral Sweden (Faber and Thorson 1996), and in the county of Dalarna in westcentral Sweden (Hjelm 1995), have shown a weak positive relationship between frequency of bark stripping and forest productivity (expressed as m^3 forest growth/ha/yr) at the stand and landscape level. Johansson (1979) found that the frequency of bark stripping on young Scots pine stands in the same region as GWRA was twice as high on stands with forest productivity over 5.5 m^3 forest growth/ha/yr. Andrén and Angelstam (1993) in southcentral Sweden also found pine bark stripping was positively correlated with apical shoot length, i.e., an index of site class productivity, and this relationship was significant.

Similar trends were seen in bark stripping of Norway spruce as in pine. It was found that these damages also had a higher frequency of occurrence in spruce stands on areas of higher productivity (Axelsson 1990, Pehrson and Faber 1993) in southern Sweden.

Faber and Thorson (1996) in southcentral Sweden found a weak negative relationship between stand size and percent bark stripping on pine. In contrast, Andrén and Angelstam (1993) and Hjelm (1995) found no such effect.

A weak negative relationship has also been found between bark stripping frequency and pine stem density (Hjelm 1995, Faber and Thorson 1996). In pine sapling stands, Andrén and Angelstam (1993) found moose browsing damages including bark stripping to be reduced at stem densities over 1,500/ha and 2,500/ha in northern and southcentral Sweden, respectively.

PLAUSIBLE HYPOTHESES EXPLAINING BARK STRIPPING BY MOOSE

There has been much research and many hypotheses advanced to explain the occurrence of bark stripping by cervids in general, especially red deer (*Cervus elaphus*), in continental Europe and the British Isles (McIntyre 1972; Gill 1992a, b). However, until recently relatively little scientific work has been published on the subject in regards to moose in Fennoscandia (Nygrén 1990, Hjelm 1995, Faber 1996, Faber and Thorson 1996). We have adapted for moose the most plausible hypotheses suggested to explain bark stripping by red deer (McIntyre 1972), which include the following: (1) Bark contains high concentrations of certain trace elements and vitamins, and has been found by some investigators to have a digestible energy and mineral content which is frequently higher than that of other available foods; (2) bark contains much lignin and is thus a good source of the roughage necessary for proper rumen functioning; (3) bark stripping is a behavioral trait caused by human disturbance within the forest; and (4) bark stripping damage is caused by a few individuals only, though in time others may acquire the habit.

Although no single hypothesis has been demonstrated, most authors agree that bark stripping in winter appears indicative of browse shortage, while in spring moose direct activity towards, and actively select for pine bark (DesMueles 1968, Faber 1996).

QUALITATIVE ASPECTS OF BARK STRIPPING

When considering why moose bark strip pine trees, Faber (1996) looked at the nutritional value of pine bark compared to other more traditional moose browse species, specifically bilberry (*Vaccinium myrtillus*) and birch. Digestibility analyses (i.e., *in vitro* dry matter disappearance) showed that pine bark is within the range of digestibilities of bilberry, and twigs of birch and willow (*Salix* spp.) which are normally browsed. Furthermore, nutrient analyses show that the concentrations of 6 major nutrients (crude protein (CP), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K)) in pine bark were generally lower in spring and early summer than in leaves and twigs of both bilberry and birch. Thus, the cause of bark stripping did not appear to be selection for higher concentrations of any of these 6 major nutrients (Faber 1996).

Acid detergent fiber (ADF) and acid detergent lignin (ADL) in pine bark were somewhat higher throughout the year than in bilberry and birch. In addition, at the peak of bark stripping in April and May (Fig. 1), ADF and ADL in pine bark (Fig. 2) showed a corresponding peak; whereas the fiber in bilberry and birch had much lower values and showed a definite decreasing trend (Faber 1996). This suggests the possibility that moose require additional amounts of fiber (i.e., pine bark) in the diet during spring and early summer to assure proper rumen function by offsetting the high-moisture, low fiber contents of the main browse species (i.e., birch and dwarf shrubs of Ericaceae) being consumed then (Faber 1996).

Furthermore, it was also found that pine bark contains significantly higher amounts

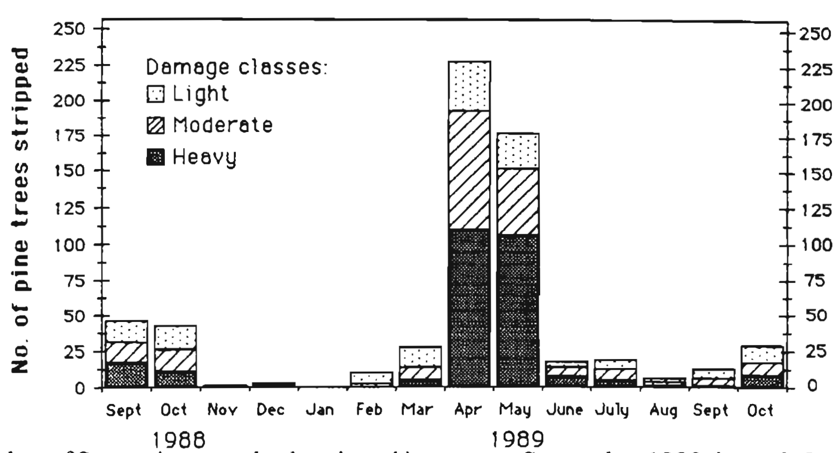

Fig. 1. Number of Scots pine trees bark stripped by moose, September 1988 through October 1989, along 3 line transects on each of 4 pine plantations within the Grimsö Wildlife Research Area, Sweden, based on monthly surveys (from Faber 1996).

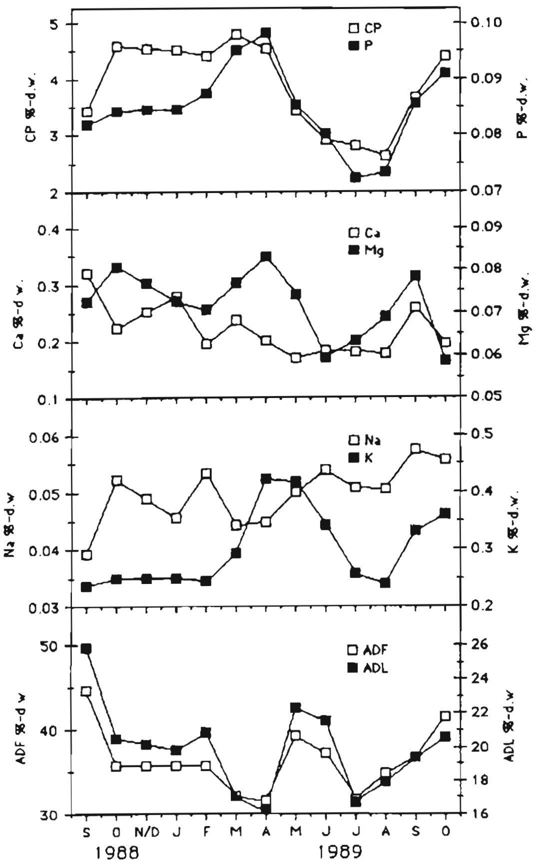

Fig. 2. Concentrations in percent of dry weight (%-d.w.) of crude protein (CP), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), and the fiber fractions acid detergent fiber (ADF) and acid detergent lignin (ADL), analyzed from Scots pine bark collected between September 1988 and October 1989, at the Grimsö Wildlife Research Area, Sweden. (from Faber 1996).

of starch and total carbohydrates during spring and summer than during the rest of the year (Fig. 3), coinciding with the peak in bark stripping (Fig. 1)(Faber 1996). This suggests that these elevated levels of starch and total carbohydrates, in addition to making pine bark more palatable, also give an input of energy in the diet, albeit small (Faber 1996). Additionally, regarding winter bark stripping of pine in Finland, Nygrén (1990: 51-52) states "Palatable deciduous

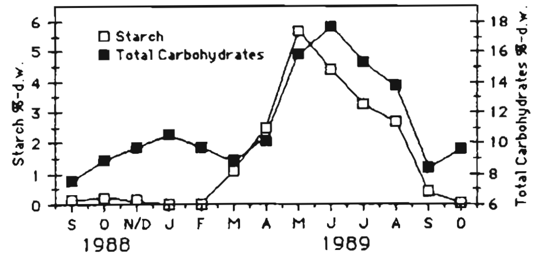

Fig. 3. Concentrations in percent of dry weight (%-d.w.) of starch and total carbohydrates (the sum of the simple sugars glucose, fructose, sucrose, fructan, maltodextrin, and starch) analyzed from Scots pine bark collected between September 1988 and October 1989, at the Grimsö Wildlife Research Area, Sweden. (from Faber 1996).

trees and the inner bark of pine may act as a complementary or alternative source of the carbohydrates needed for mobilizing endogenous nitrogen for microbial synthesis in the rumen of overwintering moose." At present however, it remains difficult with the results obtained in the various studies (Nygrén 1990, Faber 1996, Faber and Thorson 1996) to determine any definitive qualitative factor underlying moose bark stripping in Fennoscandia. This should seem plausible considering that most qualitative aspects concerning bark and bark stripping including nutrient concentrations, digestibility, fiber, and site productivity seem to be interrelated thus making it difficult to identify any single mechanism as the definitive cause leading moose to bark strip (Pehrson and Faber 1993).

METHODS FOR REDUCING BARK STRIPPING DAMAGE

General Aspects

When discussing means to reduce damage it is important to consider both the trees (food plants) and moose. Models of plant-animal dynamics indicate multiple stable states in the interaction between moose and trees, dependent on initial plant density, density of animals, herbivore per capita attack (consumption) rate, and plant growth rate (Noy-Meir 1975). Thus, with respect to damage by moose, stable states may exist at different combinations of tree:moose densities. However, acceptable levels of damage will ultimately be a political decision. No controlled experiments have been performed designated to assess methods for reducing bark stripping damage by moose in Fennoscandia.

Moose Density

The general positive relationship between moose density and frequency of bark stripping suggests that culling may be one means of reducing overall damage. For example, in the early and mid-1980's damage to Scots pine by moose in Sweden, including bark stripping, was increasing due to high moose population numbers (Hörnberg 1995). Subsequently, in order to reduce damage there was a considerable increase in the moose harvest (Cederlund and Markgren 1987), which later resulted in decreased damage to young pine stands (Hörnberg 1995). However, since there are indications that bark stripping may be done by a few specialized individuals only, as has been suggested for red deer (McIntyre 1972), damage would be expected, at least locally, also after a reduction in moose density. This would be particularly pronounced if bark stripping is a cultural phenomenon, i.e., transferred from cow to calf. This has not been proven for moose.

Regulation Of Tree Density And Spacing Of Trees

Since there seems to be an inverse relationship between frequency of bark stripping and tree (stem) density, a high stocking rate of trees could be advocated to reduce damage. Results by Faber and Thorson (1996) suggest that delaying thinning until Scots pine trees have grown above 4 m should reduce the amount of damage by maintaining a higher density of saplings during the critical 1.5-4 m size range. In commercially managed forests, regular spacing of trees should be the objective, as an uneven spacing seems to increase the risk of damage (Hjelm 1995).

Increase The Abundance Of Preferred Food

In parts of Fennoscandia bark stripping is reported to be negatively associated with the abundance of highly preferred winter food plants such as aspen (*Populus tremula*), rowan (*Sorbus aucuparia*), and willow (Nygrén 1990, L. Edenius, *unpubl. data*). Thus, measures to increase or maintain a high abundance of these species, such as delayed or selective pre-commercial thinnings in sapling stands, may reduce incidence of bark stripping. Prescribed burning, which is favorable for recruitment of these species, has been re-introduced as a forest management tool in Fennosocandia. In 'thinning-stage stands' abundance of forage is low because of poor light conditions, which reduces the potential to use food plant availability as a management tool.

Retention Of Suppressed Trees

In 'thinning-stage stands' trees with reduced growth seem to be particularly susceptible to bark stripping. Retention of suppressed trees or delayed thinning may reduce the risk of damage to commercially valuable trees. Retention of suppressed trees could also lessen the burden on main stems by increasing overall food abundance.

Fencing Valuable Stands

Fencing is of course the most effective way of preventing bark stripping. However, the cost is considerable, which limits the applicability of the method (Faber *et al.* 1996). Fencing is therefore recommended as an extraordinary measure to protect the most economically valuable stands in areas where moose aggregate during winter.

CONCLUSIONS

Bark stripping of conifers by moose in commercial forests of Fennoscandia is a common and natural occurrence, albeit at low frequencies. Although total bark stripping damages in this region are negligible on the landscape level, important economic losses for small-scale forest owners may occur, and thus suggested methods for reducing bark stripping damages should be considered. There is as yet, no single method that can completely eliminate this problem, however a reduction in such damages can be achieved through improved moose and timber management practices

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