Alaska Department of Fish and Game
Division of Wildlife Conservation
Wildlife Technical Bulletin #10

Harvesting Birch-Spruce Forest to Enhance Moose Habitat in the Matanuska Valley Moose Range

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March 1992

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HARVESTING BIRCH-SPRUCE FOREST TO ENHANCE MOOSE HABITAT IN THE MATANUSKA VALLEY MOOSE RANGE

SUMMARY

A variety of timber-harvested sites within the Matanuska Valley Moose Range (MVMR) were surveyed to determine how they were harvested and what effects different cutting and site preparation techniques had on hardwood (browse) regeneration and associated moose habitat values.

While stump and/or root sprouting contributed to the overall regeneration of paper birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*), and willows (*Salix* spp), reestablishment by seed was by far the most significant, particularly in sites where trees had been clearcut and the organic mat had been disturbed. The most dense regeneration occurred where scarification exposed mineral soil but did not displace nutrient-rich organic material more than 24" from any given point.

Canadian bluejoint grass (*Calamagrostis canadensis*) became an intense competitor with browse species by the second growing season following overstory removal. It was critical that site preparation occur before or during the first growing season after overstory removal. Timely scarification not only allowed for germination of stored hardwood seeds but also enabled seedlings to develop enough to compete successfully against increasing competition from bluejoint grass.

By contrast to the above hardwood species, regeneration of aspen (*Populus tremuloides*) depended primarily on root sprouting rather than on seedling establishment, and it appeared adversely affected by scarification. The most dense stands of resprouting aspen occurred in clearcuts where all aspen were cut, particularly where entire clones were removed and where cutting occurred during dormancy.

Browse availability was the principal determinant of moose distribution within clearcuts of the size surveyed. Utilization was relatively uniform throughout individual clearcuts. Willows were the most preferred, followed by paper birch, then aspen and balsam poplar. Most stump or root sprouts of these species reach a height available to moose by the end of their second growing season, but seedlings required an additional 2 years to become available as browse. By 13 years, however, most current annual growth will occur above the reach of moose.

Recommendations for enhancing hardwood regeneration in southcentral Alaska forests are given.

Key Words: moose, *Alces alces*, browse, forest clearcutting, site preparation, scarification, Southcentral Alaska

Table of Contents

Page

BACKGROUND

Moose have strong preference for early seral stages of forest succession. Certain shrubs and hardwood trees are major components of their diet. Availability of browse within the boreal forest zone is largely the result of disturbances which cause portions of the landscape to revert to early successional condition. According to Rowe (1961), mature or decadent boreal forest does not "return through an inevitable cycle to youth and an optimum phase but rather tend[s] to remain open, ragged, awaiting the rejuvenating touch of fire, flood, or windfall-ploughing of the soil."

In southcentral Alaska, the principal browse species of moose -- paper birch (*Betula papyrifera*), willow (*Salix spp.*), balsam poplar (*Populus balsamifera*) and aspen (*Populus tremuloides*) -- require a seedbed of exposed mineral soil and adequate sunlight in order to regenerate from seed. They will also regenerate through stump or root sprouts, particularly if the forest canopy is opened to allow sufficient sunlight to reach the understory. Birch reproduces primarily by seed, whereas, under most conditions, aspen reproduces by root sprouts.

The two principal natural forces resulting in retrogression of plant communities are fire and fluvial action. The most significant in terms of acreages affected has been fire. During recent decades, however, fire suppression has nearly eliminated this force as a stimulus for production of moose browse. This represents a significant change in the ecosystem, one which causes moose to become increasingly dependent on riparian vegetation and sites where vegetation has been disturbed by man.

In the boreal forest, complete removal of the overstory by logging can be used in conjunction with scarification techniques to mitigate for habitat lost as a result of fire suppression. Overstory removal by itself seldom provides hardwood seeds with necessary exposure to mineral soil. Additional steps must be taken to scarify the soil in order to obtain significant regeneration of most hardwood species. Aspen is an exception in this regard, since it can regenerate a dense stand by root sprouting.

Since 1982 several small areas within the Matanuska Valley Moose Range (MVMR) have been clearcut logged with the intention of stimulating browse production for moose, while at the same time enabling commercial and private wood cutters to utilize renewable timber resources. Clearcutting within MVMR was conducted with minimal understanding of how harvesting and site preparation techniques would affect tree regeneration and associated browse production in that ecosystem. The survey reported herein was conducted to determine what harvesting systems and site preparations were most effective in producing moose browse.

OBJECTIVES

The primary objectives of this survey were to: 1) document how sites were harvested and subsequently treated to stimulate deciduous tree/shrub regeneration, 2) identify factors which enhance or inhibit browse regeneration in the MVMR, and 3) evaluate various clearcuts in terms of their suitability as moose habitat.

LITERATURE REVIEW

Moose Habitat Enhancement

The primary problem faced by managers of moose populations today and in the future is the maintenance of adequate habitat (Franzmann 1978). Prescribed burning, logging, selected land clearing and mechanical rehabilitation are means by which vegetation can be returned to early successional stages favorable to moose (Oldemeyer 1977). Timber harvest plans not only need to address enhancement of browse but also need to ensure that adequate escape and thermal cover are retained in close proximity to feeding areas.

With the progressive exclusion of fire from forest ecosystems, timber harvest increasingly constitutes the most practical means of restoring a diversity of seral conditions favorable to moose. From the standpoint of browse production, clearcutting of moderate-sized patches is usually more beneficial to moose than selective cutting or thinning (Murphy and Ehrenreich 1965). According to Lykke and Cowan (1968) the great increase in Scandinavian moose populations this century has resulted from selective-cutting being replaced by clearcutting as the preferred system of timber harvest. The primary benefit of clearcutting has been to allow full sunlight to reach the ground thereby stimulating production of shade-intolerant, browse species.

Considerable discussion has developed in the past 2 decades regarding the optimum width for clearcuts where habitat enhancement for moose is a prime consideration. Moose prefer to graze within a certain safe distance of escape cover. According to Todesco et al. (1985) however, most width recommendations have been based on theory. They suggest that smaller openings trap snow more effectively than larger ones, thereby causing moose to prefer larger openings when snow depth begins to inhibit their movement. Furthermore, few investigators have described the ameliorating effect of rapidly developing cover on moose use within clearcuts. Rapid growth of cover within clearcuts may, in part, be the reason there is so much variation in reported distances that moose are willing to browse away from edges of cutover areas (Peek 1971, Neu et al. 1974, Stone 1977, Hamilton 1980, McNicol and Gilbert 1980).

Site Preparation (scarification)

Among the potential reasons for following timber harvest with some type of site preparation (Daniel et al. 1974) are: 1) improvement of soil moisture conditions, 2) removal of competing vegetation, 3) reduction of slash, 4) improved wildlife food and/or cover, and shortened time for tree regeneration. Depending on tree species and site characteristics, site preparation objectives can be accomplished by the harvesting system itself, burning of harvest residues and understory, or by post-harvest mechanical treatments.

Mechanical means of site preparation typically scarify the soil in such a way that patches of the organic layer are stripped off and cast to the side. Thorsen (1978) described several beneficial effects of scarification in boreal forests, including elevation of soil temperature to favor root development in tree seedlings. Removal of ground cover also allows soil to reradiate heat during the night thereby reducing frost damage to new seedlings. Perhaps most important to hardwood seedlings is that scarification reduces competition from other plants for light, nutrients and water.

Thorsen (1978) also described several problems which can be associated with scarification. Scarification in morainic soils having a high content of silt and fine loam increases the risk of frost heave damage to new seedlings if soil disturbance is too deep or extensive. Likewise, scarification which is too deep and/or narrow may also result in excessive accumulations of water and may readily be covered by adjacent vegetation laying over the scarified patch. Scarification may also result in a reduced supply of nutrients where mineral soil is exposed, because nutrient rich organic matter has been cast aside. However, warming of the soil brought about by overstory removal and disruption of the organic mat may result in no net change or an actual increase in soil solution nitrogen, phosphorus and potassium by increasing microbial mobilization of these nutrients (Van Cleve and Dyrness 1983). According to Heilman (1968) rapid mineralization of these nutrients occurs in exposed mineral soils. Thickening of a moss and/or duff layer on top of these soils results in lower rates of mineralization and reduced availability for uptake by roots.

Aldridge (1967) reported that larger patches of exposed soil resulted in better tree regeneration than smaller ones. In the case of paper birch, this is because germinants survive better on mineral soil than on litter or mosses (Perala 1987). However, Zasada et al. (1977) found that paper birch grows faster where its roots have access to organic matter. According to Teikmanis (1956), seedlings occur most often on edges of cultivation because soil mix qualities are superior. Optimal exposure of soil, thus, may represent a tradeoff between eliminating or reducing competing vegetation while retaining hardwood seedling access to nutrient-rich organic material. It is also dependent on how readily adjacent vegetation can reinvade or lay over the scarified patch.

Thicknesses of organic and mineral soil horizons, fertility of the mineral soil and wetness of the site affect the selection of scarification method. The most common methods of scarification for mesic soils in Scandinavia develop either continuous furrows or scarified patches (Appelroth 1981) neither of which exceed 18 - 24 inches in width. Similar scarification is preferred in Canadian boreal forests and utilizes much of the same equipment developed in Scandinavia (Coates and Haeussler 1987). It is important to note, however, that use of incorrect methods or operation of correct equipment by untrained operators can devastate a site by too severely disrupting its nutrient, moisture and temperature relationships (Smith 1988).

Wet sites often must be drained by ditching and/or mounding. On drier sites full-tree skidding with branches intact can also prepare an ideal seedbed if it is done during snow-free periods and where the organic mat is not too thick (Safford 1983). According to Perala (1987) grazing aids in birch establishment but he cautions that continued heavy grazing hinders survival of seedlings after they have become established.

Densmore (1988) evaluated 2 scarified clearcuts within the MVMR (labeled as Sites 2 and 6 in the present study) to determine the effectiveness of site treatment by a flat blade versus a clearing blade (sometimes also referred to as a root rake). She determined that scarification by the clearing blade produced higher birch seedling density and growth rate. Scouler willow (*Salix scouleriana*) densities did not differ significantly. However, she reported that birch and willow seedlings were "virtually absent" where scarification was shallow and had not removed all of the organic layer. Seedling densities and growth rates were greatest where the A-horizon was exposed, but considerably lower on exposed B-horizon. On B-horizon sites, the best growth occurred at the edges where seedlings were apparently protected from needle ice and had access to nutrients in adjacent unscarified soil.

Densmore (1988) compared planting of greenhouse-propagated, containerized willow seedlings with direct seeding of scarified sites and concluded that both methods were marginally effective. She recommended retention of mature willows within logged areas to ensure natural seeding.

Browse Ecology

Paper birch, aspen, willows and balsam poplar all are adapted to taking advantage of disturbed sites (Viereck and Shandelmeier 1980). All can reproduce from seed where mineral soil is exposed and competition from herbaceous species is reduced. Each of these species may develop from stump sprouts, but according to Argus (1973), willows are premier in this regard. However, willow densities usually are relatively low in well developed birch-spruce stands as a result of shading, and, consequently, their total production by sprouting may be quite low compared to sprouting species which compete well in the overstory. Of the sprouting species which occur in the overstory, aspen and, to a lesser extent, balsam poplar reproduce well by root- and stump- sprouting, providing the stand is clearcut. In the case of aspen, the entire clone should be clearcut in order to eliminate apical dominance which suppresses adventitious bud development. Aspen stands treated in this manner may produce over 80,000 stems per acre (Gregory and Haack 1965). Paper birch does not root- sprout but does stump-sprout fairly well until 40 - 60 years of age (Perala 1987).

Each of these browse species reproduces best in large openings and full sunlight where the organic mat has been disturbed (Safford 1983, Zasada et al 1983, Viereck and Schandelmeier 1980, Argus 1973). They often dominate early successional stages but become decreasingly important as relatively stable mature vegetation develops. Loss of necessary seedbed conditions under developing forests reduces the opportunity for browse species to regenerate and remain in later successional stages. Significant reduction of willows is also a result of competition for light by taller trees and shrubs (Argus 1973). Older birches, likewise, do not tolerate shade (Perala 1987)

Willow, balsam poplar and aspen produce large quantities of light, tufted seeds which can be transported long distances by wind (Viereck and Shandelmeier 1980, Argus 1973). However, because these seeds are viable for only a short time, they must readily encounter ideal seedbed and weather conditions in order to successfully establish. While enhanced seedling establishment on mineral soils has usually been ascribed to better moisture conditions, Zasada et al. (1983) suggest that there probably are influences other than available water, since during many summers periodic rainfall keeps the organic layer sufficiently wet to prevent desiccation of seedlings. Nevertheless, reproduction of these hardwoods from seeds is greatly improved by exposure to mineral soil.

Paper birch also produces heavy seedfalls, up to 2600/ft^2 (Zasada and Gregory 1972), but its seeds are winged and are relatively heavy compared to the other species. Most paper birch seeds fall within 100 - 200 feet of the parent tree. Bjorkbom (1971) estimated paper birch seedfall at clearcut edges to be 60% of interior stand seedfall, but only 10% at 50 m into the clearcut. Therefore it is recommended that clearcuts of this species be less than 300 feet wide or contain 3 - 5 well distributed seed trees per acre (Safford 1983, Zasada 1972).

Canadian Bluejoint Ecology

Canadian bluejoint (*Calamagrostis canadensis*) is the most common of over 100 species and sub-species of the genus *Calamagrostis*, ranging throughout Alaska and most northern latitudes (Tolmochev (1964). It prefers open, mesic sites in burned or cleared boreal forest (Bliss 1973, Laughlin 1969) but can inhabit a variety of settings, from wet, lowland sites to dry, windswept alpine ridges (Mitchell and Evans 1966).

Mueller and Sims (1966) reported that bluejoint preferred fine textured, moist soils. Hernandez (1972) stated that bluejoint was also a good pioneer of dry upland sites. In any case, bluejoint is widespread, and even where it occurs inconspicuously in mature forest it can quickly capitalize on any disturbance which reduces competition from overstory species (Bliss 1958, Mueller and Sims 1966).

Bluejoint readily monopolizes cutover areas of boreal forest (Mitchell and Evans 1966), thereby eliminating favorable conditions for hardwood seed germination. Those hardwood seedlings which do begin to establish themselves must compete with bluejoint for water and nutrients. New hardwood seedlings must also be able to withstand shading and smothering effects of the tall grass, as it often bends down, forming dense mats which in combination with snow may bend hardwood seedlings to the ground (Mitchell and Evans 1966).

Bluejoint is a winter hardy perennial that begins producing new growth from seeds or rhizomes in mid-May. By mid-June it may reach heights of 4 to 7 feet (Mitchell and Evans 1966). The nutritional value of this grass rapidly declines after seedheads begin to form in late June (McKendrick 1983). Seeds are not dropped until late September, thereby ensuring that they will not germinate until the following spring when conditions are favorable for establishment (Mitchell 1968). In addition, he found that the number of seedheads produced increased by 700% in disturbed areas, individual seedheads producing a maximum of 150 seeds each.

Rhizome spreading is an equally effective means by which bluejoint can colonize disturbed sites (Mitchell 1968 and McKendrick 1984). Disturbance of rhizomes may actually result in propagation of a higher density stand than prior to disturbance, if conditions are favorable for multiple segments of broken rhizomes to develop (Hernandez 1972). Rhizomes need to be completely eliminated if one is to ensure that bluejoint does not immediately rebound via vegetative reproduction.

Whereas McKendrick (1984) reported that bluejoint status within a plant community is favored by moderate levels of uniform grazing, Mitchell (1979) and Klebesadel and Laughlin (1964) found that bluejoint is intolerant of intensive cropping, particularly if grazing begins in spring and the grass is completely cropped 3 or more times during the growing season This is because its growing point is elevated and easily removed by grazing animals. Removal of the growing point forces the plant to go through the more expensive process of developing from adventitious buds of rhizomes. Repeated several times during a season, this process will deplete nutrient reserves within the rhizome.

METHODS

Initially, timber sale files located with Division of Forestry, Big Lake were reviewed to determine as much as possible about pre-harvest stand characteristics; type, timing and duration of timber harvest activities; and type, timing and coverage of scarification. A field survey of each clearcut was then planned to determine some of the history not available in timber sale files.

Forty 5m^2 plots were systematically dispersed throughout each clearcut to determine densities, ages, percent utilization, above-ground biomass, and current annual growths (length and weight) of each browse species within each of four height classes: 0-15cm, 16-50cm, 51-100cm, and 101-200cm. Distance from the edge of the clearcut and percent cover by bluejoint grass, moss, litter and bare ground were also estimated within each plot. Ten soil cores were taken from each plot in order to estimate percent cover by scarification and to determine the depths of O- and A-horizons. Stump sprouting and height of browsing were also measured at each plot.

The effects of scarification were examined in closer detail to determine what conditions associated with soil and vegetation disturbance are most important for successful establishment of birch seedlings. Scarified patches in Site 6 were sampled at 50 cm intervals from their edge for density, age, height, current annual growth and cover of birch and height and cover of bluejoint. Depths of soil horizons were noted at each interval, and 8 cores of the top 5 cm of soil at each interval were collected, frozen and later analyzed for NH4, NO3, total N, P and K. Data were analyzed under a randomized block design, where scarified patch was the blocking variable and distance from edge was the explanatory variable.

RESULTS AND DISCUSSION

Site Characteristics

Sites 1 through 12 (Table 1, Figure 1) are well drained birch-spruce sites occurring on level to rolling glacial moraine. Soils are primarily of the Homestead-Knik association. They are silty and shallow over loose sand and gravel. Vegetation potentials of these sites are probably the same although differences in proportions of birch, white spruce, aspen and balsam poplar in their overstories can be observed. Variability among sites in regard to the presence of aspen is primarily dependent upon the degree to which dry, shallow, gravelly soils of steep slopes and ridges are present. The understory of these 12 sites is dominated by bluejoint grass, oak fern (*Gymnocarpium dryopteris*), horsetail (*Equisetum arvense*), lowbush cranberry (*Vaccinium vitus-idaea*) and highbush cranberry (*Viburnum edule*).

Site 13 is a gently sloping site which supports paper birch, white spruce and black spruce, but no aspen. By contrast to the other 12 sites its soils are poorly drained, moderately deep silt over firm, moderately fine textured sediments. It receives seepage and runoff from uplands and is wet year round. Its soils are in the Coal Creek series. Bluejoint grass dominates the understory of adjacent uncut stands. Alder is more abundant on this site than on the others.

Timber Harvest and Post-cut Site Characteristics

Timber sale files described location, timber volume, approximate dates of harvest, and general harvest guidelines, including prescribed scarification coverage. Ecological characteristics such as overstory and understory coverage and/or density by species were not included in stand descriptions. Likewise, ages and growth rates of woody species, soil conditions, seed sources, weather conditions at the time of harvest and methods of scarification were seldom described in harvest reports. Consequently, most of this type of site information was obtained from memories of people dealing with the timber harvests or reconstructed based on observations of current conditions, stumps and slash, and adjacent uncut forest stands.

The following focuses primarily on methods of harvest and scarification, subsequent regeneration of woody species and development of competing ground cover. Sizes of harvests, methods of harvest and scarification, and general post harvest characteristics are summarized in Table 1. Densities of hardwood species and white spruce are summarized in Tables 2 through 6.

Site 1. This stand was cut primarily during winter 1981-82. Since harvest was by personal use firewood cutters and because it occurred in the winter, little if any scarification occurred as a result of the harvest itself. In summer 1983, the site was scarified by use of a flat dozer blade. Use of the flat blade was significant in that it exposed wide patches of B-horizon, placing most of the organic and A-horizon in berm piles. As a result, many of the large scarified patches were essentially stripped of nutrients and have since developed limited or poor regrowth by woody species. Moss (*Polytrichum spp.*) dominates on most sites where the B-horizon has been exposed. Seedlings of birch and willow which have established on those sites are stunted from lack of nutrients and/or frost heaving which is common of large patches of fine-textured B-horizon.

Site 2. This site was also logged primarily in winter on a personal use basis, and scarification was by a flat dozer blade. Greater hardwood densities have developed on this site even though soil cores indicate that total coverage by scarification was approximately 1/2 that of Site 1. Better regeneration on this site may be partially due to the fact that it was scarified within the same year as completion of cutting. Scarification within the year not only allows residual seeds to germinate (most hardwood seeds are not viable after one year) but also limits the time bluejoint has in which to thicken and dominate the site before hardwood seedlings can become established. It is not known to what degree seed fall from adjacent forest varied between the years Sites 1 and 2 were harvested.

Site 3. Prior to harvest, the majority of trees in this site were aspen. The stand was commercially harvested in winter. Although the density of aspen root sprouts was good relative to the densities of other hardwoods occurring on other harvested sites, regeneration was poor relative to the potential for aspen. Poor root sprouting most likely was the result of not all trees being cut and the clearing being small. Aspen root sprouting is suppressed by the apical dominance of intact stems left in the clone as well as by shading at the edge of the clearing. Browse production per acre could have been increased 10 to 20 times by more complete removal of trees and enlargement of the clearing. It also appeared that heavy utilization of aspen by moose occurred because the site is a small, isolated occurrence which provides a relatively unique food item within the general area.

Site 4. This site was commercially harvested in winter and, therefore, only resulted in scarification of main skid trails. Some follow up scarification with a flat blade was done along the perimeter of the site, but it was excessively deep and resulted in large, relatively infertile patches of soil. Even considering that only the perimeter was scarified, the amount of bare ground still showing far exceeds that of any other site (Table 1) and is indicative of the depth and severity of scarification. Most unmerchantable spruce and some aspen were left standing. Hardwood regeneration within the unscarified portion was limited primarily to stump sprouts. Most establishment of birch seedlings was along the edges of the main haul road.

A series of seed traps placed in an east-west line, perpendicular to the edge of this clearcut in 1989 and 1990 indicated that adequate numbers of seeds, dispersed from adjacent forest, reached the center of this site even in low seedfall years (Figure 2). Seed dispersal was less uniform further from the edge, presumably as a result of seeds accumulating in depressions and snow drifts. However, these accumulations coincide with scarified patches or other breaks in the grass cover. It should also be noted from Figure 2 that approximately 1/3 of total seed fall occurred in the first month (1 September - 2 October). Seed distribution was strongly affected by the Matanuska Valley wind which prevails out of the northeast. Apparently few seeds were dispersed into the clearcut from its western (downwind) edge.

In mid July 1990 a 1/2 acre plot near the south end of the site (Figure 3) was treated with the herbicide glyphosate to test its effectiveness in reducing competition by bluejoint. One-half of the plot was burned in the first week of August to remove dead grass. Four 20 X 20 foot plots in the burned portion and 1/2 of the unburned portion were then scarified with a clearing blade in mid October 1990 to test combined effects on hardwood seedling establishment. Alternating strips of the remainder of the site were scarified by a clearing blade mounted on a Case 660 skidder, a TTS-35 disk trencher pulled by a Case 660, or left untreated as a control. Previously scarified areas near the perimeter of the stand were rescarified in an attempt to drag nutrient-rich organic material and soils from adjacent berms back into infertile patches in order to reclaim them.

Scarification tests in 1990 indicated that the amount of slash and standing trees left following cutting were excessive and reduced the efficiency of scarification.

<u>Site 5</u>. This site was chained in March 1983 by two D-9 dozers dragging an anchor chain between them. The chain was first dragged in one direction and then in the opposing direction. Initially it was planned that the clearing would follow a zig-zag pattern in order to maximize edge effect for wildlife. However, much of this planned effect was lost due to the difficulty of maneuvering the dozers accordingly while at the same time dragging the chain. Nevertheless the clearing is long and relatively narrow, thus maintaining a high edge:area ratio.

While the chain was effective at tipping trees, it resulted in little scarification because it skidded along the top sides of tipped trees rather than contacting the ground. Most scarification was associated with soil exposed by upturned stumps. Deep snow and frozen soil may also have reduced chain contact with the ground, and scarification effects may have been better in late summer or fall. Money for this project was only available in winter or, at the latest, early summer when soil was too wet for operation of the dozers and chain.

Downed timber within this site was subsequently gleaned by firewood cutters. Apparently, however, the twisted and tangled nature of the downed timber and dirt-imbedded wood reduced its desirability and utilization. Thus, this site had more than twice the amount of slash ("litter", Table 1) of any other site. Not only would this amount of slash greatly limit follow-up scarification, but in places it is sufficient to impede movement by moose even after having had 7 years to decompose.

Site 6. This site has excellent regeneration of birch and Scouler willow within a band through the center of the clearcut, and very poor regeneration on either side of that. The central portion of the clearcut was scarified with a clearing blade in fall 1984. This scarification not only took advantage of the peak period of birch seedfall, but the clearing blade resulted in less removal of organic and A-horizon soil from scarified patches. This is indicated by the high A- to B-horizon ratio (Table 1). Within the scarified area, a higher percentage of scarification coverage was also achieved. Some of the berm piles at this site continue unbroken for 100 feet or more, but high levels of browse utilization indicate that the piles have not restricted use of the site by moose.

Sites 7 - 10. These sites were commercially harvested and scarification was the result of road building, skidding and decking of logs. Each of these sites is characterized by relatively high densities of aspen saplings. Densities of aspen are particularly high on hillsides and ridge tops where well developed stands existed prior to cutting. Overall densities of birch for each site are roughly inversely proportional to the area covered by aspen. The greatest escapement (proportion of stems in 1-2 m height class) of aspen from browsing by moose appears to be occurring in Sites 7 and 10 where there are the highest densities of aspen and hardwoods overall (Tables 2-5). Higher rates of escapement indicate the importance of higher stem densities in relieving the detrimental effects of browsing by moose. It will be informative to monitor the development of birch in Site 6 which has not had as much time for seedlings to develop into the taller height classes but which has a relatively high birch stem density.

Sites 11 and 12. Even though these sites were harvested in winter and received little scarification, all four hardwood species reproduced well, likely because the sites had healthy components of all species prior to cutting. Most stems of aspen, balsam poplar and willow in the stand are root or stump sprouts. Birch likewise sprouted from stumps, but for unknown reasons a relatively high number of birch seedlings also established.

Site 13. This site was logged in winter because it is to wet for operation of machinery at any other time of year. Consequently, less than 1% of the site was sufficiently disturbed to be considered scarified. The absence of scarification is reflected by very poor regeneration of hardwoods. Furthermore, the wetness of the site has contributed to development of a very dense stand of bluejoint which is 4 - 5 feet tall. Birch regeneration has occurred on hummocks or upturned stumps where seedlings are elevated above the high water table, able to receive greater exposure to light, and less likely to be damaged by tall grass matted down by snow. A planting of 2-year old balsam poplar seedlings at this site totally failed at least in part because seedlings were less than 18 inches high and were bent over and suffocated by grass matted down by snow.

A comparison of this site with adjacent uncut sites suggested that removal of trees reduced evapotranspirative loss of water, allowing the water table to rise to the surface. Furthermore, it appears that the only way the adjacent stands have been able to perpetuate themselves has been through a process of mature trees falling and thereby creating hummocks of exposed soil upon which new seedlings could become established. Thus, post-logging site preparation for wet stands of this type probably will require creation of hummocks and/or development of drainage ditches.

Moose Habitat Values

The principal determinant of moose distribution within clearcuts was the availability of browse. Freshly fallen trees and lopped branches were readily browsed by moose, even while logging was in progress. Aside from slash, little or no winter browse was available in clearcuts in the first year following clearcutting. As browse production by sprouting or by seedling establishment increased, the presence of moose increased.

Mean lower height of browsing was 62 cm (SE 18.2, range 42 - 122). Lower height of browsing apparently was influenced by snow depth. Wind exposed portions of clearcuts were browsed at the lowest heights, while leeward hillsides and protected edges of clearcuts were browsed higher.

By the second year following clearcutting, stump and/or root sprouts of all species began to reach a height of winter availability to moose. However, in the absence of abundant seedling stock, birch stump sprouts were heavily utilized, and many began to die by year 4 or 5. Root and stump sprouts of aspen, balsam poplar, and willow appeared better able to maintain themselves in regenerating stands, even though in some sites their height development was retarded by heavy browsing.

Few hardwood seedlings were browsed prior to year 4 or before plants had grown into the 50 - 100 cm height class. By the time seedlings had reached the 1 - 2 m height class, all willow and most birch began to show signs of retarded height development as a result of browsing. By contrast, in Site 12 relatively few individuals of any species other than willow showed much retardation by browsing, and the terminal buds of most had already escaped the reach of moose by year 6. Wind-deposited snow at this site usually blocks access by moose by mid winter. Evidently, willows were browsed prior to deep snow.

Unchecked, aspen and balsam poplar will produce most of their current annual growth beyond the reach of moose by age 10. The most productive height class in terms of available browse appeared to be 2-4 m. However, in most sites, browsing typically prevented hardwoods from reaching that height (Table 7). While all species exhibited the potential to reach that height class by year 5 or 6, as indicated by terminal leader development, only balsam poplar reached that potential across all sites (Table 7). This was primarily the result of the low moose preference for balsam poplar. By contrast, willows exhibited comparable growth potential, but not one individual of the species was found which had developed to the 2-4 m category.

The structural characteristics of those shrubs which showed no evidence of having been browsed during their lifetimes indicated that approximately 75% of the current annual growth of birch, balsam poplar and aspen occurred within the height development of their last 2 years (Figure 6, Table 7). In other words, most of the current growth of these plants occurred at the top, and very little new growth occurred on lower side branches. Given this relationship, and in view of rates of height increase (Table 7), it is apparent that most of the current annual growth of unbrowsed shrubs will be produced above 4 m height within 2 - 3 more years. As these species grow taller than 4 m, their stem diameters at breast height generally exceed 4 cm (the approximate upper limit to what moose will break in order to obtain browse beyond their reach).

Scouler and feltleaf willows (*Salix scoulerana* and *S. alaxensis*) were clearly the most preferred browse items in clearcuts. During both winters of this survey, moose browsed willow stems before utilizing stems of any other species. Willows were heavily browsed by 15 December both years. Paper birch was the next most preferred browse species, since it received the second highest percentages of twigs browsed while being the most abundant species in most stands. Although aspen was totally utilized in sites where it was sparse or otherwise limited in total quantity, it was generally utilized at much lower percentages in clearcuts where its total availability was similar to other species. Aspen was heavily browsed in Site 3, a stand which occurs in the midst of an area where aspen is generally scarce. The least preferred browse species, balsam poplar, had the lowest percentages of twig utilization where it occurred in similar stem densities to other species. The low preference for balsam poplar was somewhat surprising, considering the nearly total utilization of this species in nearby floodplain sites where it dominates. However, less restrictive snow conditions on windy floodplains may enhance the attractiveness of dense, monotypic stands of balsam poplar relative to dispersed and poorly accessible browse in adjacent areas of deeper snow.

Except for along the margins of logging roads, browse utilization by moose in the 1 - 2 and 2 - 4 m height classes was relatively uniform throughout all portions of each clearcut. Heavier utilization occurred along logging roads, presumably as a result of snowmachine traffic maintaining a trail through the snow. There were no indications that the distribution of moose on clearcuts was affected by size, configuration or location of the clearings. However, it should be noted that all clearcuts sampled were relatively narrow and within the range of widths reported by other investigators as being entirely acceptable to moose. Furthermore, by age 5 years, density and height of regeneration at site 11 had produced hiding cover equivalent to uncut forest. Dense accumulations of slash in some areas of the chained clearing may have inhibited use by moose.

The MVMR clearcuts are located in an area heavily used by recreationists. People regularly walk, ride ORV's, mountain bike, ride horseback, ski, snowmachine, mush dogs or drive highway vehicles through all clearcuts except at Site 13 which is too wet for most of these activities. Easy vehicular access has also resulted in relatively heavy hunting in the general area. Barriers have been erected to close some of the haul roads to vehicular traffic, yet all have remained open, as people have simply gone around the barriers. Even with these high levels of human use, utilization by moose was uniformly distributed within clearcuts, except along roads where utilization was heavier.

Scarification Effects

Through the course of this survey, it became increasingly apparent that scarification following clearcutting is necessary to produce site conditions supportive of seedling establishment by birch, scouler willow, felt leaf willow, and balsam poplar. Seedlings of these species simply were not found where sites had not been scarified post harvest or in the process of logging. Regeneration of birch, willow and balsam poplar by stump or root sprouting did not result in sufficient densities to simultaneously support reforestation and browsing by moose. By contrast, aspen regenerated well by root sprouts.

Removal of overstory by logging, particularly in winter, does not match the effects of fire or the natural uprooting of trees, since it does little to expose mineral soil. Logging also eliminates the possibility for natural uprooting of stumps, since it removes the portion of a tree which wind and gravity leverage to tip the stump. In upland sites, elimination of these two natural forces leaves only the minor influence of burrowing or digging animals to expose hardwood seeds to mineral soil.

Given the importance of scarification, questions of how and when best to scarify should be addressed. In some cases, such as Sites 1 and 2, deep scarification was too severe, because it displaced nutrients too far from scarified patches and/or produced soil conditions leading to frost heaving of new seedlings. In other instances scarification was too late relative to removal of the overstory. This was particularly evident in stands which were logged over a long period of time and/or left unscarified for more than two years after completion of logging. Under these conditions bluejoint became so well established that scarification equipment was rendered partially or totally ineffective, and bluejoint was readily able to monopolize scarified patches.

Size of scarified patch also had a significant effect on hardwood seedling establishment. Scarified patches less than approximately 12 inches wide were readily overgrown by adjacent grass, whereas central portions of patches exceeding 5 feet width were too infertile or otherwise harsh for vigorous hardwood seedling establishment and produced stunted growth or seedling death as a result of poor nutrition and/or frost heaving.

Availability of ammonia (NH_4), phosphorus (P), and potassium (K) all significantly ($p < .05$) decreased with increasing distance from the edge of scarified patches (Tables 8 - 10). NO_3 also decreased but at $p = .0518$ (Table 11). SQRT(NH_4) and SQRT(P) both decreased in quadratic fashion (r^2's = 0.786 and 0.678, respectively) (Figures 3 and 4) whereas K decreased in a linear fashion ($r^2 = 0.3552$) (Figure 5). All of the above relationships were observed without blocking for possible site differences. Obviously, each of these soil nutrients were found in greater abundance at the edge of scarified patches where O- and A-horizons were deposited.

It was then assumed that the concentration of nutrients found at edges of scarified patches would favor seedling establishment (density) and growth (height and current annual growth). A stepwise regression procedure (Neter and Wasserman 1974) was used to determine the best predictors of paper birch height, density and current annual growth from the possible predictors of total N, P, and K. An alpha of 0.05 was used to determine which variables were significant and should be left in the model. The same procedure was used to determine the best predictors of birch height and current annual growth, using the natural log of the response variables.

Using the natural log of height, K was the only significant predictor of height (alpha = 0.05). The best predictive model was:

$$\ln(\text{birch height}) = 2.090054 + 0.014061 \times \text{potassium}.$$

The model had an R^2 of 0.3468.

Likewise, using the natural log of current annual growth, K was the only significant predictor of current annual growth. The best predictive model was:

$$\ln(\text{current annual growth}) = 1.475102 + 0.012223 \times \text{potassium}.$$

The R^2 for this model was 0.3751.

At alpha = 0.05, none of the variables were significant predictors of paper birch density, meaning that density is a poor indicator of soil macronutrients. This would suggest that micro-environment is more critical in the initial establishment of seedlings than it is for their growth after 2 or 3 years when roots have had a chance to access more fertile soil.

Indeed, the relatively low predictive values of the above models may best be explained by the absence of micro-environmental characteristics as explanatory variables. This is not to say that fertility is not an important aspect of seedling survival and growth in scarified soil. In actuality, seedlings found in the central portions of large scarified patches showed definite signs of poor nutrition. However, these observations, taken in conjunction with those of seedlings near edges, spanned strong thermal, cryogenic and evapotranspirative gradients, the effects of which overshadowed soil nutritional effects.

Perala (1987) presented a good review of micro-environmental effects, making a strong case for incorporation of humus and coarse woody debris into mineral soil. The value of such a practice is believed to be the result of improved nutrition, surface thermal and moisture characteristics, and possibly soil mychorrhizae relationships. Perala (1987) observed that most seedlings occurred on mineral soil, but they had the poorest growth.

Levels of ammonia and potassium remained high within 50 cm (20 inches) of edge, whereas phosphorus changed less with distance. It should be noted however that paper birch is particularly sensitive to P availability (Perala 1987) and any change in availability at the already low levels characteristic of southcentral Alaska soils is significant with regard to paper birch regeneration. Phosphorus is particularly important in enabling seedlings to survive and to develop roots (Hoyle 1965, 1969). Nitrogen is the second most limiting element for birch. Both limited and excessive N can reduce seedling growth (Ingestad 1977).

Based on the above observations, ideal scarification should expose A-horizon soil in patches or strips not exceeding approximately 24 inches wide, with stripped-off organic matter being deposited at the edges. Wider patches will require incorporation of woody debris and/or relatively grass-free humus into the exposed mineral soil in order to maintain favorable micro-environmental conditions similar to at the edge. While exposure of A-horizon soil and retention of humus may be most desirable, in practice it is difficult to separate these from bluejoint rhizomes and other competitive vegetation. Consequently, some patches of B-horizon may be exposed. However, this is not necessarily a problem if nutrient rich organic materials and their micro-environmental influences are within approximately 12 inches of exposed B-horizon. While seedlings may initially be stunted by poor nutrition when establishing on B-horizon soil, by the second or third year their roots can reach fertile soil under these conditions. Limiting exposure of B-horizon will have additional value in reducing frost heaving commonly associated with larger patches that are less protected by surrounding vegetation, litter and debris.

With regard to birch seed germination it should be noted that few seedlings became established after the first year following scarification. The reason may be twofold: Seeds from the year prior to cutting are plentiful, viable, and immediately ready to take advantage of disturbance, whereas transported seeds are not present to take advantage of the best seedbed conditions and experience an exponential decrease in their distribution away from their source. The porous and open characteristic of the scarified surface immediately begins to "heal over" as it becomes compacted by rain, covered by litter, and revegetated by mosses and competing herbaceous vegetation. For these reasons it is most advantageous for scarification to occur within the year following cutting and immediately prior to or during the period of heaviest seed dispersal (1 September through 30 October).

Scouler and feltleaf willow establishment apparently is enhanced by early- to mid-summer scarification, since their seeds are dispersed during that time and do not remain viable for more than a few weeks. Therefore, scarification to enhance establishment of these species would optimally be completed by mid July, earlier than the peak period of birch seedfall. I am undecided whether earlier scarification is less advantageous for birch establishment, but considering that scarification during the fall period of birch seed dispersal may be delayed by rainy weather, scheduling or equipment breakdowns and that onset of winter may force postponement until the following year, it probably is most practical to allow scarification for birch, as well as willow, to begin as soon as conditions permit in early summer. At the very least, early scarification for birch will take advantage of stored seed, and it is likely that at least a portion of seedfall in September and October will still be able to come in contact with good seedbed conditions.

New, but apparently temporary, seedlings of both paper birch and the willow species continue to appear in large exposed patches of B-horizon even after the first year, since these sites are annually churned up by frost heaving, blown clear of litter, and poorly covered by competing vegetation. But given the unstable, poor growing conditions of these sites, occurrence there of 1- and 2-year-old seedlings is not necessarily a good indicator of stand regeneration. Furthermore, the relatively high seedling densities often associated with exposed sites should not be used in the computation of regeneration success (as is currently the practice) if such sites are sparsely and/or poorly distributed, since, even if all seedlings survived beyond 3 -4 years, subsequent intra-species competition would eliminate the vast majority of individuals and likely result in an overall poorly stocked stand.

RECOMMENDATIONS

1. Clearcutting, including personal use firewood cutting, whether for enhancement of moose habitat or simply for utilization of timber resources, should not be attempted without site-specific requirements and guaranteed funds for proper scarification and/or special site preparation. Without proper site preparation hardwood regeneration may not be sufficient to meet guidelines of the Forest Practices Act (FPA), let alone capitalize on browse production potentials. Furthermore, restocking of cutover areas at rates equivalent to FPA requirements often appears inadequate because browsing by moose results in considerable stem damage and/or death of saplings.

2. Before timber sales are advertised for bid, a preharvest inventory should be conducted which minimally includes the following information: basal area by tree species; tree density by species for full range of heights; willow density; understory cover by dominant shrubs and herbaceous species; and general description of soils and topographic features.

3. Histories of timber harvests should be recorded, including: mapped location and layout, total size, dates and methods of harvest, slash disposal/accumulation, and prevailing weather and soil conditions during harvest.

4. Site preparation for each site should be described in terms of: method, date, % coverage by surface soil horizon, prevailing soil conditions, and the subsequent year's seedfall (as determined from 5 traps systematically distributed across the clearcut.

5. All preharvest inventory and regeneration surveys should be recorded on standardized forms, and this information should be filed in a permanent archive and made available to both DOF and ADF&G. Both agencies should work together to develop sampling and data recording procedures which satisfy both agency's needs.

6. All clearcutting (including personal-use firewood cutting) and scarification should be completed in a timely manner to take advantage of stored seed, to ensure optimal synchronization with seed drop, and to reduce the lag period in which competing grass cover has time to monopolize the site. This means that all cutting should be accomplished in discreet geographic phases which can be site-prepped at the appropriate time within one year of cutting.

7. Unless spruce regeneration is the primary objective, selective cutting should not be conducted unless immediately followed by firewood cutting or some other means of completely removing all overstory except seed trees.

8. All aspen stems exceeding 4 feet height should be cut.

9. Aspen sites should only be harvested between 1 October and 30 April. Late winter harvest is preferred.

10. Aspen harvests should be laid out to encompass entire clones.

11. Sites having soils and understory vegetation indicative of poor drainage or high water table should not be harvested unless research demonstrates appropriate site preparation techniques.

12. All downed stems larger than 4" diameter should be piled or removed from sites in order to allow efficient scarification of the site.

13. All stems smaller than 4" diameter should be scattered for eventual incorporation into soil by scarification.

14. Stump heights should not exceed 1 foot. Higher stumps impede scarification.

15. Five or six well spaced birch seed trees per acre should be left uncut until regeneration objectives have been met.

16. Tall shrub or tree-sized willows should be left intact for seed and browse production wherever they do not necessarily impede logging.

17. When contracts to cut timber or firewood are advertised for bid, they should include performances clauses requiring scarification of 60% of the site according to the following specifications:
    a. Scarification should remove O-horizon material from patches or strips, leaving behind as much humus and A-horizon as possible. This means that equipment must be operated at the shallowest depth which will still allow displacement of O-horizon. Patches or strips of B-horizon which unavoidably become exposed should not exceed 24 inches in width.

  - b. Scarification for every acre harvested must be completed between 1 May and 31 October within one year of harvest.
  - c. Unless research identifies better methods and/or equipment, scarification should be done using a disk trencher or clearing blade. Uprooting, bunching and skidding of whole trees during summer can in some cases also provide acceptable scarification
  - d. Tree-sized willows should not be uprooted by scarification.
  - e. Swales, potholes, or other sites that do not have tree cover prior to harvest should not be scarified or included in the determination of percent coverage by scarification.
  - f. Operators of scarification equipment should be trained to comply with scarification guidelines. Improper scarification can devastate a site.

18. Requirements outlined in DOF timber harvest contracts need to be monitored more closely by agency staff to ensure that successful bidders are complying with stipulations concerning times and methods of cutting, site cleanup and scarification procedures.

19. Research should be conducted to determine:
    - a. the effectiveness of other methods of scarification, with special attention given to controlling grass competition and incorporating humus and woody debris into scarified soil;
    - b. optimal timing of scarification;
    - c. specific methods for enhancing willow establishment in cutover areas;
    - d. an upper limit to clearcut width for moose as well as other species (In making this determination, distribution of wildlife in clearcuts of varying widths should be investigated at 5 year intervals, because cover values and associated use by wildlife change rapidly.);
    - e. methods for maintenance of browse stands, since rejuvenation of a stand probably entails less risk and greater returns than establishment of new browse stands from mature forest;
    - f. use of herbicides to control grass competition in the early stages of browse seedling establishment;
    - g. use of livestock to control grass competition and to promote other site conditions beneficial to browse seedling establishment;
    - h. optimal cutting time for stimulation of root sprouting by aspen.
    - i. valid site preparation techniques for wet sites.

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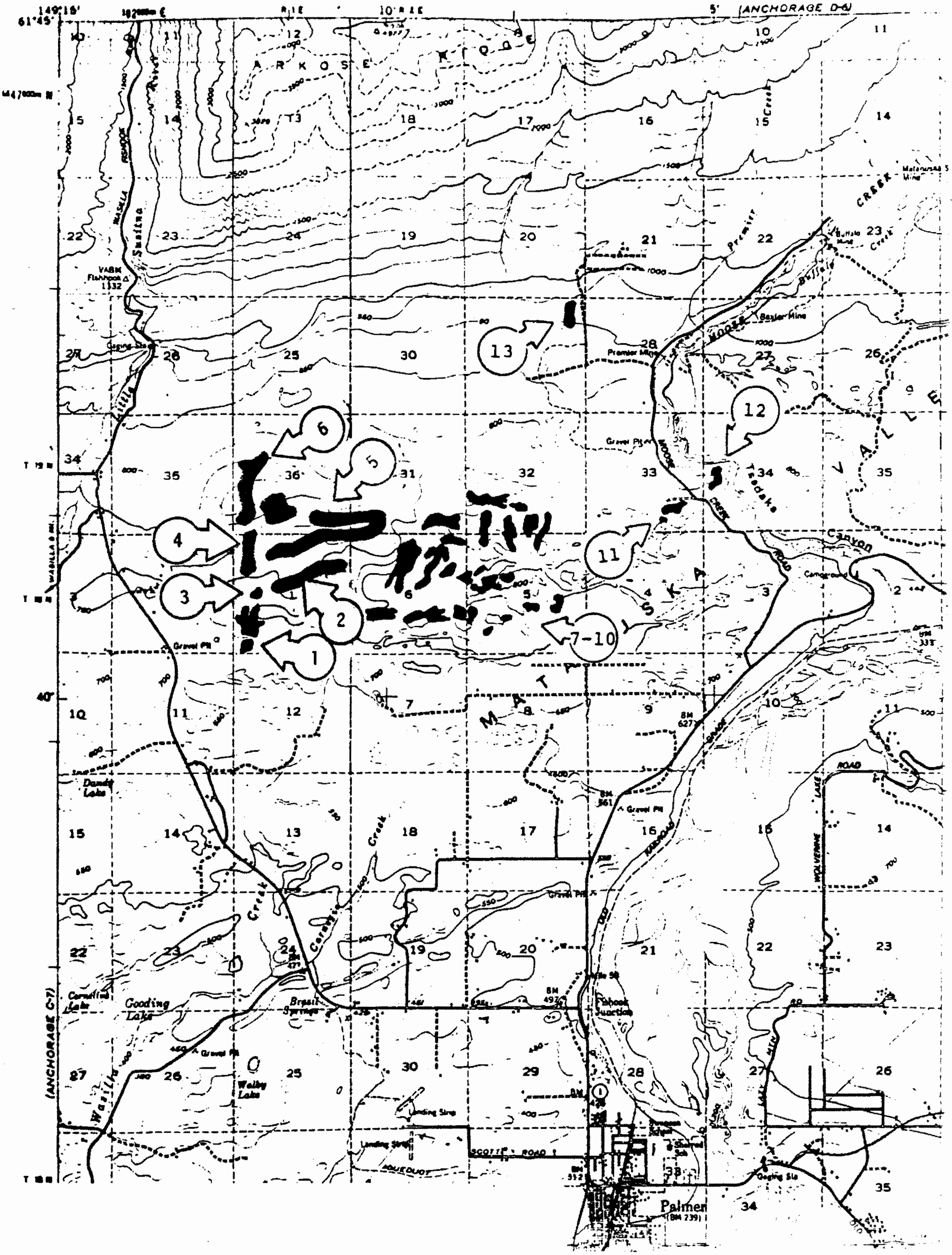

Figure 1. Timber harvest/study sites, Matanuska Valley Moose Range.

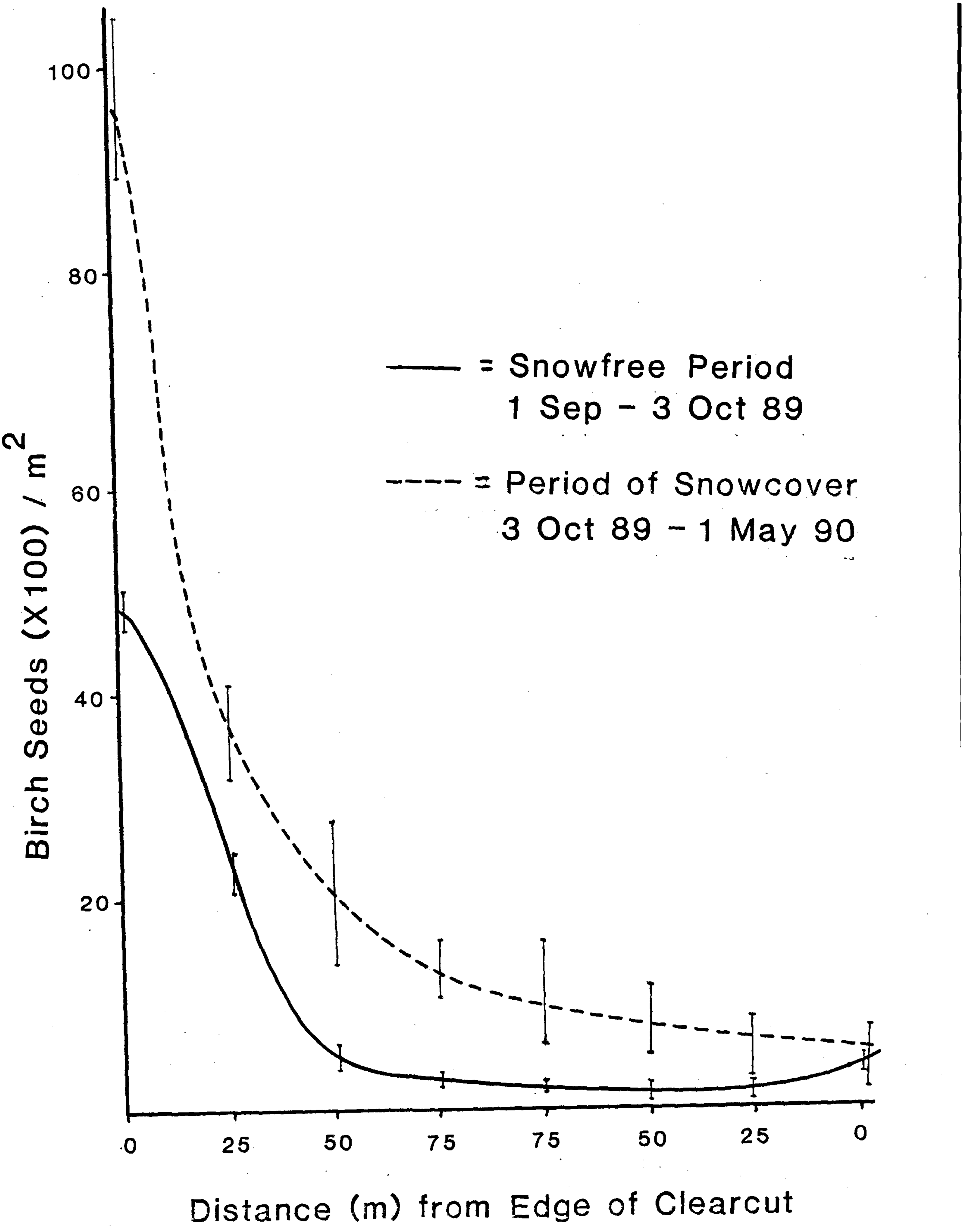

Figure 2. Birch seed distribution relative to distance from edge of clearcut.

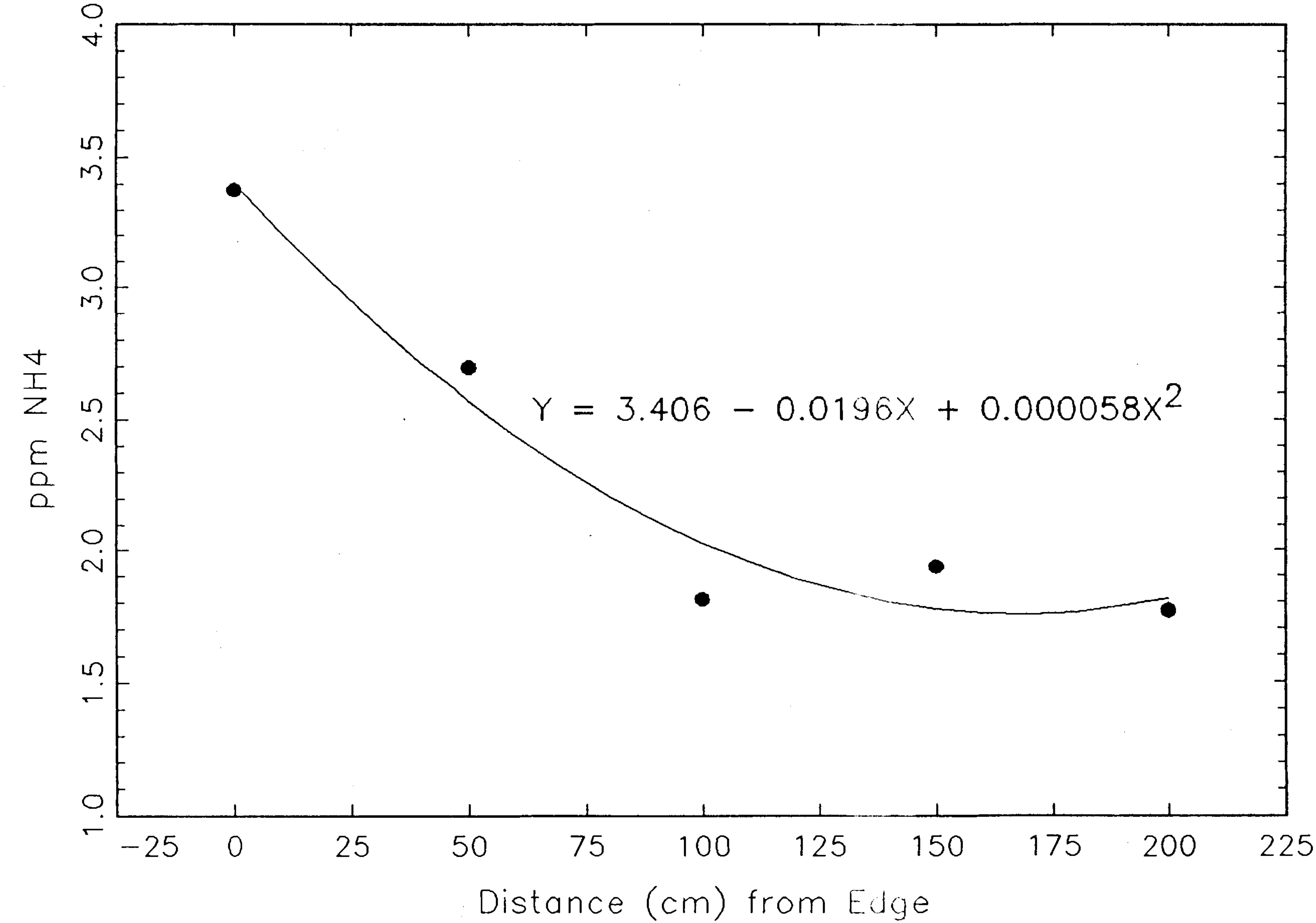

Figure 3. Distribution of NH4 from edge in scarified patch.

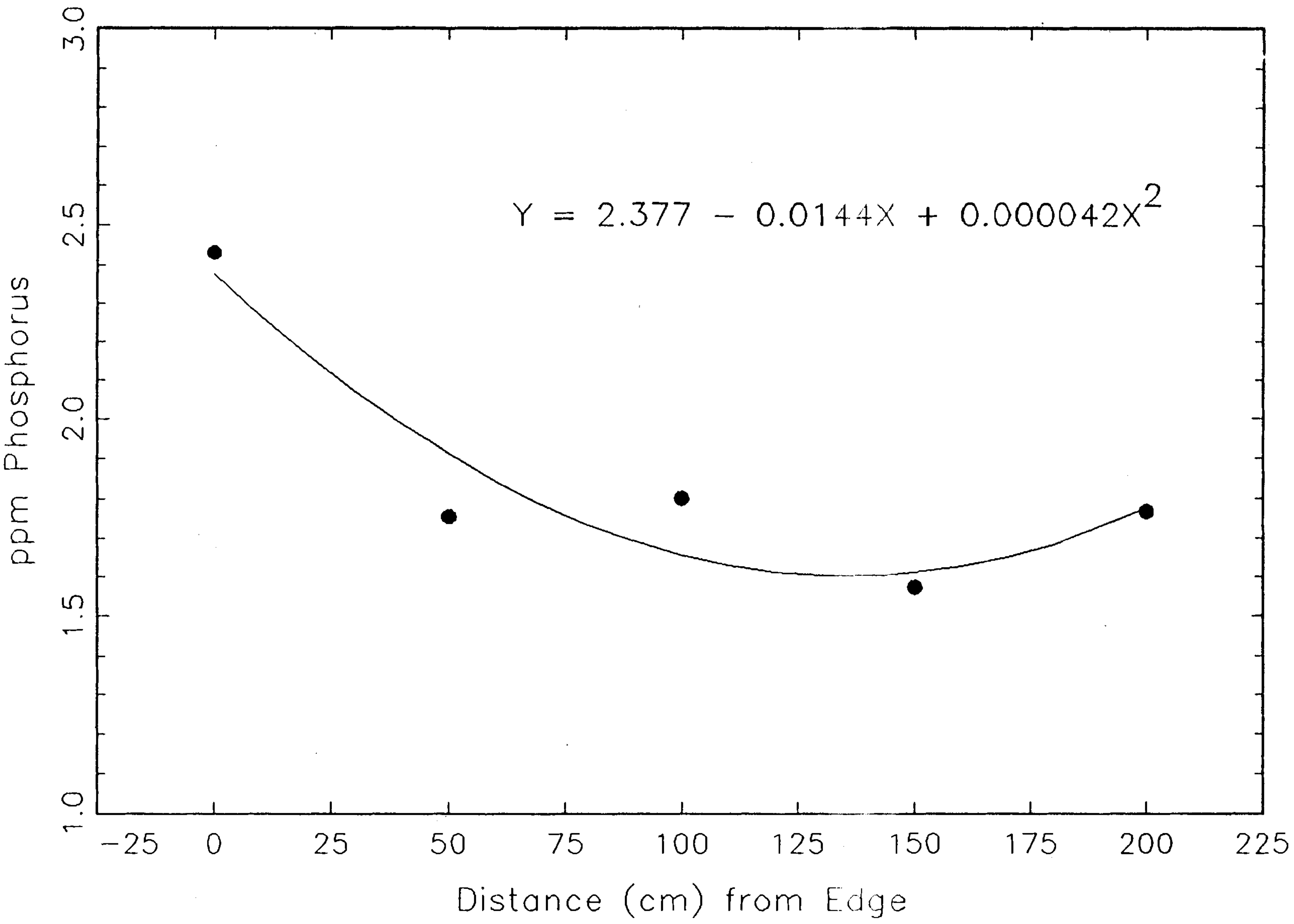

Figure 4. Distribution of phosphorus from edge in scarified patch.

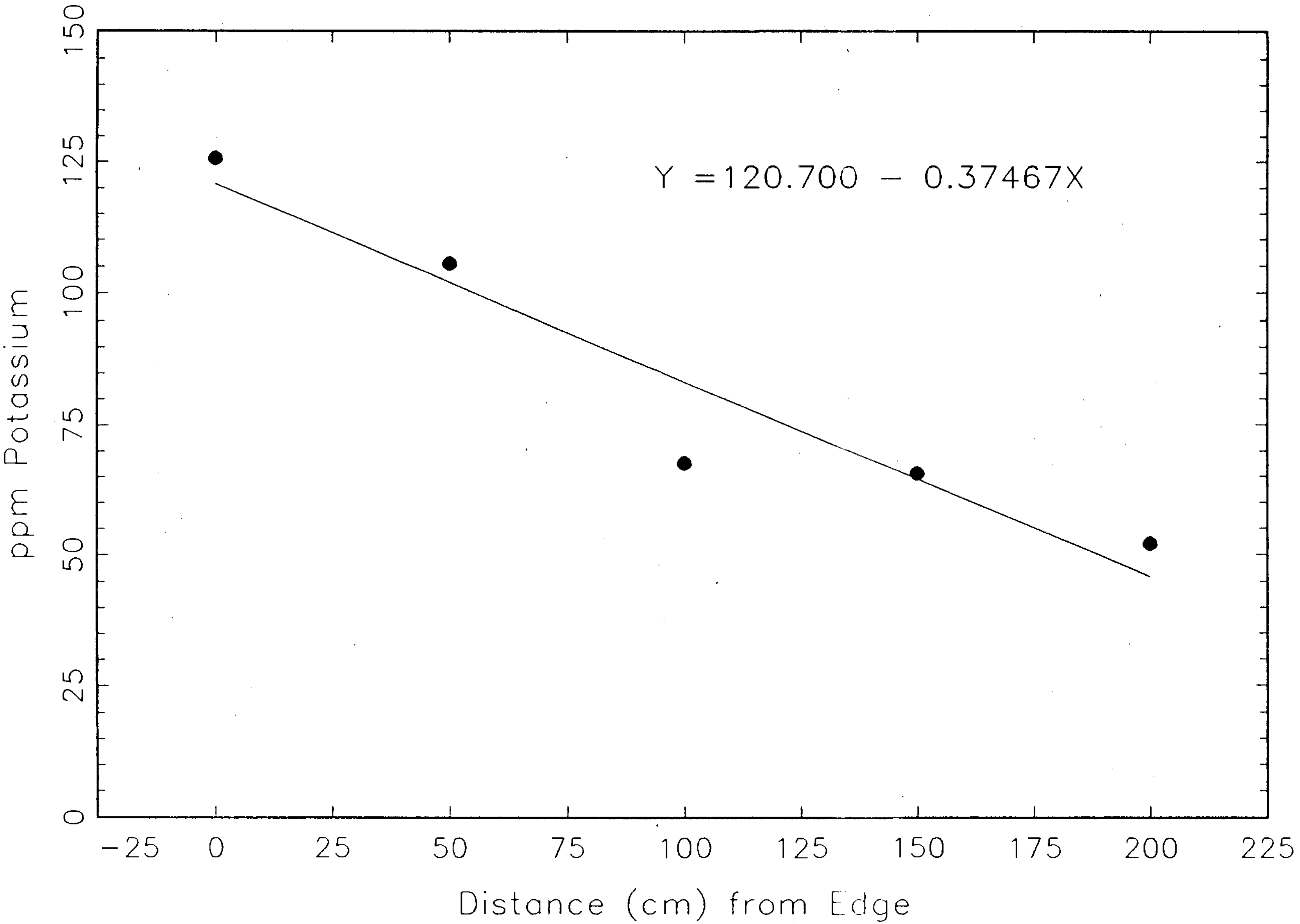

Figure 5. Distribution of potassium from edge in scarified patch.

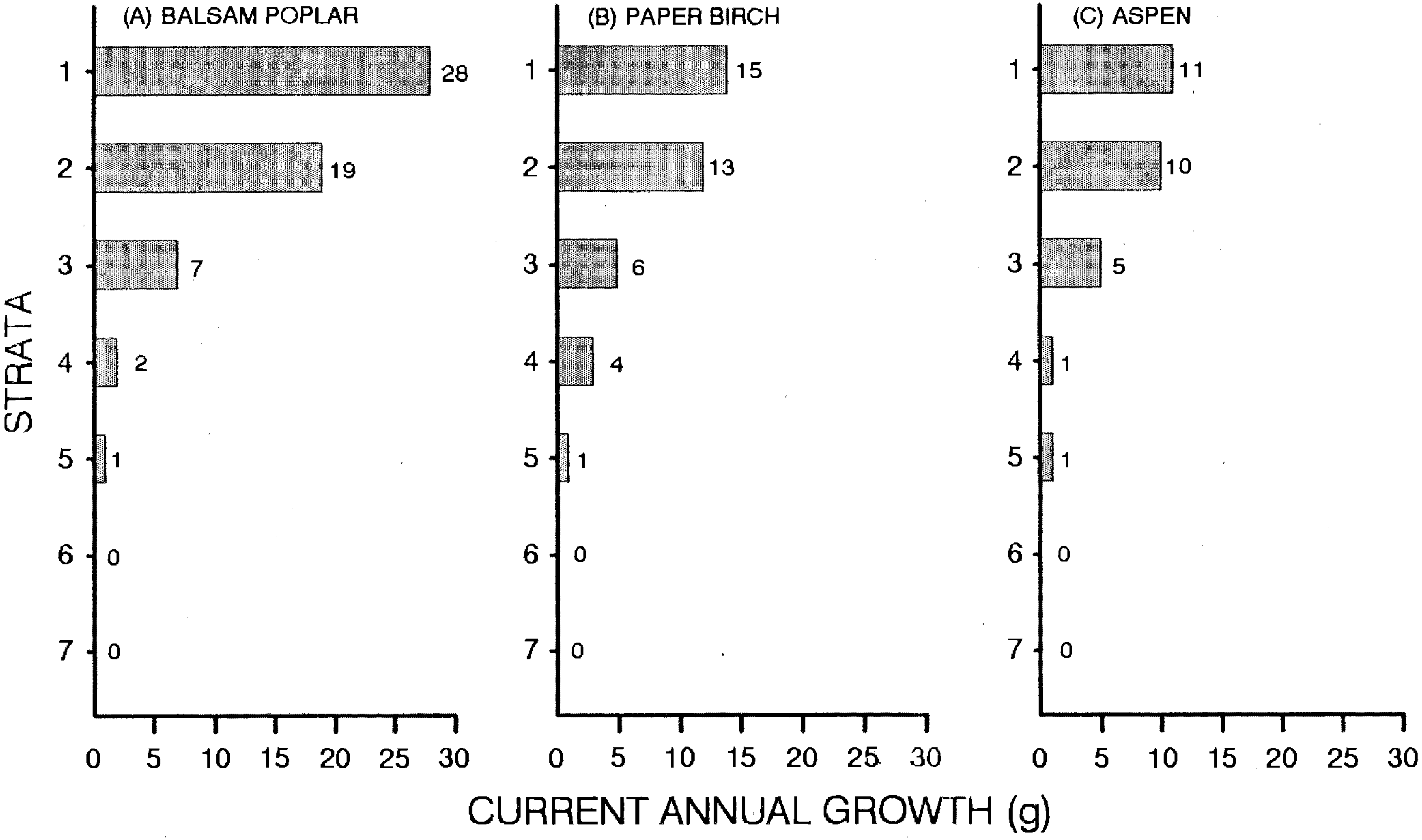

Figure 6. Current annual growth (CAG) by age:height strata for 3 species of browse. Each strata includes all CAG which developed between the terminal growth points of that year and the previous year. CAG in the upper most strata (1) is bracketed by that growth which is 1-year-old; CAG of the next lower strata (2) is breacketed by 2-year-old growth, etc., continuing down to the last strata which brackets CAG which occurred in that range of plant height that developed 7 years ago. N = 30 for each species.

Table 1. Historic sand conditions of forest clearcuts within the Matanuska Valley Moose Range.

Site	Type[1]	Acres	Date	Method	Site Preparation	% Scarified		% Grass	% Moss	% Litter	% Bare ground
						A	B				
1	Bepa-Potr-Poba-Pigl	23	winter 81-82	personal use	flat bladed summer 83	23	10	70	19	11	<1
2	Bepa-Pigl	43	82-83	personal use	flat bladed summer 83	12	5	77	16	6	1
3	Potr-Bepa	3	winter 83-84	commercial fuelwood	none	11	4	84	13	3	<1
4	Bepa-Pigl-Potr	19	winter 83-84	commercial fuelwood	flat bladed near edges	16	6	59	23	10	8
5	Bepa-Pigl Potr	94	83	chained	chained	3	<1	74	5	21	<1
6	Bepa-Pigl	40	82-83	personal use	rootraked fall 84	19	<1	75	16	9	<1
7	Potr-Bepa-Pigl	6	84-85	commercial fuelwood	none	7	3	76	7	10	7
8	Bepa-Potr-Pigl		84-85	commercial fuelwood	none	8	5	79	7	9	5
9	Bepa-potr-Pigl		84-85	commercial fuelwood	none	3	5	80	8	11	1
10	Bepa-Poba-Potr-Pigl		83-84	commercial fuelwood	none	9	4	78	8	10	4
11	Bepa-Potr-Pigl	7	82-83	commercial fuelwood	none	3	<1	86	7	7	<1
12	Potr-Poba-Bepa	7	winter 83-84	commercial fuelwood	none	1	0	89	1	10	0
13	Bepa-Pigl (wet site)	8	winter 82-83	commercial fuelwood	planted Poba	1	<1	94	<1	6	0

[1] Bepa = *Betula papyrifera*, Potr = *Populus tremuloides*, Poba = *Populus balsamifera*, Pigl = *Picea glauca*.

Table 2. Paper birch stem densities (stems/acre) and percentages of stems browsed within 4 height classes.

Site	Height Classes 0-.15m	.15-.5m	.5-1.0m	1.0-2.0m	Total
1	1,922 (0)	809 (0)	769 (68)	445 (85)	3,945
2	3,076 (0)	1,457 (0)	567 (64)	1,254 (76)	6,354
3	648 (0)	1,052 (0)	405 (65)	0 --	2,105
4	1,558 (0)	587 (0)	162 (56)	32 (72)	2,339
5	425 (0)	412 (0)	728 (62)	364 (96)	1,929
6	2,813 (0)	3,865 (0)	1,558 (70)	104 (82)	8,340
7	74 (0)	810 (0)	1,113 (69)	931 (97)	2,928
8	3,973 (0)	841 (0)	203 (57)	57 (95)	5,074
9	2,639 (0)	870 (0)	92 (12)	0 --	3,601
10	1,618 (0)	1,254 (0)	1,092 (26)	890 (23)	4,854
11	176 (0)	242 (0)	682 (32)	1,365 (82)	2,465
12	567 (0)	891 (0)	405 (87)	729 (97)	2,592
13	0 --	62 (0)	115 (15)	16 (62)	193

Table 3. Balsam poplar stem densities (stems/acre) and percentages of stems browsed within 4 height classes.

Site	Height Classes 0-.15m	.15-.5m	.5-1.0m	1.0-2.0m	Total
1	0 --	22 (0)	23 (0)	0 --	45
2	41 (0)	36 (0)	40 (21)	0 --	117
3	0 --	0 --	0 --	0 --	0
4	0 --	15 (0)	0 --	0 --	15
5	0 --	0 --	70 (16)	0 --	70
6	0 --	0 --	0 --	104 (82)	104
7	0 --	0 --	0 --	0 --	0
8	174 (0)	232 (0)	220 (28)	16 (56)	642
9	162 (0)	551 (5)	710 (78)	53 (90)	1,476
10	95 (0)	26 (0)	12 (0)	35 (0)	168
11	264 (0)	176 (0)	528 (17)	990 (49)	1,958
12	0 --	27 (0)	108 (25)	378 (14)	513
13	0 --	0 --	0 --	0 --	0

Table 4. Aspen stem densities (stems/acre) and percentages of stems browsed within 4 height classes.

Site	Height Classes				Total
	0-.15m	.15-.5m	.5-1.0m	1.0-2.0m	
1	0 --	182 (0)	81	0 --	263
2	0 --	60	140	0 --	200
3	0 --	486 (100)	2,550 (100)	0 --	3,036
4	0 --	20 (100)	145 (100)	0 --	165
5	0 --	45 (96)	47 (100)	0 --	92
6	0 --	0 --	0 --	0 --	0
7	0 --	145 (0)	1,174 (41)	3,846 (45)	5,165
8	0 --	288 (0)	145 (20)	0 --	433
9	522 (0)	486 (61)	817 (31)	0 --	1,825
10	0 --	566 (0)	556 (47)	1,376 (62)	2,498
11	0 --	44 (0)	440 (45)	1,474 (81)	1,958
12	0 --	108 (0)	405 (47)	2,538 (36)	3,051
13	0 --	0 --	0 --	0 --	0

Table 5. Willow (approximately 90 % *Salix scouleriana* and 10 % *S. alaxensis*) stem densities (stems/acre) and percentages of stems browsed within 4 height classes.

	Height Classes				
Site	0-.15m	.15-.5m	.5-1.0m	1.0-2.0m	Total
1	61 --	142 --	40 (100)	0 --	243
2	101 (0)	204 (0)	84 (100)	38 (100)	427
3	0 --	35 (100)	769 (100)	0 --	804
4	45 (0)	283 (100)	68 (100)	57 (100)	453
5	15 (0)	56 (0)	0 --	112 (100)	183
6	17 --	186 (0)	131 (100)	0 --	334
7	0 --	0 --	172 (76)	54 (73)	226
8	171 (0)	750 (0)	147 (74)	0 --	1,068
9	147 (0)	0 --	66 (0)	0 --	213
10	92 (0)	0 --	0 --	145 (100)	145
11	0 --	0 --	198 (11)	1,430 (98)	1,628
12	0 --	0 --	0 --	0 --	0
13	0 --	0 --	0 --	0 --	0

Table 6. White spruce stem densities by height class within different clearcut sites.

Site	Height Classes			
	0-.15m	.15-.5m	.5-1.0m	1.0-2.0m
1	121	60	0	0
2	96	18	0	0
3	0	0	0	0
4	45	283	0	57
5	15	12	62	34
6	17	36	0	0
7	20	18	23	15
8	0	0	0	0
9	140	0	62	0
10	0	0	156	0
11	22	66	42	39
12	0	0	0	0
13	0	0	0	0

Table 7. Regrowth of hardwoods and white spruce in clearcut areas of the Matanuska Valley Moose Range. Means are followed by standard deviations in parenthesis.

Species	Height class (cm)	Age (yrs)	Total height (cm)	Terminal leader (cm)	Terminal leader (g)[1]	Current Annual Growth (g)[1]
Birch	0-15	1.5(0.8)	nd[3]	nd	nd	nd
	15-50	3.1(0.9)	nd	nd	nd	nd
	50-100	4.5(3.3)	82(11)	28(11)	0.6(0.4)	0.9(0.7)
	100-200	6.4(2.8)	182(18)	54(14)	2.2(1.2)	5.8(5.7)
Aspen	0-15	1.0(0.0)	nd	nd	nd	nd
	15-50	2.7(0.7)	nd	nd	nd	nd
	50-100	3.6(0.9)	92(5)	38(5)	1.1(0.3)	1.6(0.6)
	100-200	4.8(1.2)	128(12)	61(13)	3.0(1.4)	6.5(3.7)
Balsam poplar	0-15	1.2(0.2)	nd	nd	nd	nd
	15-50	3.3(0.5)	nd	nd	nd	nd
	50-100	3.6(0.3)	90(16)	34(16)	1.3(1.1)	1.9(1.8)
	100-200	4.9(1.3)	148(23)	28(14)	2.8(2.1)	7.8(5.8)
	200-400	5.0(0.0)	282(59)	58(24)	15.6(11.0	41.6(27.0)
Scouler willow	0-15	1.0(0.0)	nd	nd	nd	nd
	5-50	2.6(0.8)	nd	nd	nd	nd
	50-100	3.8(1.0)	76(15)	25(14)	0.3(0.3)	0.5(0.4)
	100-200	5.4(1.9)	125(10)	56(19)	2.1(1.7)	5.8(5.7)
White spruce	0-15	1.6(0.9)	nd	nd	nd	nd
	15-50	7.1(1.8)	nd	nd	nd	nd
	50-100	14.2(3.9)	nd	nd	nd	nd
	100-200	19.2(11.7)	nd	nd	nd	nd

[1] Grams oven-dry weight.

Table 8. Analysis of variance for NH_4 relative to distance from edge of scarified forest soil, Matanuska Valley Moose Range.

SOURCE	DF	SS	MS	F	P
BLOCK					
Site	5	8.953			
TREATMENT					
Distance	4	11.827	2.957	11.93	0.0005
ERROR					
Error	20	4.957	0.248		

Table 9. Analysis of variance for phosphorus relative to distance from edge of scarified forest soil, Matanuska Valley Moose Range.

SOURCE	DF	SS	MS	F	P
BLOCK					
Site	5	2.879			
TREATMENT					
Distance	4	2.586	0.646	5.99	0.0024
ERROR					
Error	20	2.1578	0.108		

Table 10. Analysis of variance for potassium relative to distance from edge of scarified forest soil, Matanuska Valley Moose Range.

SOURCE	DF	SS	MS	F	P
<u>BLOCK</u>					
Site	5	27377			
<u>TREATMENT</u>					
Distance	4	23004	5750.9	12.92	0.0001
<u>ERROR</u>					
Error	20	8904	445.2		

Table ll. Analysis of variance for NO_3 relative to distance from edge of scarified forest soil, Matanuska Valley Moose Range.

SOURCE	DF	SS	MS	F	P
<u>BLOCK</u>					
Site	5	3.493			
<u>TREATMENT</u>					
Distance	4	1.391	0.348	2.83	0.0518
<u>ERROR</u>					
Error	20	2.455	0.123		