Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Final Research Report
1 July 1990- 31 December 1995

Wildlife Habitat Enhancement in the Spruce-Hardward Forest of the Matanuska and Susitna River Valleys

William B Collins

Craig Gardner

Grants W-23-5, W-24-1
W-24-2, W-24-3
Study 1.44
July 1996

Alaska Department of Fish and Game
Division of Wildlife Conservation
July 1996

Wildlife Habitat Enhancement in the Spruce-Hardwood Forest of the Matanuska and Susitna River Valleys

William B. Collins

Federal Aid in Wildlife Restoration
Research Final Report
1 July 1990–31 December 1995

Grants W-23-5, W-24-1
W-24-2, W-24-3
Study 1.44

If using information from this report, please credit author(s) and the Alaska Department of Fish and Game.

STATE OF ALASKA
Tony Knowles, Governor

DEPARTMENT OF FISH AND GAME
Frank Rue, Commissioner

DIVISION OF WILDLIFE CONSERVATION
Wayne L. Regelin, Director

Persons intending to cite this material should receive permission from the author(s) and/or the Alaska Department of Fish and Game. Because most reports deal with preliminary results of continuing studies, conclusions are tentative and should be identified as such. Please give authors credit.

Free copies of this report and other Division of Wildlife Conservation publications are available to the public. Please direct requests to our publications specialist.

Mary Hicks
Publications Specialist
ADF&G, Wildlife Conservation
P.O. Box 25526
Juneau, AK 99802
(907) 465-4190

The Alaska Department of Fish and Game administers all programs and activities free from discrimination on the basis of race, religion, color, national origin, age, sex, marital status, pregnancy, parenthood, or disability. For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD) 1-800-478-3648, or FAX 907-586-6595. Any person who believes she/he has been discriminated against should write to ADF&G, PO Box 25526, Juneau, AK 99802-5526 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

FINAL RESEARCH REPORT

STATE: Alaska **STUDY:** 1.44

COOPERATORS: none

GRANTS: W-23-5, W-24-1, W-24-2, W-24-3

STUDY TITLE: Wildlife Habitat Enhancement in the Boreal Forest of the Matanuska and Susitna River Valleys

PERIOD: 1 July 1990-31 December 1995

SUMMARY

Timber harvest, scarification, burning, livestock grazing, various mechanical treatments and an herbicide were tested for their effectiveness in stimulating early successional hardwood production and enhancing wildlife habitat in boreal forest of southcentral Alaska. In most mature boreal forest stands, a combination of overstory reduction and timely exposure of mineral soil was essential for promoting early successional hardwood growth and associated habitat enhancement. Prescribed burning was the most economical and natural means to accomplish this habitat enhancement, but its extent of application was limited by concerns of safety, land use, smoke emission and public perception. Clear cutting (with retention of seed trees) of mesic and dry sites was a viable alternative to burning, providing harvest and scarification was completed within one year before competing ground cover could exclude hardwood seedling establishment. I was unable to identify effective site preparations for wet stands which had been logged. Young hardwood stands (pole-sized or smaller) which had grown beyond the reach of moose were effectively rejuvenated by crushing and hydroaxing in winter. Legal and/or physical access were the greatest obstacles to habitat enhancement.

Key words: boreal forest, logging, scarification, grazing, herbicide, prescribed burning, browse, vegetation succession, riparian management, habitat, wildlife cover measurement.

CONTENTS

BACKGROUND

Moose (*Alces alces*), snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*) and other early successional wildlife are dependent on early growth hardwood forests and associated plants which establish following fire, fluvial erosion or other forest disturbances (Kelsal, et al. 1977, Peek et al. 1976, Koehler and Brittell 1990). Early successional herbivores, in turn, exert major influence on successional development of the boreal forest (Wolff and Zasada 1979, Bryant 1987, Pastor et al. 1988, Johnson and Naiman 1990). Not only are these herbivores dependent on young hardwoods for food but as primary consumers they represent the major sources of food for numerous boreal predators. Consequently, those factors responsible for maintenance of early growth hardwoods are basic to productivity and health of the boreal forest ecosystem.

In southcentral Alaska two principal forces responsible for maintenance of early successional vegetation are fire and erosion by rivers and streams. 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 hardwood vegetation. By suppressing natural wildfires, man has unwittingly caused an extensive yet insidious change in the major force affecting the diversity and productivity of boreal habitats and their wildlife.

Principal hardwood species of the boreal forest–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 to regenerate from seed. Aspen and willow will also regenerate through root and stump sprouts if the forest canopy is opened sufficiently to allow sunlight to reach the understory. Birch regenerates poorly by stump sprouting, and not at all by root sprouting, but reproduces well by seed. Under most conditions in Alaska, aspen reproduces best by root sprouting following overstory decrease. Reduction of overstory and ground covers by logging or clearing practices can mimic natural disturbances otherwise responsible for stimulating hardwood regeneration.

Intense public concern for moose following the severe winter of 1989-1990, coupled with local debate regarding the acceptability and process of logging southcentral Alaska forests, led to legislative appropriation from the State of Alaska's General Fund for "moose habitat enhancement, improvement of access to browse for moose, and research, development, and implementation of proposals to reduce moose mortality, including railroad-related mortality in southcentral Alaska." Consequently, the major emphasis of this project was to select and conduct appropriate large-scale habitat enhancements, while simultaneously evaluating their efficacy.

OBJECTIVES

The principal objectives of this project are listed.

1. Enhance habitat for early successional wildlife living in the boreal forest of southcentral Alaska.
2. Begin assessment of biological and socio-economic potential for habitat enhancement by:
   a. logging
   b. forest clearing without harvest of wood products
   c. browse rejuvenation by crushing or hydroaxing
   d. prescribed burning

LITERATURE REVIEW

MOOSE HABITAT ENHANCEMENT

Maintenance of adequate habitat is a principal problem faced by managers of moose populations (Franzmann 1978). Prescribed burning, logging, selected land clearing and mechanical rehabilitation can return vegetation to early successional stages favorable to moose (Oldemeyer 1977). Timber harvest plans not only need to address enhancement of the browse resource but also ensure that adequate thermal cover is retained for moose (Schwab and Pitt 1991, Renecker and Hudson 1986).

With progressive exclusion of fire from the boreal forest, other forms of forest disturbance increasingly represent alternatives to maintaining diversity of seral conditions favorable to moose. From the standpoint of browse production, clearcutting of moderately 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 in this century occurred when clearcutting replaced selective cutting as the preferred system of timber harvest. The primary advantage of clearcutting is that it allows full sunlight to reach the ground, stimulating production of shade-intolerant browse species.

Considerable discussion has developed in the past 2 decades regarding optimum width of clear cuts where habitat enhancement for moose is the principal consideration. According to Todesco et al. (1985), width recommendations have been based primarily on theory. They suggest that smaller openings trap more snow than larger ones, thereby causing moose to prefer larger openings when snow depth inhibits their movement. Few investigators have acknowledged that productive browse stands often have inherently dense horizontal cover associated with them. Rapid growth of cover within clear cuts may, in part, be the reason there is so much variation in distances moose are reported to browse away from forest edges (Peek, 1971, Neu et al. 1974, Stone 1977, Hamilton 1980, McNicol and Gilbert 1980, Oldemeyer and Regelin 1980).

POSTLOGGING SITE PREPARATION

Daniel et al. (1974) suggested the following reasons timber harvest may need to be followed by some type of site preparation: 1) improvement of soil moisture conditions, 2) removal of competing vegetation, 3) reduction of slash, 4) improved wildlife food and/or cover, and (5) shortened time for tree regeneration. Depending on tree species and site characteristics, site preparation objectives can be accomplished by the harvesting system itself, by burning of harvest residues and understory, or by postharvest mechanical treatments. Mechanical site preparation can result in a great variety of soil conditions (Orlander et al. 1990).

Mechanical means of site preparation typically scarify the soil in such a way that patches of mineral soil are exposed when the organic layer is stripped off and cast aside. Thorsen (1978) described several beneficial effects of scarification in boreal forest, including elevation of soil temperature to favor root development in 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) described several problems associated with scarification: Scarification in morainic soils having high silt and fine loam content increases risk of frost heave damage to new seedling 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 reduce the supply of nutrients where mineral soil is exposed because nutrient-rich organic matter has been cast aside. According to Heilman (1968) and Jansson (1987), rapid mineralization of nutrients occurs in exposed mineral soils. Successional thickening of moss or duff on top of these soils lowers rates of mineralization and reduces nutrient 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 elimination or reduction of competing vegetation and retention of hardwood seedling access to nutrient-rich organic material. Seedling survival is also dependent on how readily adjacent vegetation can reinvade or lay over the scarified patch. Grass or other herbaceous vegetation not only competes with hardwood seedlings for nutrients, sunlight and water, but they often provide a base for snow accumulation which presses young seedlings to the ground, further decreasing their competitive vigor and usually leading to death during the next growing season.

Selection of scarification method is determined by fertility, wetness of mineral soil, and thicknesses of organic and mineral soil horizons. The most common methods of scarification for mesic soils in Scandinavia develop either continuous furrows or scarified patches (Appelroth 1981), neither of which exceed 45 to 60 cm 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 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).

Skidding of trees with branches intact can prepare a good seedbed on drier sites if it is done during snow-free periods and where the organic mat is not too thick (Safford 1983). According to Perala (1987) disturbance by grazing aids in birch establishment, but he cautions that continued heavy grazing hinders survival of seedling after they have become established. Overstory removal with its associated reduction in evapotranspiration results in increased soil moisture (Margolis and Brand 1990), further complicating site preparation in wetter forest sites. Such sites often must be drained by ditching and/or mounding.

Densmore (1988) evaluated 2 scarified clear cuts within the Matanuska Valley Moose Range (MVMR) to determine the effectiveness of site treatment by flat blade versus clearing blade (also called a root rake). She determined that scarification by clearing blade produced higher birch seedling density and growth rate. Scouler willow (*Salix scouleriana*) densities did not differ significantly between scarification treatments. However, she reported that birch and willow seedling 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 edges where seedlings were apparently protected from needle ice and had access to nutrients in adjacent unscarified soil.

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

BROWSE ECOLOGY

Paper birch, aspen, willow species, and balsam poplar are adapted to establishing on 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; consequently, their total production by sprouting may be quite low compared to sprouting species which compete well in the overstory. Of sprouting species which occur in 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 200,000 stems/hectare (Gregory and Haack 1965). Paper birch does not root-sprout but does stump-sprout fairly well until 40 to 60 years (Perala 1987).

Each of the boreal hardwood browse species reproduces best in large openings and full sunlight where 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, later successional overstory 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). 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 willow seeds are viable for only 2 to 3 weeks, 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) determined that reproduction of willows from seeds is greatly improved by exposure to mineral soil. Willow seeds fail to germinate on organic material, even when it is kept sufficiently moist to prevent desiccation of seedlings.

Paper birch produces heavy seedfalls, up to 28,000/m^2 (Zasada and Gregory 1972), but its seeds are winged and are relatively heavy compared with the other hardwood browse species. Most paper birch seeds fall within 30 to 60 m of the parent tree. Bjorkborn (1971) estimated paper birch seedfall at clearcut edges to be 60% of interior stand seedfall, but only 10% at 50 m into clear cuts. Therefore, Safford (1983) and Zasada (1972) recommended that clear cuts of this species be less than 100 m wide or they contain 7 to 12 well-distributed seed trees per hectare.

CANADIAN BLUEJOINT ECOLOGY

Canadian bluejoint (*Calamagrostis canadensis*) is the most common of over 100 species and subspecies 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 lowlands to dry, windswept alpine ridges (Mitchell and Evans 1966).

Mueller and Sims (1966) reported that bluejoint prefers fine textured, moist soils. Hernandez (1972) stated that bluejoint is 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, Crouch 1986, Lieffers and Stadt 1993). Bluejoint vigor is greatly reduced by shading (Lieffers and Stadt 1993).

Bluejoint readily monopolizes cutover areas of boreal forest (Mitchell and Evans 1966), eliminating favorable conditions for hardwood seed germination. Those hardwood seedlings which do begin to establish must compete with bluejoint for water and nutrients. New hardwood seedlings must also be able to withstand shading and smothering effects as tall grass often bends over them, forming dense mats which, in combination with snow, may bend hardwood seedlings to the ground (Mitchell and Evans 1966, Blackmore and Corns 1979).

Bluejoint is a winter-hardy perennial that naturally propagates from seeds or rhizomes in mid May. By mid June it may reach heights of 1 to 2 m (Mitchell and Evans 1966). Its nutritional value rapidly declines after seedheads begin to form in late June (McKendrick 1983). Mitchell (1968) determined that bluejoint seeds are not dropped until late September, thereby ensuring germination the following spring when conditions are favorable for establishment. He also found that seedhead production increased by 700% in disturbed areas, with individual seedheads producing a maximum of 150 seeds each. Conn (1990) determined seeds buried as deep as 15 cm retained 9% viability after 4.7 years.

Rhizome spreading is an equally effective means by which bluejoint can colonize disturbed sites (Mitchell 1968, McKendrick 1984). Disturbance of rhizomes may lead to propagation of a higher density stand than prior to disturbance if conditions are favorable for multiple segments of broken rhizomes to develop (Hernandez 1972). Bluejoint can completely colonize new openings by clonal spread in as little as 1 year (Ahlgren 1960), but typically require 3 years (Hogg and Lieffers 1991). MacDonald and Lieffers (1993) concluded that bluejoint rhizome development follows an "opportunistic guerrilla" strategy whereby nutrients are allocated in direction of most favorable microsites, thereby avoiding competition and resource-poor patches in favor of unexploited habitats. Powelson and Lieffers (1991) determined that rhizomes need to be chopped into pieces less than 1 nodal segment length to reduce sprouting of dormant buds. Otherwise, coarse chopping leads to significant sprouting and quick rebound via vegetative propagation.

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. Bluejoint's 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 development from adventitious rhizome buds. Repeated several times during a season, this process will deplete nutrient reserves within the rhizome.

METHODS

LOGGING

Within the relatively undeveloped forest industry of southcentral Alaska, variations in observed logging practices were primarily the products of individual logger's preferences rather than prescriptions driven by industrywide experience. Significant variations in logging practices were identified through consultation with Division of Forestry personnel and local loggers. Stands logged by different practices were then selected for evaluation of hardwood regeneration as related to wildlife requirements.

Hardwood seedling and sprout density were determined by double-sampling (Wilm et al. 1944). I visually estimated stem densities for harvested areas while walking surveys of entire sites. Then 1 of every 5 harvested areas was sampled by systematically distributing 35 to 60 5 m^2 plots throughout to determine densities, ages, percent utilization, above-ground biomass, and length and weight of current annual growth (CAG) (length and weight) of each browse species within each of four height classes: 0-15 cm, 15-50 cm, 50-100 cm, and 100-200 cm. Plot-estimated densities (all height classes combined) were then used to adjust the entire-cut estimates by regression analysis.

Four-year-old scarified patches were sampled at 50 cm intervals from their edges for density, age, height, CAG and cover by birch, and height and cover by bluejoint grass. 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, and total N, P, and K by the University of Alaska Agricultural and Forestry Experiment Station Laboratory. Nitrogen was determined by combustion using a LECO CHN-1000 analyzer. Phosphorus and K were measured by elemental analysis of a nitric-perchloric (5:3 ratio) acid digest of the plant tissue using an ICP emission spectrometer. Data were analyzed using a randomized block design, where scarified patch was the blocking variable and distance from edge was the explanatory variable.

Frost heave potential in different substrates was determined by vertically placing 0.3 x 10 cm pegs 5 cm into the ground in A-horizon, B-horizon, moss and grass dominated microsites, and by determining the number of pegs forced out of the ground after 1 winter. Ten transects, each consisting of 22 pegs positioned at 10 cm intervals, were randomly located in each type of microsite. A Pearson chi-square test of independence (Snedecor and Cochran 1980) was used to test for differences among microsites with regard to frequency of frost heaving.

Three transects perpendicular to edges of clearings were established in each of 4 clear cuts to determine seed distribution. Each transect contained 30 x 30 cm screen traps located at 25 m intervals and extended completely across clear cuts. Traps were left in place from 1 September to 1 May each year for 3 years. Seeds trapped between 1 September and 1 October and those trapped between 1 October and 1 May were counted separately.

Mechanical control of bluejoint grass on harvested birch-spruce sites was evaluated by determining browse density on clear cuts scarified by flat dozer blade, clearing rake, disk trencher, or whole-tree logging/skidding. The first three methods were evaluated as implemented in summer and in fall, whereas the last technique was implemented only in summer. Treatment areas were inspected monthly during the growing season to determine when seedlings germinated. Density of hardwood regeneration was determined after 3 years by counting stems in systematically placed 1 x 30 m belt plots.

Chemical control of bluejoint grass on harvested birch-spruce sites was tested by treating 1- to 5-year-old birch-spruce clear cuts with glyphosate at 1.6, 3.4, and 5.0 kg/ha, 5.0 kg/ha glyphosate followed by burning, and 5.0 kg/ha glyphosate followed by scarification with disk trencher. Treatments were applied in mid July 1990 according to a randomized block design. Treatments were replicated 4 times, with each replication covering 37.2 m^2.

Biological control of bluejoint grass on wet, harvested birch-spruce sites was tested by establishing high-intensity, short duration grazing treatments with cattle and horses. Grazing treatments were maintained in two 4-ha paddocks over 4 growing seasons to eliminate seed production and to radically deplete grass carbohydrate reserves and competitive vigor. Initial grazing in spring was begun as soon as most tussocks were producing shoots in the 3- to 4-leaf stage. Grass phenology was visually monitored weekly between grazing periods, and paddocks were regrazed whenever the paddocks were again dominated by grass 20 cm high. Carbohydrate reserves of bluejoint grass were indexed by determining dry weight of etiolated growth early each June after covered plants had ceased growing. Etiolated growth was obtained from beneath systematically located halves of 55-gallon barrels, 8 inside and 8 outside each paddock. Bluejoint rhizomes and shoots were collected biweekly inside and outside of paddocks during the last grazing season, and they were analyzed for total nonstructural carbohydrates, N, P, and K. Total nonstructural carbohydrates were extracted from ground samples with 0.2 N H_2SO_4 and measured by the iodometric method (Smith 1969). Nitrogen was determined by combustion using a LECO

CHN-1000 analyzer. Phosphorus and K were measured by elemental analysis of a nitric-perchloric (5:3 ratio) acid digest of the plant tissue using an ICP emission spectrometer. Shoots were additionally analyzed for in vitro dry matter digestibility (Tilley and Terry 1963). Hardwood seedling density was determined at the end of each grazing season by counting individuals within 15 1 x 30 m belt plots in both paddocks. Water upstream and downstream of treatments was sampled monthly for total nitrogen (NO^3) and fecal coliform. EC and A-1 mediums were used to test for fecal coliform (Greenberg et al. 1992).

Clearing without Harvest

Forest clearing without retrieval of wood products was limited to upland black spruce stands, since those trees were small diameter (average 6.35 cm dbh) and of no harvestable value to commercial or public interests. Wet black spruce stands were not treated because clearing and soil disturbance are prohibited by wetland provisions in Section 404 of the Clean Water Act, unless the trees are being harvested. Sites were cleared by flat-bladed dozers in spring after snowmelt but before thaw of soil A-horizon. Trees and ground cover were pushed into piles in the process of clearing.

Density and height of hardwood regeneration was determined annually in late August or early September after horsetail (*Equisetum sylvaticum*) had died and fragmented. Herbaceous ground cover was sampled prior to horsetail decline. Individual birch seedlings were marked with plastic toothpicks in microsites dominated by sphagnum moss (*Sphagnum* angustifolium), horsetail-covered A-horizon, or predominately bare B-horizon. I marked toothpick plots with conduit stakes to help locate them later. For 3 years I counted surviving seedlings in August.

Browse Rejuvenation

A 16-hectare stand of birch, scouler willow (*Salix scouleriana*), aspen and balsam poplar which had exceeded the browsing height of moose 8 to 10 years previously was hydroaxed in early and late winter. Varied snow depths in late winter resulted in stems being cut between 0 and 1.4 m height. A 4-ha patch of feltleaf willow (*Salix* alaxensis) was hydroaxed in early spring before leafout; most stems were cut at 10 to 15 cm height. Stem mortality, sprouts per stem, CAG, and utilization were measured after 2 years in treated plots and in adjacent untreated controls.

Prescribed Burning

A 364-ha and a 2630-ha were prepared for burning by prescription. Prescriptions were developed in cooperation with Division of Forestry following their format. A 240-ha grid of 200 sensors was installed in each stand to measure fire intensity. I applied spots of fire sensitive paints (developed for foundry uses) to aluminum tags for recording temperature at 100°C increments from 100-1200°C 1 m above ground (Cole et al. 1992). I applied strips of these same paints to tiles and thermal insulative boards and inserted them into duff and soil so that paint strips were oriented vertically and would record depth of heat penetration at each temperature increment. I also painted a strip of 60°C-sensitive paint on ground sensors so that depth of killing heat penetration could be recorded. Each tile or board was inserted into the ground so that their upper surface was flush with the top of the duff layer. This allowed depth of duff reduction to be measured against the tiles or insulative boards following the fire.

Approximately 50 ha of the 364-ha burn area were crushed by dozer 1 year before burning to allow a test of the effects of fuel consolidation at the surface. An additional 5 ha was crushed for the same purpose 1 day before burning. Fuel moistures were computed according to the formula: weight of fuel moisture/ovendry weight of fuel x 100 (Schroeder and Buck 1970). Moss, duff, 10-cm lengths of twigs and branches, and 2-cm thick cross sections of boles greater than 4 cm diameter were systematically collected along 10 transects encountering most of the area to be burned. Collections from each transect were sealed in plastic bags until collection weights could be determined; they were dried at 60°C for 1 week and reweighed.

Belt plots (1 x 30 m) were used to estimate seedling and sprout density of each hardwood species in late August 2 years after burning. All seedlings and sprouts were counted within 20 randomly located belt plots in each of 3 sites: unburned, burned, and crushed-and-burned. Cover by plant species or material was estimated by points recorded at 50 cm intervals along the 30 m tape used to reference the long axis of each belt plot.

BROWSE REDUCTION IN RIGHT-OF-WAYS

Pure stands of paper birch, balsam poplar, willow, and alder were steamed in mid July 1991 and again in July 1992. Experimental plots (7.31 x 7.31 m) were selected having uniform coverage by single species, individual plant heights being 1 to 2 m. Three plots were selected for each species, and each plot was subdivided into three 2.44 x 7.31 m plots for treatment durations of 2, 4, or 6 seconds. Steam was delivered at 88° C through a pair of 1.2 m manifolds mounted vertically in opposite corners of a 1.2 x 1.2 x 1.5 m hood. Sprouting by defoliated shrubs was determined by total count in each subplot.

RESULTS AND DISCUSSION

LOGGING

Ninety-six clear cut or selectively cut sites in the Matanuska and Susitna valleys were surveyed between 1990 and 1995 to determine the significance of overstory reduction, disturbance of ground cover, and size of clearings relative to habitat enhancement by logging. Densities of regenerating hardwoods were ocularly estimated in 66 sites (Table 1). Reliability of ocular estimates was supported by close agreement between ocular estimates and estimates based on plot counts (Fig. 1). Densities were not estimated in the remaining 30 sites because times since logging and/or scarification were insufficient to allow accurate estimates of seedling establishment. Characteristics of several clear cuts near Palmer were reported previously (Collins 1992).

Surveys consistently indicated complete or nearly complete overstory removal and soil scarification were most favorable to establishment of early successional hardwood communities. This is consistent with observations that overstory removal and scarification are essential components of natural disturbances–fire, windfall, and fluvial erosion–upon which the boreal forest is dependent for maintenance of early successional vegetation and wildlife habitat (Rowe 1961, Viereck and Schandelmeier 1980, Zasada et al. 1983, Perala 1987). Clearcut sites which did not incur scarification either in the logging process or in postlogging site preparation characteristically failed to support establishment of hardwoods by seed. Clear cuts originally comprised partially or fully of aspen produced abundant browse if cut during dormancy.

In all selectively cut sites, bluejoint grass increased prolifically, and limited hardwood production from seeds was restricted to naturally upturned root wads or haul roads where overstory was relatively open. Apparently, retained overstory sufficiently limited light and heat penetration essential for development of hardwood seedlings. Remaining timber also blocked operation of scarification equipment.

Mechanical Site Preparation

Removal of overstory by logging in winter did not mimic the effects of fire or natural uprooting of trees by exposing mineral soil, except on haul roads and principal skid trails. Summer logging, while somewhat better than winter logging in terms of inherent scarification, produced limited opportunity for hardwood establishment by seed. Logging eliminated the possibility for natural uprooting since it removed tree boles which otherwise enabled wind and gravity to leverage root wads from the ground. Bluejoint grass subsequently dominated sites where ground cover was left undisturbed, increasing from approximately 167 to 1344 kg/ha in moist sites and from 736 to over 3600 kg/ha in wetter sites. Depending on soil moisture and the means and timing of scarification, disturbance of ground cover and soil created microsites which favored hardwood seedling establishment. Wet sites did not respond to scarification with any detectable increase in hardwood regeneration.

In dry and mesic sites, scarified patches less than approximately 60 cm wide typically became overtopped by adjacent grass. Soil shaded by grass did not support hardwood seed germination, and grass which overhung planted seedlings enabled snow press damage. Scarification which penetrated the B-horizon resulted in poor seedling nutrition, presumably because it displaced nutrient-rich O- and A-horizon soils into piles.

Availability of ammonia (NH_4), phosphorus (P), and potassium (K) in scarifications properly developed with a clearing blade decreased significantly (ANOVA's, df = 20, 4, $P < 0.0005$, $P < 0.0024$, and $P < 0.0001$ respectively) with increasing distance from edge of scarification (Table 2). NO_3 also decreased but at $P < 0.518$. Square root (SQRT) of NH_4 and P both decreased in quadratic fashion (R^2's = 0.786 and 0.678, respectively) (Figs. 2 and 3) whereas K decreased in a linear fashion ($R^2 = 0.355$) (Fig. 4). All of the above relationships were observed without blocking for possible site differences. Obviously, each of these soil nutrients was found in greater abundance at the edge of scarified patches where O- and A-horizons were deposited.

Birch height, cover and CAG decreased with increasing distance from edge (Figs. 5-7), whereas density increased (Fig. 8).

To test if the concentration of nutrients at edges of scarified patches favors seedling establishment (density) and growth (height and CAG), I applied a stepwise regression procedure (Neter and Wasserman 1974) to determine the best predictors of paper birch height, density and CAG from N, P, and K. Using the natural log of height, K was the only significant predictor of height ($P < 0.05$).

The best predictive model was:

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

$$R^2 = 0.3468$$

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

$$\ln(\text{CAG}) = 1.475102 + 0.012223 \times \text{potassium}.$$

$$R^2 = 0.3751.$$

At alpha = 0.05, none of the variables was a significant predictor of paper birch density, suggesting soil macronutrients are poor indicators of density or that other factors interact in the initial establishment of seedlings. However, the relatively low predictive values of the above models do lessen the importance of fertility to seedling vigor in scarified soil. Seedlings found in central portions of large scarified patches showed definite signs of poor nutrition compared with those at edges. A combination of competitive exclusion among the more quickly growing seedlings at edges and overtopping by vegetation growing immediately adjacent to scarification may be responsible for decreased birch density near edges of scarifications.

Levels of ammonia and potassium within scarified patches remained high within 50 cm of edge, whereas phosphorus changed less with increasing distance from edge. It should be noted, however, that paper birch is particularly sensitive to P availability and any change in availability at the already-low levels characteristic of southcentral Alaska soils is significant with regard to its 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). These observations indicate dimensions of scarification patches should not exceed the 1- or 2-year growth potential of new seedling roots, so the nutrients in displaced O- or A-horizon soils are available. I have observed roots of most birch and willow seedlings extended laterally at least 30 cm by the end of their second year. Humus, woody debris and other decaying plant materials should be incorporated into wider patches, not only as sources of nutrients but for moisture retention and amelioration of microclimate (Perala 1987). This practice results in improved nutrition, better surface thermal and moisture characteristics, and possibly improved soil mychorrizae relationships. Perala observed that most seedlings occurred on mineral soil, but they had poorest growth rates if not in close association with woody debris or other organic matter.

In practice it is difficult to expose A-horizon soil by stripping away overlying humus because bluejoint grass rhizomes and other competitive vegetation typically bind the two together. Consequently, some patches of B-horizon are unavoidably exposed, particularly if the grass has had a season or two to increase following logging. However, this is not necessarily a problem if nutrient-rich organic materials and associated microclimatic effects are within the 2-year reach of seedling roots.

Relatively few birch seeds germinated in scarified patches more than 1 year following treatment, the reason apparently being twofold: First, the porous and open characteristic of scarified soils immediately began to "heal" as the soil became compacted by rain, covered by litter, and revegetated by mosses and competing herbaceous vegetation, greatly reducing the availability of microsites supportive of seedling establishment. Secondly, viability of residual seeds declined sharply after the first year, and seeds blown into a site following cutting experienced an exponential decrease with distance from source (Fig. 9). Considering that September seedfall supplied approximately 1800 seeds/m^2 30 m from trees, and assuming this seedfall was the most viable of the annual seedfall (Perala 1987), the practical seeding distance of paper birch in Alaska was approximately 30 m or equivalent to that observed elsewhere (Perala 1987). For these reasons, a minimum of 15 seed trees per hectare should be retained to continue providing viable seeds to take advantage of subsequent, albeit reduced, germination opportunities, and scarification should be completed within 1 year of cutting, before or during the period of heaviest seed dispersal (approximately 1 September through 30 October).

Scarification by flat dozer blade yielded the poorest hardwood regeneration, because it typically exposed wide patches of B-horizon and displaced most nutrient-rich O- and A-horizon into piles where they were not readily available to those seedlings which did establish on scarified patches. Scarification by clearing blade displaced much less nutrient into piles and resulted in greater seedling densities and faster rates of growth.

Scarification by clearing blade more than 1 year after overstory removal produced poor results because, by then, bluejoint grass roots had consolidated A-horizon soil, making it virtually impossible to scarify without completely displacing the nutrient-rich soils into piles.

Exposure of large patches of B-horizon by any method was detrimental to seedling establishment because that soil was also more frost active, causing root damage and/or ejection of new seedlings from the ground where the microsite was not protected by vegetation. Most seedlings occurring in exposed B-horizon had twisted taproots and elevated root crowns. Frost heaving of pegs was not significantly different (X^2 = 3.021, df = 1, Exact p-value = 0.2483) between moss and grass covered sites. Frost heaving in A-horizon (9.1% of pegs heaved) was significantly different (X^2 = 30.84, df = 1, Exact p-value = 0.0000) from combined moss and grass sites (0.68% of pegs heaved). Frost heaving between A-horizon and B-horizon microsites was significantly different (X^2 = 122.4, df = 1, Exact p-value = 0.0000), B-horizon heaving 6 x more pegs than A-horizon.

Scarification by disk trencher produced the best postlogging scarification but only if completed within 1 year of overstory removal. Delay of disk trenching more than 1 year after timber harvest typically produced poor results because increased grass production and root mass built up in front of disks, decreasing their effectiveness. Unlike the clearing blade or flat blade, the disk trencher produced a great variety of microsites increasing the probability of hardwood seeds finding optimum conditions for germination and survival. Furthermore, once the disk trencher was adjusted for specific site conditions, it did not require operator attention or effort to maintain proper depth of scarification, making it ecologically safer to employ than clearing or flat blades.

Of those forms of timber harvest producing their own scarification, whole-tree logging during snow-free seasons was most effective. This is a form of clear cutting, the unique feature being that dozers are used to uproot and skid trees to decking sites where stumps and limbs are removed. The processes of uprooting and dragging trees with protruding appendages produces extensive scarification. On mesic and dry sites, whole-tree logging was approximately as effective as disk trenching. Whole-tree logging had the distinct advantages that scarification was automatically completed in a timely fashion and accomplished without costs in addition to logging.

Clearing and scarification by "chaining" was not as effective as any of the foregoing methods because downed trees kept chains from adequately contacting soil. Furthermore, the resultant jumble of trees was unattractive and dangerous to firewood cutters who retrieved the downed timber.

No form of scarification was effective on wet sites because bluejoint grass was well established before clearing and readily monopolized sites following timber harvest and/or scarification. Furthermore, use of machinery on wet sites was limited to winter when ground was frozen and capable of supporting machinery, conditions which do not occur every winter or in all wet sites.

Chemical Site Preparation

All 3 rates of glyphosate application resulted in 100% kill of bluejoint grass and all tall forbs and shrubs. Some moss and dogwood (*Cornus canadensis*) were protected from killing exposure to the herbicide by dense overhanging grass. Treatment differences in birch seed germination 1 year after treatment (Table 3) have not changed after 4 years, as there has not been any additional hardwood establishment in "herbicide-only" plots.

Birch seeds did not germinate in herbicide/disk plots until late July 1991. Bluejoint seeds began germinating at the same time, but they only grew 8-16 cm before the end of the growing season and apparently did not compete with birch seedlings during their first year.

On wet sites, dense bluejoint residue continued to block reestablishment of bluejoint and other herbaceous species 4 years after treatment. Although dense accumulation of killed bluejoint was effective in reducing competition with planted trees, it did not support natural regeneration by hardwoods since bare ground was not exposed.

Fire did not penetrate organic mat to mineral soil in sites treated with glyphosate because fuels left after logging were inadequate to support fire of adequate duration. Consequently, herbicide kill followed by burning was no more effective in supporting hardwood seed germination than herbicide treatment by itself.

Scarification of sites treated with glyphosate allowed establishment of hardwoods by seed but also enhanced germination of residual bluejoint seed, allowing renewed dominance of the grass within 2-3 years. Consequently, hardwood seedling establishment was limited to the growing season immediately following scarification. Timely scarification without glyphosate pretreatment produced essentially the same opportunity of hardwood seedling establishment, but without the cost of herbicide treatment. Neither treatment was effective in wet sites.

Biological Site Preparation

Logged, wet birch-spruce stands exhibited poor hardwood regeneration, whether scarified, slash burned, or competing vegetation killed by herbicide. In all cases, competition from bluejoint grass and fireweed was intense within one year of clearing, the grass becoming 1.2 to 1.5 m tall and total vegetation cover equaling 100%. Depending on year and location, bluejoint production was 1334 to 2084 kg/ha (Table 4), and fireweed production was 1344 to 1580 kg/ha, the two species representing 86% of total production. Given these conditions, livestock were grazed to weaken competition from bluejoint and fireweed and to scarify the soil. I focused on bluejoint grass in my monitoring of paddock response to grazing since it recovers much more quickly than fireweed to dominate a disturbed site.

Initially paddocks were grazed by a small herd of beef heifers, averaging 506 (S.D. = 27.0) kg individual live weight. The cattle had been accustomed to early spring pasture at a lower elevation prior to use in these treatments. Paddocks were stocked at rates of 9.9 animal units (AU) per hectare to impose approximately 90 % utilization of bluejoint grass in approximately 7 days. Under this high-intensity, short-duration rate, heifers maintained weight or lost an average of 0.36 kg/day, depending on whether a "shrink" factor of 2.5% or 3% was used in adjustment of weights following handling and trucking to scales. Unfortunately, the livestock owner switched to a fall breeding strategy which prevented use of his animals after the first year of this study. All subsequent grazing was by horses.

Prior to initiation of grazing treatment, ground surface was completely covered by dead bluejoint grass and other plant litter or large woody debris (tree stumps and logs). Cattle and horses consumed much of the dead grass and fireweed remaining from the previous summer, and their hoof action accelerated breakdown of remaining litter, resulting in a 39.8% reduction of cover by those materials after 1 season. Exposed surface was primarily humus and, secondarily, large woody debris. Reduction of litter and breakdown/compaction of humus also exposed standing water to the extent of 9% of the area in late August, further indicating the wetness of these sites. After initial and subsequent grazing seasons, spring greenup inside paddocks preceded that outside by 8-10 days, presumably because the insulative effects of cover were reduced, allowing earlier warming of the soil.

After 1 year, etiolated bluejoint growth had declined 63% and 73% in paddocks 1 and 2, respectively. After 2 years, etiolated growth had declined 93% and 90% in paddocks 1 and 2, respectively. Etiolated growth did not decrease after the first 2 years. Based on this response, this grazing treatment resulted in substantial loss of bluejoint carbohydrate reserves. At time of this writing, however, I still have not received results of chemical analyses of bluejoint tissues which include biweekly samples of carbohydrate reserves (total nonstructural carbohydrates) during treatment and recovery periods. In plots which were covered after they had been grazed 3 years, etiolated growth of fireweed was sparse or absent, but horsetail was more abundant than prior to grazing.

Within the first season following cessation of grazing, bluejoint in paddocks 1 and 2 averaged 43.9 and 43.8 cm height versus 66.0 and 71.9 cm height, respectively, in control stands. Even though culm elongation was decreased and leaves were considerably finer following grazing, stem density was increased, resulting in increased bluejoint productivity (Table 4). Height and productivity of fireweed were greatly depressed following the grazing treatment, but horsetail production and dominance remained unchanged or increased.

Hardwood regeneration did not increase in grazed paddocks. Seedlings of birch and willow were found exclusively on decaying spruce stumps and logs and on some soil hummocks which remained moist but not saturated with water. Soil hummocks appeared to be the result of anciently upturned root wads. Few decayed birch stumps supported seedlings. Spruce seedlings tolerated wetter sites but favored the same conditions as birch. Birch regeneration benefits from elevation of the seedling above competition on the forest floor (Helm and Collins submitted, Beatty and Stone 1986, Jonsson and Dynesius 1993), and, in some instances, perpetuation of wet birch-spruce forest seems dependent on these conditions. Seedling establishment was not necessarily prevented by trampling or grazing since no seedlings were ever observed in late summer (2-3 weeks after removal of livestock) except in microsites described above, yet this is the most favorable time of year for birch seed germination. The few birch suckers originating from birch stumps in the paddocks were not browsed by the cattle or horses.

The biological significance of bluejoint grass response to grazing in wet sites may only be academic since after 4 years of treatment, I did not observe that hardwood establishment has been enhanced or that competition from bluejoint is effectively reduced for more than 1 season following cessation of grazing. Apparently, bluejoint is extremely well adapted to disturbance (Lieffers and MacDonald 1993) and capable of rebounding quickly even after this magnitude and duration of grazing. Regardless of grazing effectiveness in reducing bluejoint competition, hardwood regeneration on wet sites seems dependent on availability of raised microsites which are not saturated with water and therefore capable of warming to meet germination requirements.

Clearing without Harvest

One year after flat-blading and piling of upland black spruce, I estimated 2,119,999 (SE = 326,110) birch seedlings per hectare in stands cleared while soil was frozen. Mean seedling density (392/m^2) was significantly greater ($P < 0.01$) on microsites of exposed A-horizon than on O-horizon (152/m^2) or B-horizon (179/m^2). A-horizon sites were created where moss and other vegetation neatly separated from frozen soil. O-horizon sites were predominantly characterized by sphagnum moss which had its living upper portion sheared away without disrupting the dead portion's contact with mineral soil. These conditions were established where moss was frozen at the time of clearing. Moss mats which broke loose from the soil during clearing lost capillary contact with soil moisture and were too prone to drying to allow seedling survival.

By midsummer 2 years after clearing, seedlings growing on O-horizon had experienced 39% mortality, compared to 6% and 14% mortality among A-horizon and B-horizon seedlings, respectively. Most mortality was the result of dry, early summer weather, as dead seedlings still retained leaves formed in the spring. Mortality resulting from intraspecific and interspecific competition would have eventually surpassed this early mortality as plants began competing for space and nutrients.

Within 1 year of clearing, dense cover of horsetail developed over much of the sites, raising concern that most new birch and willow seedlings would be excluded by competition or snow press damage within their first year. It later became apparent that birch seedlings growing within the protection of horsetail had the lowest mortality. Even where horsetail completely covered A-horizon sites, late-season die-back of the plant was so light and friable it did not contribute to snow press damage as do tougher plant residues.

The last stand of black spruce to be cleared was dozed and piled after substantial thawing of surface soil. This resulted in excessive disruption and displacement of O- and A-horizon soils, contributing to droughty conditions unfavorable to seedling establishment in the first two years following clearing. Dryer than normal summers and the fact this site was more hilly than the other sites also contributed to its dryness. However, in the third year summer precipitation, cloud cover, and humid conditions were frequent, enabling 32,562 (SE = 5,959) birch seedlings per hectare to germinate and survive. Spot checks indicated willow seedlings also established in response to moister conditions, but it was too tedious to sample their density since their appearance is easily confused with fireweed seedlings if not examined individually very closely. Both density and species determination for willows will be more efficient after the willows are 3 years old.

Clearing of upland black spruce stands by dozer in 1991 averaged $544 per hectare. By comparison, chaining of a spruce-aspen stand in the same vicinity in 1983 cost $247 per hectare, indicating chaining may be the less expensive mechanical option. Heavy equipment contracting costs in 1983 were approximately the same as in 1991. However, chains tended to ride over trees knocked down in their path, essentially preventing adequate scarification. Chaining followed by burning may be a more effective option than simply chaining but incurs additional costs associated with burning.

By 1 year after clearing and piling by dozer, aspen had resprouted approximately 68,346 (SE = 8,614) stems per hectare. Prolific root sprouting by aspen was also observed in the second year but not counted. One year after clearing, scouler willow resprouted at 1,706 (SE = 506) stems per hectare, while birch seedlings established at 1,785 (SE = 467) stems per hectare. While representing an effective method for stimulating early hardwood growth, clearing costs were $865 per hectare on level ground. Clearing on slopes where most pure stands of aspen occur would be more cost prohibitive, and in most cases would not be operationally feasible. Considerable care by the operator is required to avoid displacement of shallow soils typically associated with aspen stands, and most sloping aspen sites are extremely susceptible to erosion after clearing by heavy machinery.

Felling aspen with chainsaws cost approximately $220 per hectare when wages were $6/hr. However, the resultant jumble of trees on the ground was 60 to 90 cm deep and probably a barrier to wildlife. Aspen in Alaska are not of high enough value to support harvest of trees by cutting; therefore, aspen management practices developed in Wisconsin and Minnesota (Gullion 1984, DeStefano et al. 1994) typically are too costly to apply.

BROWSE REJUVENATION

It is generally accepted that the nutritious parts of principal tree or tall-shrub browse species grow out of reach of moose within approximately 20 years. However, when not topped by browsing or otherwise damaged, these hardwoods even more quickly elevate most of their CAG beyond the reach of moose. Unbrowsed balsam poplar, paper birch and aspen occurring in young seral stands exceeded 4 cm diameter at breast height (the apparent upper limit to what moose will break to obtain elevated browse) within 9 years; scouler willow generally required 10 years. Since more than 75% of scouler willow CAG and more than 90% of the other species' CAG occurs within the upper-most 3 years of growth (Fig. 10), browse availability is greatly diminished much sooner than 20 years if the upward growth of these hardwoods is not retarded by browsing or other damage. These phenomena were particularly evident within the abandoned Point MacKenzie Agricultural Project where extensive old-field succession produced excess browse relative to the associated moose population, resulting in light browsing pressure and quick escapement of hardwoods from potential browsing. In this situation or others, such as browse production after an extensive fire, some form of browse rejuvenation/maintenance may be valuable in extending browse availability.

Birch density in a 23-year-old birch-dominated stand within a relatively high-density moose wintering area increased from approximately 10,992 (SE = 1114.0) to 59,600 (SE = 4,751.7) stems/hectare within 2 years after hydroaxing. Scouler willow in the same stand increased from approximately 292 (SE = 75.5) to 8,127 (SE = 2,675.3) stems/hectare, and balsam poplar increased from 83 (SE = 54.7) to 867 (SE = 573.7) stems/hectare. Pretreatment browse was above the reach of moose, whereas all posttreatment stems were available as browse. Within 1 year of treatment, browsable CAG of birch increased from 0 to approximately 90 kg/ha; scouler willow, 2.2 to 49 kg/ha; and balsam poplar, 0 to 5.6 kg/ha.

For future reference, length-weight and diameter-weight relationships were determined for each browse species to enable nondestructive sampling, as well as estimation of CAG of browsed twigs. Length-weight relationships for each species were best described using the power equation $y = cx^b$, whereas the diameter-weight relationships were best described using the polynomial equation $y = b + c_1x + c_2x + ... c_6x^6$ (Figs. 11 - 16). Shoot development (Fig. 17) was essentially complete by 1 August, making it acceptable to use length, diameter and clipping estimates of CAG obtained as early as that date.

High-cut stems sprouted from adventitious buds located at first, second and third year stem nodes, but basal sprouts dominated regrowth. Root crowns of birch cut at or near ground surface had a greater tendency to be split or otherwise damaged, resulting in 29 % of low-cut versus 17 % of high-cut birch dying. No dead low- or high-cut willows or balsam poplar were observed. High cutting was advantageous because it allowed hydroaxing while snowpack was still in place. Hydroaxes operated effectively in late season snow as deep as 1.2 m.

Stem density of feltleaf willow hydroaxed along the Gulkana River in later winter increased 47 times by stump sprouting in the first season, with total available browse increasing 3 times. This stem density is expected to decline substantially each year for the first few years, but at the same time surviving stems will produce increasing amounts of browse within the reach of moose. Maximum net gain in browse production probably will be realized in 3 to 4 more years.

Prescribed Burning

A 364 ha stand of upland black spruce near Rolly Creek (6 miles west of Willow, Alaska) was burned by prescription on 13 and 14 July 1993. Ignition of the main fire was preceded by a 1 ha test fire. The main fire was started at approximately 1730 on 13 July. Most burning was accomplished in the first 5 hours. After that, rapidly rising relative humidity restricted attempts to burn out unblackened areas. The fire was declared out on 18 July, although some smoldering continued for 2 weeks in interior portions of the burned area. After that, rain extinguished remaining hot spots.

The fire was ignited using the Canadian "ping pong ball" system, progressing into the wind by a series of ignition lines perpendicular to the wind. At the time of ignition, wind was SSE, variable at 4.8 to 8.0 km/h at tree-top level. Ignition proceeded rapidly while relative humidity was below 35%. Fuels had dried for 2 days under northwesterly air flow and low relative humidity, but the fire could not be ignited until winds shifted to the south to carry smoke away from populated areas. Upon wind shift to the south, relative humidity began to rise, temporarily falling below 35% only in late afternoon on 13 July. Prescribed fires in the Susitna Basin will probably always be limited to a similar sequence of conditions, since low relative humidities are generally associated with airflows out of the interior, and smoke management will always require southerly flows.

Surface materials consisting primarily of feather moss, dead needles, ericaceous shrubs and foliose lichens were the principal fuels involved in the Rolly Creek fire. The most intense portion of the fire consumed 38 to 45 metric tons of fuel per hectare, of which 34 to 36 metric tons were surface fuels (Ottmar, pers. commun.). Standing dead trees and living twigs with needles accounted for most of the remaining fuel consumed.

Temperature-sensitive paints on aluminum tags were not adequate for recording temperatures 1 m above the forest floor and limited interpretation of fire intensity. Seventy-seven percent of tags melted during the fire, indicating temperatures in excess of 631°C (1180°F), the melting point of aluminum. However, none of the copper wires affixing tags to stakes were melted, indicating fire temperature did not exceed 1071°C (1980°F) and that copper tags may be a more suitable material for this use. Since maximum temperatures may be brief in duration, it is important that the substrate to which paints are applied quickly reach equilibrium with air temperature. By comparison, surface temperature recorders should not conduct heat faster than the soil substrate. In this regard, tiles and insulative boards provided good record of heat penetration into soil and were stable references to duff removed by burning.

The significance of surface fuels in the spread and effect of fire was reinforced by the way ash accumulations from the 1992 eruptions of Mt. Spur retarded spread of this fire. Volcanic ash accumulated up to 5 mm deep on top of fallen deciduous leaves and foliose lichens, whereas it dispersed down through the living profile of feather moss. Fire did not burn ash-covered aspen leaves or lichens and in many places killing temperatures did not penetrate those profiles.

In the area crushed 1 year prior to burning, fuel moisture in 2.54 to 7.62 cm diameter stems had declined to 42% but only to 61% in living trees. Stems 0.64 to 2.54 cm diameter had dried to 19% moisture, versus 41% for living stems of like diameter class, adding significantly to availability of combustible fuel on the crushed site. Fuels on the crushed site were also concentrated closer to the forest floor, providing an environment for hotter and longer-lasting fire.

Both moss and duff in the cushed site had dried to less than 25% of their moisture in undisturbed forest (Table 5). Greater fuel loading, combined with significantly drier moss/duff in the crushed site, resulted in exposure of mineral soil over 36.2% (S.D. = 3.2%) of the site, versus 24% (S.D. = 2.5%) in the site which was only burned. In either case, reduction of forest mat (moss and duff) occurred primarily in the moss layer. An additional year of drying would have resulted in more downed woody material being consumed, since 2.54 to 7.62 cm stems contained only 26% (S.D. = 2.4%) moisture after 2 years of drying. However, it is questionable whether greater combustion of larger stems would have greatly increased exposure of mineral soil. Consolidation of fuels by crushing is of value where restrictions in burn prescriptions and/or lack of carrier fuels will not support spread of fire.

Exposure of mineral soil and depth of heat penetration in areas where fire crept along the ground were approximately the same as where the fire rapidly consumed overstory (Table 5), further indicating the overriding significance of surface fuels in the effects of fire on seedbed preparation. Overstory functioned primarily to spread fire quickly but did not directly affect quantity of ground cover incinerated or amount of mineral soil exposed. All moss was killed by heat and fire where overstory burned intensely, but not in places with less intense, creeping fire. Regardless of overstory fire intensity, incineration of moss to mineral soil was primarily a function of the ability of moss and other understory species to support fire independently of the overstory. Development of microsites capable of supporting hardwoods is benefited by overstory fire in terms of reduced shading effects and eventually by natural scarification caused by tipping of dead trees and their root wads.

By late September 1993 (6 weeks after the fire), aspen and willow were resprouting vigorously, ranging in height from a few centimeters to more than 40 cm. High soil temperature, from reduced cover, a black surface, and dryer than normal summer weather, precluded germination or establishment of hardwood seeds and most herbaceous species by late August 1994. A significant exception was seen in the profuse germination of Rock Harlequin (*Corydalis sempervirens*) in late August 1993. These annual/biennial plants grew to 1 cm height, then overwintered and grew to 90 cm by mid June 1994, completely dominating the site. I have never observed this species in any of my surveys of undisturbed forest in southcentral Alaska, and its occurrence in the burn area is slightly beyond the range described by Hulten(1968). By mid June 1994, dense mats of a large thalloid liverwort (*Marcantia polymorpha*) had established in crushed areas where mineral soil (primarily B-horizon) had been exposed by uprooted trees. Scattered individuals of fireweed (*Epilobium angustifolium*), bluejoint grass, and carex (*Carex* spp) were also sprouting by mid June 1994. By summer 1995 Rock Harlequin had greatly reduced density and showed less vigorous growth, becoming less dominant than fireweed and carex.

Changes in cover by living vegetation were similar between burned and crushed-and-burned sites (Table 6). Notable exceptions were the liverwort, *Marcantia polymorpha*, and fireweed which were much more abundant in the site that was crushed and burned. Presumably, much of this difference was the result of greater exposure of mineral soil, both by burning and by tipping of trees during the crushing treatment. Liverwort, in particular, was associated with B-horizon soils exposed where tree root systems were tipped aside.

By August 1995, aspen clones within standing burned stands had root sprouted 88,067 (SE = 6746) stems per hectare. Aspen within crushed-and-burned stands sprouted 116,933 (SE = 12,846) stems/hectare. These are considered high densities anywhere within the range of aspen. Since aspen root clones covered approximately 11% of both stands, average densities for entire stands were approximately 9,687 and 12,863 stems/hectare for burned and crushed-and-burned treatments, respectively. Before burning, this site had fewer than 100 stems/hectare, all of which were mature and of limited food value to native wildlife.

Birch seedlings were significantly ($P < 0.01$) more abundant in crushed-and-burned stands (9018 stems/ha) than in adjacent burned stands (1235 stems/ha). Willow seedlings also were in significantly greater abundance ($P < 0.01$) in the crushed-and-burned stand (3296 stems/ha) versus adjacent burned stands (235 stems/ha). Presumably, greater disturbance and exposure of mineral soil in the crushed-and-burned area favored seedling establishment. Nevertheless, highest densities of either species were in lightly burned areas which were ignited after relative humidity rose above prescription.

Unfortunately, the greater densities of hardwoods in areas burned during high relative humidity were not noticed in time to methodically sample them during the 1995 sampling period. I excluded these areas from initial sampling because they were considered "poorly burned" at the time of the fire, and reconnaissance 1 year after the fire did not lead me to believe successful seedling establishment would occur. Not until after the 1995 sampling was complete did I notice the high densities of new seedlings in these areas.

Very few seedlings of birch or willow could be found before July 1995, presumably because summer 1994 was too dry. During the same time, 19 kilometers east of the burn, poor hardwood seedling establishment was observed in an identical upland black spruce stand which I cleared by dozer. Abundant seedlings established in both stands in summer 1995 because precipitation was frequent enough to allow survival of new seedlings having limited root development.

In forest burned at low intensity, relatively few fine branches and twigs of spruce were consumed, some birch and aspen trees survived, and approximately 2/3 of big red stem moss (*Pleurozium schreberi*) and feather moss (*Hylocomium splendens*) survived exposure to fire or heat. Burning in these areas was termed as "creeping" by fire personnel from DOF. Fire moved slowly through the site, creeping through ground cover and igniting trees individually rather than simultaneously by crown fire. Most moss which did ignite eventually smoldered or burned to mineral soil. This produced bare-soil microsites where hardwood seeds could germinate but also left vegetation which ameliorated the microclimate in favor of seedling survival during hot, dry days.

Surface soil and organic substrates in intensely burned areas typically became powder dry within a few days after rainfall, whereas less intensely burned sites remained moist. Apparently, greater reduction of overstory structure and complete blackening of ground surface in the intensely burned area allowed more solar heating and more evaporative air movement at ground surface.

Greater birch seedfall occurred in lightly burned areas since not all mature trees were killed. However, this factor alone was not responsible for the greater seedling densities. Willow similarly occurred at a much lower density in intensely burned sites, even though willow seeds are airborne for great distances and their distribution is not particularly restricted by distance from source. Finally, most birch or willow seedlings in the intensely burned area were limited to more favorable microsites such as depressions, shade of downed woody material, or immediately adjacent to woody debris or accumulations of litter blocking evaporative moisture loss from soil. Intensely burned sites probably will support greater densities of hardwood seedlings in the next few years as litter from fireweed, carex, and other herbaceous species continue to accumulate, thereby increasing site albedo and lessening evaporative moisture loss at the soil surface.

The 2630 hectare burn area was not ignited because essential personnel were committed to fire suppression during the time prescription burning conditions were met. The Rolly Creek fire was successively accomplished primarily because Division of Forestry personnel from Big Lake were able to arrange prescription fire needs around their first priority, wildfire suppression. The fact that a Big Lake DOF staff fortuitously included all personnel necessary for a prescription fire also favored successful implementation of the burn. Weather also cooperated, falling within prescription when necessary firefighting personnel were not committed to wildfires.

Final cost for the fire was $38,160.65 or $104.77/hectare. By comparison, mechanical clearing of an identical black spruce stand of equivalent remoteness cost $514.78/hectare. Since Rolly Creek was the first prescribed fire of this magnitude by Big Lake DOF, many extra backups and controls were implemented which were responsible for most of the cost. Future fires of equivalent size and having natural barriers to fire spread similar to those at Rolly Creek will likely cost 70% less per acre. One additional cost not incurred at Rolly Creek will be a new EPA-mandated charge for emissions scheduled to take effect in 1995. If such a mandate had been implemented in 1993, the Rolly Creek fire would have cost an estimated additional $4000.00 ($10.97/hectare).

The Rolly Creek fire provided a good opportunity for DOF to test its organization and resources in a prescription fire. Consequently, they established a solid basis to prepare future prescriptions. However, availability of personnel for assignment to prescription burning while fire suppression needs are high is still a problem and will probably remain so unless a prescription burning program becomes of sufficient size to warrant personnel and equipment specifically for that priority.

Browse Reduction in Right-of-Ways

Steam application for periods of 2, 4, and 6 seconds were equally sufficient to defoliate Bebb willow, birch, balsam poplar and alder (*Alnus* spp.). All leaves of each species developed a dull appearance as soon as condensed steam evaporated from their surfaces, then withered and dried over the next couple of days. Bluejoint grass and other understory species were also partially to fully defoliated, leaves yellowing and dying within a few days of treatment.

Most willow stems began resprouting within a couple weeks of defoliation, but basal sprouting by alder, birch and balsam poplar was not evident until late June the year following first treatment. By mid July 1 year after treatment, 58% of birch, 94% of balsam poplar, and 96% of willow had resprouted. In addition to basally sprouting, a few alder also leafed from preexisting buds within a couple weeks of defoliation. Unfortunately, a miscommunication between agencies resulted in the alder plots being hydroaxed before sprouting percentages were determined the following summer. Bluejoint grass and other understory species regained their former degree of cover within 1 year of treatment.

A second defoliation (2-second duration) by steam 1 year after the first defoliation killed the birch and alder, but approximately 15% Bebb willow stems basally resprouted. All balsam poplar resprouted following the second defoliation, including "individuals" which appeared dead prior to the second steaming. By excavating roots, I determined that basal resprouts from "dead" balsam poplar arose from roots which were also tied to mature trees living just outside of the right-of-way; what appeared to be individuals were sprouts from extensive root systems of untreated individuals. This phenomenon indicates the difficulty of controlling root sprouters such as balsam poplar and aspen which may retain untreated above-ground biomass outside the right-of-way.

Defoliation by steam is at least as effective in killing hardwoods as is hydroaxing. Unlike hydroaxing, steaming does not disturb soil or ground covers, thereby enhancing hardwood regeneration by seed. Treatment by steam or hydroax should be most effective if defoliation is complete and if resprouting is treated again before new leaves have a chance to replenish plant reserves. Unfortunately, economics typically limit right-of-way maintenance to a 3-year cycle, not only allowing hardwoods adequate time to recover but enabling them to produce current annual twigs at heights easily browsed by moose.

RIPARIAN HABITAT MANAGEMENT

Because the Susitna River and its major tributaries represent high-density wintering habitat for moose, a 15-year study of riparian vegetation/habitat succession was reexamined and extended to include management perspective (Appendix A).

COVER MEASUREMENT

An important characteristic of wildlife habitats is horizontal cover. However, compared to vertical cover methods, horizontal cover techniques are either inefficient, subjective and inconsistent between observers, or produce significant biases, making analysis or meaningful comparisons of data difficult or impossible. A new method which is several times more efficient and overcomes limitations of other methods was developed (Appendix B).

LEGAL ACCESS FOR HABITAT ENHANCEMENT

Legal access to lands represented the greatest obstacle to habitat enhancement. Difficult as it may be to fully comprehend, most public land in Alaska is highly dissected by numerous jurisdictions and land use classifications which inhibit or prohibit habitat enhancement projects in one way or another. Land disposal programs of the past have compounded this problem by interspersing wildlands with numerous small but influential private inholdings which prevent habitat enhancement activities on adjacent State lands otherwise legally available for enhancement. Within winter range of moose in the Matanuska and Susitna Valleys, only approximately 15% of lands are available for habitat enhancement (Fig. 18). However, most of that 15% is not accessible by heavy equipment, and, therefore, its enhancement is limited to prescribed burning, an option decreasingly supported by environmental regulations and the public, and rarely accepted by adjacent landowners.

MANAGEMENT RECOMMENDATIONS

The principal objective of the following recommendations is enhancement of early successional wildlife habitat in hardwood and mixed spruce-hardwood stands in southcentral Alaska. I believe these guidelines are mutually beneficial to hardwood forest management, because they enhance hardwood regeneration, and, by so doing, help reduce the effects of browsing on an otherwise limited resource. Management of stands for spruce production is not addressed, because it is not always supported by the same practices which benefit early successional wildlife.

LOGGING

1 Clear cutting, including personal use firewood cutting, should not be attempted without specification of site-specific requirements and guaranteed funds for postlogging site preparation and reforestation. Without site-specific reforestation effort, hardwood regeneration may not be sufficient to meet guidelines of the Forest Practices Act (FPA) and certainly will fail to meet potential browse and related wildlife habitat values. Furthermore, restocking of cutover areas at minimal FPA densities often is inadequate, even from a forest management perspective, when poor spacing, poor form, or browsing damage limit quantity and quality of regeneration.

2 Before timber sales are advertised for bid, a preharvest inventory should be conducted to ensure appropriate site-specific guidelines are developed and employed. This inventory should minimally include the following information: basal area by tree species; tree density by height class; understory cover by dominant shrubs and herbaceous species; and general description of soils and topographic features. Such an inventory will also facilitate development of appropriate habitat/forest management practices.

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, percent coverage by each exposed soil horizon, and prevailing soil conditions (moisture, frost). Information on seed availability would also be useful for evaluation of site preparation methods and resultant regeneration.

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

6 All clear cutting (including personal use firewood cutting) and scarification or other site preparations should be completed in 1 year to take advantage of stored seed, to ensure

optimal synchronization with seed fall, and to reduce the lag period in which competing grass cover has time to monopolize sites. This means that actual geographic units of cutting (whether they are complete cutting units or portions) should not exceed that size for which the harvester is capable of completing site preparations within 1 year of cutting.

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

8 Aspen harvests should encompass entire clones to ensure maximum release of root sprouts.

9 All aspen stems exceeding 4 feet height should be cut to ensure that dormant buds within clonal root systems are released for root sprouting.

10 Aspen sites should only be harvested during tree dormancy to ensure maximum root reserves for resprouting.

11 All aspen in predominantly birch or spruce stands should also be felled, regardless if they are to be harvested. This minimal effort more efficiently enhances wildlife habitat than any other single practice.

12 Balsam poplar and cottonwood should be clear cut during dormancy to ensure maximum stump and root sprouting.

13 Sites having soils and understory vegetation indicative of poor drainage or high water table should not be harvested unless appropriate site preparation techniques have been demonstrated for those conditions.

14 All downed stems greater than 4 inches diameter should be piled or removed from sites to allow efficient scarification.

15 All stems smaller than 4 inches diameter should be scattered for eventual incorporation into soil by scarification and decomposition.

16 Stumps should not exceed a height (typically 1 foot) which will impede operation of scarification equipment.

17 A sufficient number of well-distributed birch seed trees should be retained in clear cuts at least until regeneration objectives have been met. In most cases, 15 well-formed birch trees per hectare provides an adequate seed source. Left uncut, the trees will add to the structural diversity of the site, enhance bird habitat, and eventually become material for cavity-nesting birds and small mammals. Seed-tree groups represent an attractive alternative to scattered individual seed trees. Retention of groups rather than individuals reduces seed tree mortality commonly caused by sudden crown exposure, root or bole damage by logging, and windthrow.

18 Tall shrub or tree-sized willows should be left intact for seed and browse production wherever they do not impede logging. Tipping or crushing by logging activities is not necessarily harmful as long as the willows are not completely uprooted.

19 When contracts to cut timber or firewood are advertised for bid, they should include performances clauses requiring scarification of 50-60 % of the site according to the following specifications:

a. Scarification should remove O-horizon material from patches or strips, leaving displaced organics distributed as uniformly as possible between strips or patches; do not limit the distribution of these nutrient-rich materials by pushing them into large piles. This means that equipment must be operated at the shallowest depth which will allow displacement of O-horizon without excessive displacement of A-horizon. Patches or strips of B-horizon which unavoidably become exposed should not exceed 4 feet in width.

b. All harvested sites must be scarified within 1 year of harvest. This should be done when snow will not hamper scarification and when soils are dry or frozen enough to support equipment without becoming compacted.

c. Unless better methods or equipment are identified, scarification should be done by disk trencher, by whole-tree logging in summer, or by clearing blade. Use of the clearing blade should be limited to skilled operators who will maintain proper scarification depth.

d. Tall willows should not be completely uprooted by scarification.

e. Swales, potholes, or other sites occurring as inclusions within the cutting unit that are wet or 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 seriously retard site recovery.

20 Requirements outlined in DOF timber harvest contracts should be closely monitored by agency staff to ensure that successful bidders comply with stipulations concerning times and methods of cutting, site cleanup, and scarification procedures. Slack enforcement of requirements not only allows damage to the resource and future productivity, but it diminishes the credibility of those entrusted to manage the resource, leading to elimination of future use and management opportunities.

CLEARING WITHOUT HARVEST

1 Clear and pile upland black spruce and aspen stands when ground is frozen so soil nutrients will not be displaced into piles.

2 Flat blades and clearing blades are both acceptable for clearing, as long as ground is frozen.

3 Hardwood seed trees and willow shrubs should be retained individually or in groups of 15 or more individuals per species per hectare.

4 Retention of some downed materials on site is desirable for amelioration of microclimate in favor of seedling establishment, as long as coverage of the downed material does not prevent adequate soil warming and seedling germination.

5 The great majority of public recommend that birch and white spruce not be cleared without harvest because they have greater perceived economic value as forest products than black spruce or aspen.

BROWSE REJUVENATION

1 Cut or crush hardwood species during dormancy to stimulate maximum root and stump sprouting.

2 Cut or hydroax hardwoods 15 or more centimeters above ground to avoid unnecessary damage to root crowns.

3 After initial felling by hydroax, downed material should not be mulched, since further disturbance uproots or kills additional individuals which would resprout. Within pole-sized stands (the upper limit for efficient hydroaxing), snow loading and subsequent decay normally force downed material within soil contact in 1 to 3 years.

4 Birch older than approximately 40 years or greater than 10 cm dbh stump sprout poorly or do not produce sprouts having lasting vigor or long-term survival, and therefore do not have good potential for regeneration by cutting or crushing.

PRESCRIBED BURNING

1 Within the limits of smoke emission requirements set by Department of Environmental Conservation, burn when and where understory and ground cover will support slow-moving, meandering fire capable of burning to mineral soil.

2 Dedicate personnel and equipment to a prescribed burning program so that fires can be conducted when conditions meet prescription.

3 Maintain an active public education program regarding the essential nature of fire in the boreal forest and prominently display results of prescribed burning.

LITERATURE CITED

Ahlgren, C. E. 1960. Some effects of fire on reproduction and growth of vegetation in northeastern Minnesota. Ecol. 41:431-445.

Appelroth, S-E. 1981. Latest developments in site preparation in Finland. Paper No. 7-32, Symposium on Engineering Systems for Forest Regeneration. American Society of Agricultural Engineers, Raleigh, North Carolina. 8 p.

Argus, G. W. 1978. The genus *Salix* in Alaska and the Yukon. Publication in Botany No. 2. National Museum of Natural Sciences, Ottawa, Canada. 192. p.

Aldridge, J. W. C. 1967. The durability of scarified seedbeds for spruce regeneration. B. C. For. Serv. Res. Note 42. 20 p.

Beatty, S. W., and E. L. Stone. 1986. The variety of soil microsites created by tree falls. Can. J. For. Res. 16:539-548.

Bjorkbom, J. C. 1971. Production and germination of paper birch seed and its dispersal into a forest opening. USDA For. Serv. Res. Pap. NE-209. Northeast For. Exp. Sta., Upper Darby, PA. 14 p.

Blackmore, D. G., and W. G. Corns. 1979. Lodgepole pine and white spruce establishment after glyphosate and fertilizer treatments of grassy cutover forest land. For. Chron. 55:102-105.

Bliss, L. C., ed. 1973. Botanical Studies of Natural and Man-modified Habitats in the MacKenzie Valley, Eastern MacKenzie Delta Region and Arctic Islands. Rep. No. 73-43. Environmental-Social Committee, Northern Pipelines Task Force on Northern Oil Development.

Bryant, J. P. 1987. Feltleaf willow-snowshoe hare interactions: plant carbon/nutrient balance and floodplain succession. Ecology 68:1319-1327.

Coates, D. and S. Haeussler. 1987. A guide to the use of mechanical site preparation equipment in north central British Columbia. B. C. Ministry of Forest and Lands, Government of Canada, British Columbia. 64 p.

Cole, K., K. Klick and N. Pavlovic. 1992. Fire temperature monitoring during experimental burns at Indiana Dunes National Lakeshore. Natural Areas J. 12:177-183.

Collins, W. B. 1992. Harvesting birch-spruce forest to enhance moose habitat in the Matanuska Valley Moose Range. Wildl. Tech. Bull. No. 10. 37 p.

Conn, J. S. 1990. Seed viability and dormancy of 17 weed species after burial for 4.7 years in Alaska. Weed Sci. 38:134-138.

Crouch, G. L. 1986. Effects of thinning pole-sized lodgepole pine on understory vegetation and large herbivore activity in central Colorado. USDA For. Serv. Rocky Mt. For. Range Exp. Stn. Res. Pap. 268.

Densmore, R. V. 1988. Regeneration of paper birch and willow following scarification of logged areas in southcentral Alaska. Unpublished report, Institute of Northern Forestry, U.S. For. Serv. Fairbanks, Alaska. 21 p.

DeStephano, S., S. R. Craven, R. L. Ruff, D. F. Covell, And J. F. Kubisiak. 1994. A landowner's guide to woodland wildlife management, with emphasis on ruffed grouse. Ext. Publ. G3578, Coop. Ext. Serv. Univ. Wisconsin, Madison. 55 p.

Franzmann, A. W. 1978. Moose, p 67-81. *in* Big Game of North America, Ecology and Management. Stackpole Books, Harrisburg, Pennsylvania.

Greenberg, A. E., L. S. Clesceri, A. D. Eaton, and M. A. H. Franson, eds. 1992. Standard methods for the examination of water and wastewater. 18th ed. American Public Health Association, Washington, D.C.

Gregory, R. A., and P. M. Haack. 1965. Growth and yield of well-stocked aspen and birch stands in Alaska. Res. Pap. NOR-2, USDA For. Serv., Northern For. Exp. Sta. Juneau, Alaska. 28 p.

Gullion, G. W. 1984. Managing northern forests for wildlife. Publ. No. 13,442, Misc. Journal Series, Minnesota Agricultural Exp. Sta. St. Paul. 72 p.

Hamilton, C. D., P. D. Drysdale, and D. Euler. 1980. Moose winter browsing patterns in northern Ontario. Can. J. Zool. 58:1412-1416.

Heilman, P. E. 1968. Relationship of availability of phosphorus and cations to forest succession and bog formation in interior Alaska. Ecol. 49:331-336.

Helm, D. J. and W. B. Collins. submitted. Vegetation succession and disturbance on boreal forest floodplain. Canadian Field-Naturalist.

Hernandez, H. 1972. Surficial disturbance and natural plant recolonization in the Tuktoyaktuk Peninsula Region, N.W.T.. M. S. Thesis. University of Alberta, Edmonton.

Hoyle, M. C. 1965. Addition of phosphorus to subsoil promotes root development of yellow birch. USDA Forest Service, Northeast Forest and Range Experiment Station, Research Note NE-42, 7 p.

Hoyle, M. C. 1969. Response of yellow birch in acid subsoil to macronutrient additions. Soil Science 108:354-358.

Hulten, E. 1968. Flora of Alaska and Neighboring Territories. Stanford University Press. Stanford California. 1008 p.

Ingestad, T. 1977. Nitrogen and plant growth; maximum efficiency of nitrogen fertilizers. Ambio 6:146-151.

Johnson, C. A. and R. J. Naiman. 1990. Browse selection by beaver: effects on riparian forest composition. Journal of Forest Research 20:1036-1043.

Jonsson, B. G., and M. Dynesius. 1993. Uprooting in boreal spruce forests: long-term variation in disturbance rate. Can. J. For. Res. 23:2383-2388.

Kelsall, J. P., E. S. Telfer, and T. D. Wright. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian north: a review and selected bibliography. Canadian Wildlife Service Occasional Paper Number 32. Ottawa, Ontario. 58 p.

Klebesadel, L. J., and W. M. Lauglin. 1964. Utilization of native bluejoint grass in Alaska. Forage Res. Rep. No. 2. Agricultural Experiment Station, University of Alaska, Fairbanks. 22 p.

Koehler, G. M. and J. D. Brittell. 1990. Managing spruce-fir habitat for lynx and snowshoe hares. Journal of Forestry 88:10-14.

Lieffers, V. J., S. E. MacDonald, and E. H. Hogg. 1993. Ecology and control strategies for *Calamagrostis canadensis* in boreal forest sites. Can. J. For. Res. 23:2070-2077.

—— and K. J. Stadt. 1993. Growth of understory *Picea glauca, Calamagrostis canadensis,* and *Epilobium angustifolium* in relation to overstory light transmission. Can. J. For. Res. 24:1193-1198.

Lykke, J., and I. M. Cowan. 1968. Moose management and population dynamics on the Scandinavian Peninsula, with special reference to Norway. Pages 1-22 *in* Proceedings of the 5th North American Moose Workshop, Kenai Moose Research Station, Kenai, Alaska. 95 p.

MacDonald, S. E., and V. J. Lieffers. 1993. Rhizome plasticity and clonal foraging of *Calamagrostis canadensis* in response to habitat heterogeneity. J. Ecol. 81:769-776.

Margolis, H. A., and D. G. Brand. 1990. An ecophysiological basis for understanding plantation establishment. Can. J. For. Res. 20:375-390.

McKendrick, J. D. 1983. Alaska's rangelands, p 125-156. *in* Alaska's Agriculture and Forestry (H. L. McNicholas, ed.). Alaska Rural Development Council Pub. No. 3. University of Alaska, Fairbanks. 220 p.

—— 1984. Range management boreal zone Alaska. Cooperative Extension Service Bulletin A-00145. University of Alaska, Fairbanks. 14 p.

McNicol, J. c., and F. F. Gilbert. 1980. Late winter use of upland cutovers by moose. J. Wildl. Manage. 44:363-371.

Mitchell, W. W. 1968. Taxonomy, variation, and chronology of three chromosome races of the *Calamagrostis canadensis* complex in Alaska. Madronon 19:235-245.

——, and J. Evans. 1966. Composition of two disclimax bluejoint stands in southcentral Alaska. J. Range Manage. 19:65-68.

Mueller-Dombois, D., and H. P. Sims. 1966. Response of three grasses to two soils and a water table depth gradient. Ecol. 47:644-648.

Neter, J., and W. Wasserman. 1974. Applied linear statistical models. Irwin Inc. Homewood, Ill. 842 p.

Neu, C. L., C. R. Byers, and J. M. Peek. 1974. A technical analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Oldemeyer, J. L. 1977. Impact of LeTourneau tree crushers on moose habitat on the Kenai National Moose Range. 28th Annual Conference, Northwest Section of The Wildlife Society, Feb 17-18, 1977, Kalispell, Mt.

—— and Regelin, W. L. 1980. Response of vegetation to tree crushing in Alaska. Proc. North Am. Moose Conf. Workshop 16:429-443.

Orlander, G., P. Gemmel, and J. Hunt. 1990. Site preparation: a Swedish overview. B.C. Ministry of Forests and Lands, Victoria FRDA Rep. 105.

Pastor, J., R. J. Naiman, B. Dewey, and P. McInnes. 1988. Moose, microbes, and the boreal forest. BioScience 38:770-777.

Peek, J. M., K. L. Uruch, and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildlife Monograph 48, 65 p.

Perala, D. A. 1987. Regenerating birches: ecology and cultural requirements. Ph.D. Dissertation, University of Minnesota. 215 p.

Powelson, R. A., and V. J. Lieffers. 1991. Growth of dormant buds on severed rhizomes of *Calamagrostis canadensis*. Can. J. Plant Sci. 71:1093-1099.

Rowe, J. S. 1961. Critique of some vegetational concepts as applied to forests of northwestern Alberta. Can. J. Got. 39:1007-1017.

Safford, L. O. 1983. Silvicultural guide for paper birch in the Northeast (revised). Res. Pap. NE-535. Broomall, PA: U.S. Dept. Agric, For. Serv. Northeastern For. Exp. Sta. 29 p.

Schroeder, M. J., and C. C. Buck. 1970. Fire weather. U.S.D.A. For. Serv. Agricultural Handbook 360. 269 p.

Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Research Dept. Univ. of Wisconsin College of Agric. and Life Sciences, Madison, Wis.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical Methods, 7th Ed. The Iowa State University Press, Ames, Iowa. 507 p.

Stone, T. L. 1977. Production and utilization by deer and moose of woody and herbaceous vegetation on areas commercially clearcut in northern Maine. M.S. Thesis, Univ. Maine, Orono. 52 p.

Teikmanis, A. 1956. Om den naturligaforyngringen efter markberedningar I Norrland. Norrlands SkogsvForb. Tidsdr., 3:385-442

Thorsen, A. (ed.) 1978. Scarification. Forskningsstiftelsen Skogsarbeten. Tryckeri AB Knappen, Karlstad.

Tilley, J. M. S., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. British Grassland Society. 18:104-111.

Todesco, C. J., H. G. Cumming, and J. G. McNicol. 1985. Winter moose utilization of alternate strip cuts and clear cuts in northwestern Ontario: Preliminary results. Alces 21:447-474.

Tolmochev, A. I. (ed.). 1964. The Flora of the USSR II. *Graminae*. Moscow. 172 p.

Van Cleve, K. and C. T. Dyrness. 1983. Effects of forest floor disturbance on soil-solution nutrient composition in a black spruce ecosystem. Can. J. For. Res. 13:894-902.

Viereck, L. A. and L. A. Schandelmeier. 1980. Effects of fire in Alaska and adjacent Canada--a literature review. Bureau of Land Management Technical Report 6. 124 p.

Wilm, H. G. D. F. Costello, and G. E. Klipple. 1944. Estimating forage yield by the double-sampling method. J. Am. Soc. Agron. 36:194-203.

Wolff, J. O., and J. C. Zasada. 1979. Moose habitat and forest succession on the Tanana River flood plain and the Yukon-Tanana upland. Pages 213-245 *in* Vol 15 of the Proceedings of the North American Moose Conference and Workshop. H. G. Cumming, ed. School of Forestry, Lakehead University, Thunder Bay, Ont.

Zasada, J. C., K. Van Cleve, R. A. Werner, J. A. McQueen, and E. Nyland. 1977. Forest biology and management in high-latitude North American forests. Pages 137-195 *in* Symposium proceedings, North American Forest Lands at Latitudes North of 60 Degrees. University of Alaska, Fairbanks.

——, R. M. Van Veldhuizen, and C. E. Teutsch. 1983. Artificial regeneration of trees and tall shrubs in experimentally burned upland black spruce/feather moss stands in Alaska. Can. J. Forest Research 13:903-913.

PREPARED BY:

William Collins

Wildlife Bioogist III

SUBMITTED BY:

Charles C. Schwartz

Research Coordinator

APPROVED BY:

Wayne Regelin, Director

Division of Wildlife Conservation

Steven R Peterson, Senior Staff Biologist

Division of Wildlife Conservation

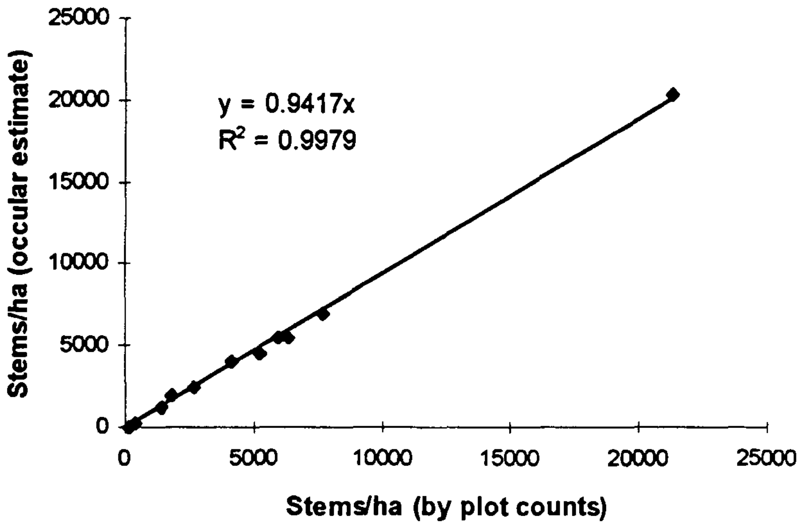


Figure 1. Linear relationship between ocular estimates and plot counts of regenerating hardwood stems in forest harvest sites in the Matanuska and Susitna Valleys.

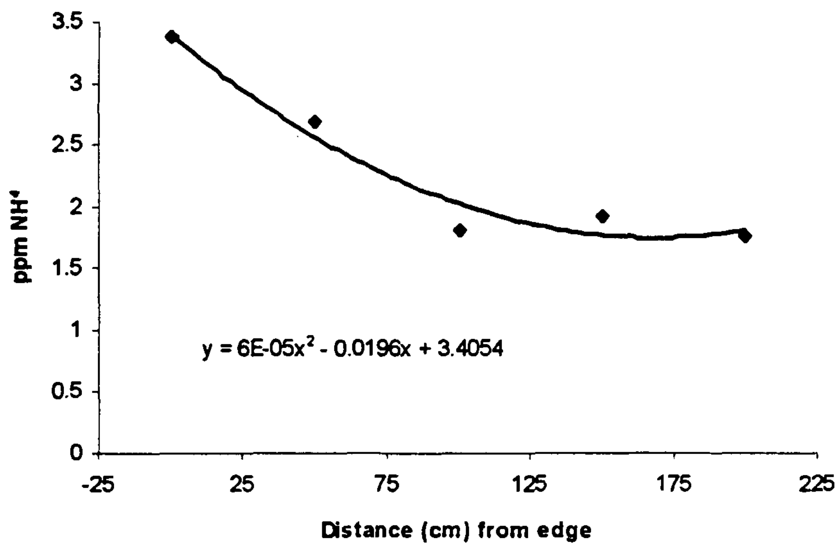


Figure 2. Distribution of NH_4 from edge in scarified patch.

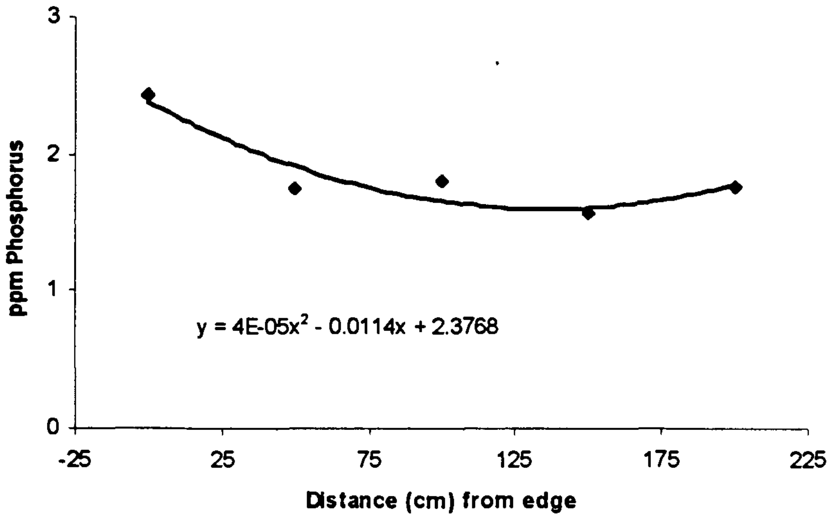


Figure 3. Distribution of phosphorus from edge in scarified patch.

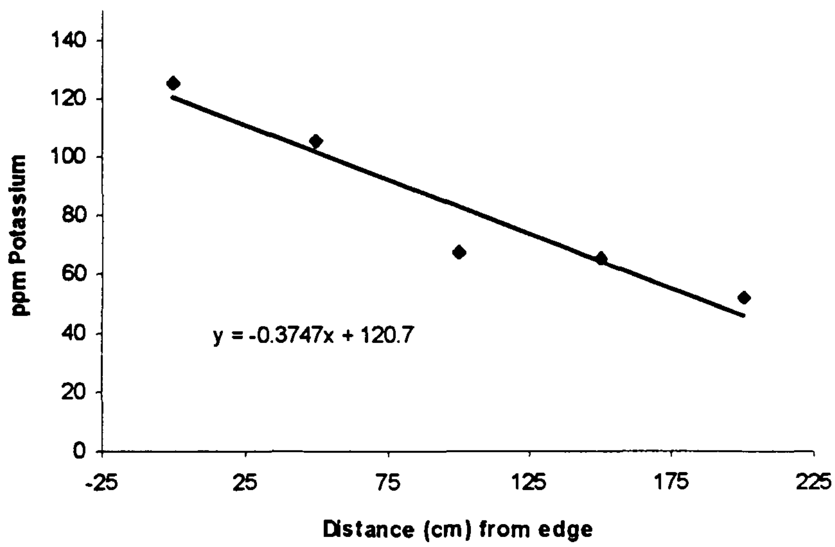


Figure 4. Distribution of potassium from edge in scarified patch.

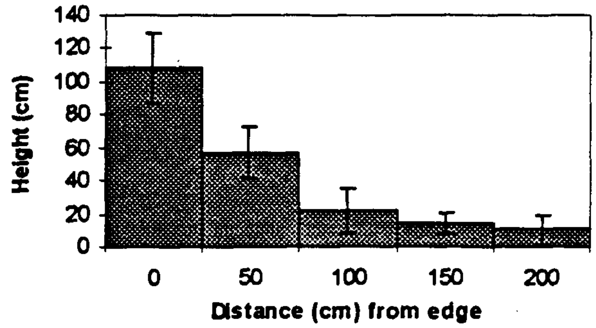


Figure 5. Height of three-year-old paper birch seedlings in scarified patches.

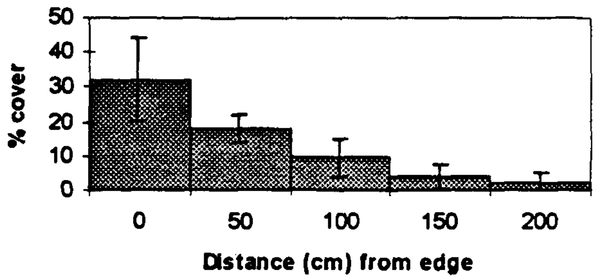


Figure 6. Percent cover by three-year-old paper birch seedlings in scarified patches.

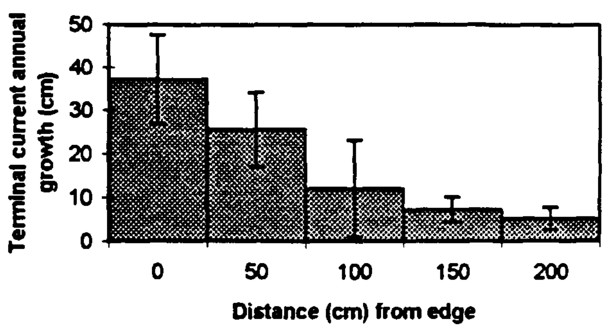


Figure 7. Terminal twig growth of three-year-old paper birch in scarified patches.

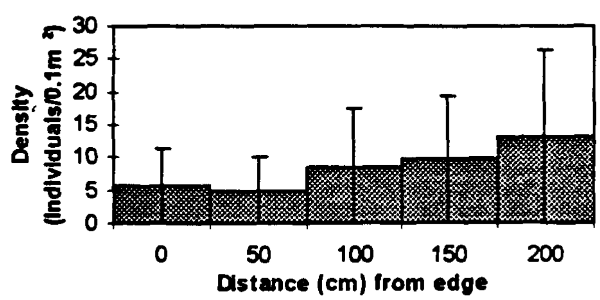


Figure 8. Density of three-year-old paper birch seedlings in scarified patches.

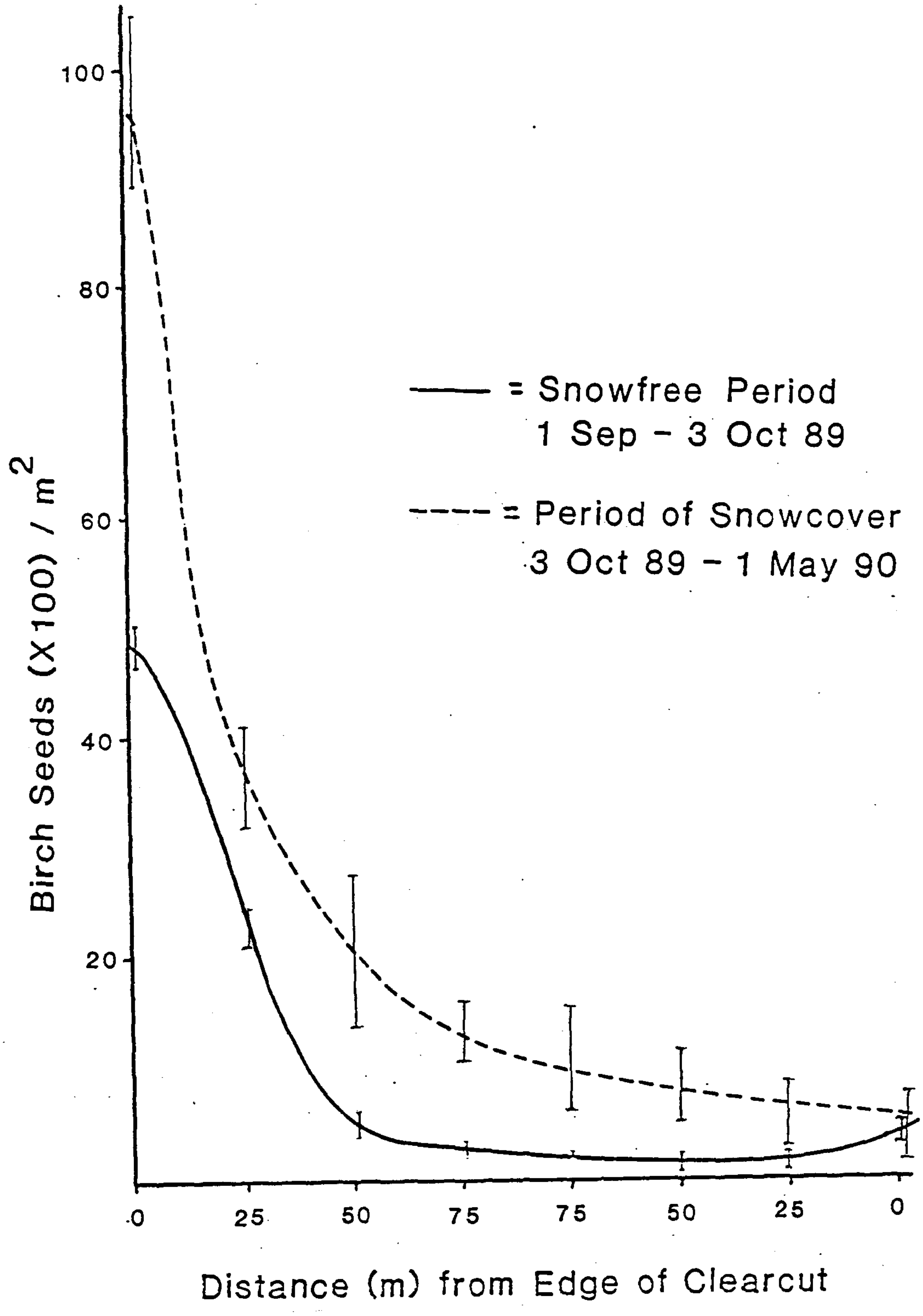


Figure 9. Birch seed distribution into clear cut openings of birch-spruce forest.

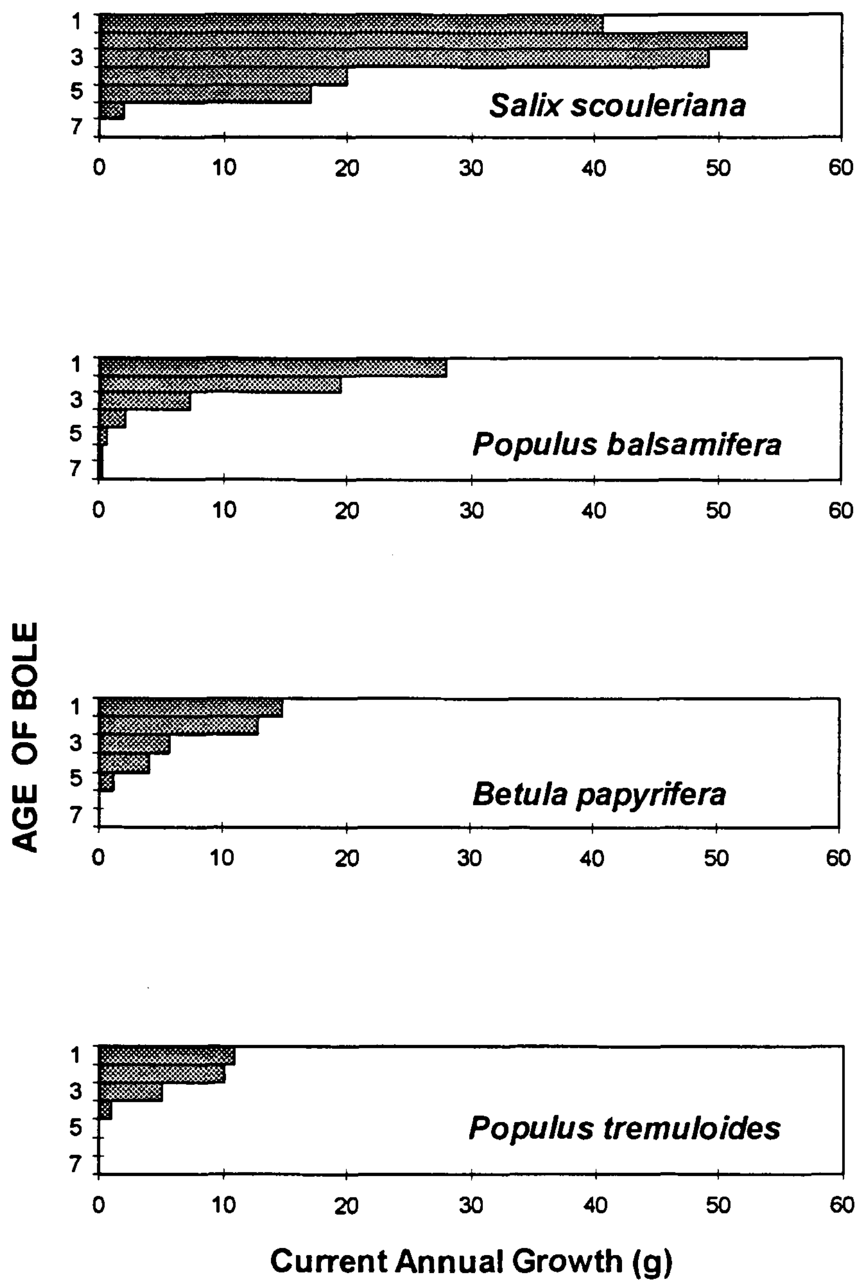


Figure 10. Vertical distribution of current annual growth (CAG) within 4 species of browse. Mean CAG of 7-year-old plants never before browsed (N = 30 for each species) is summarized relative to age of bole segment from which it originated. Thus, age of bole segment (y-axis) is plotted in descending order so that the youngest bole origins are at the top as they are in the plant.

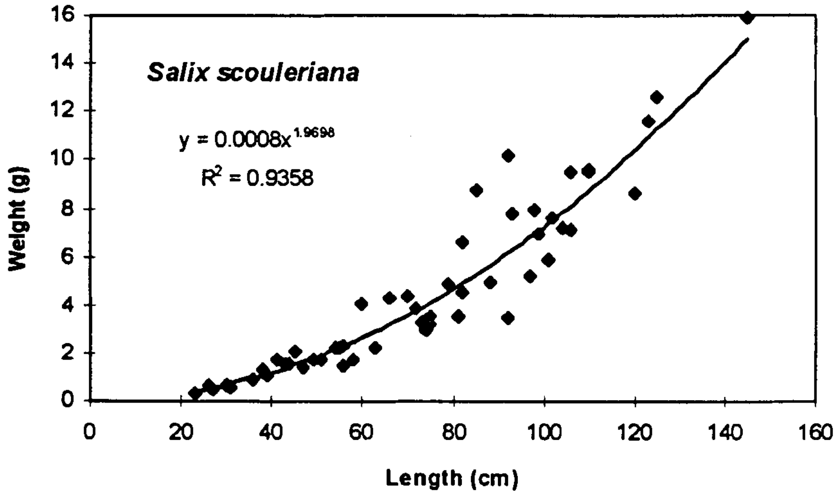


Figure 11. Relationship between length and weight of current annual twigs of scouler willow.

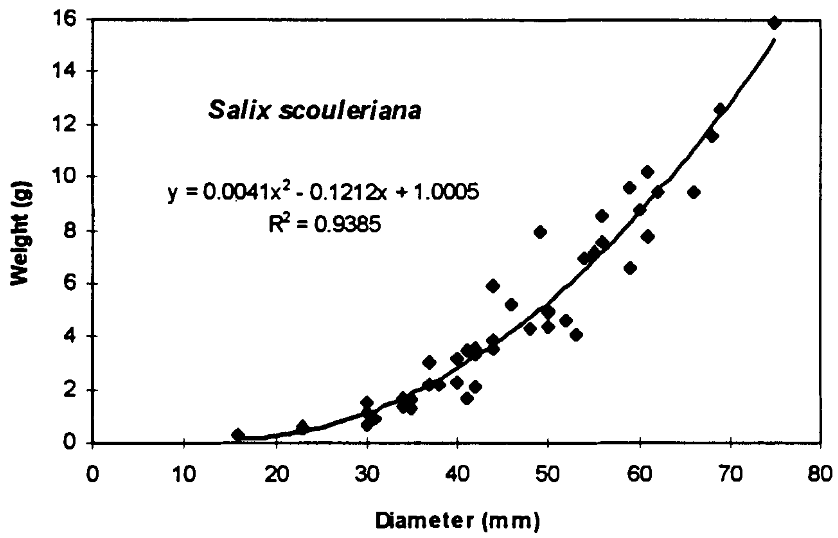


Figure 12. Relationship between diameter and weight of current annual twigs of scouler willow.

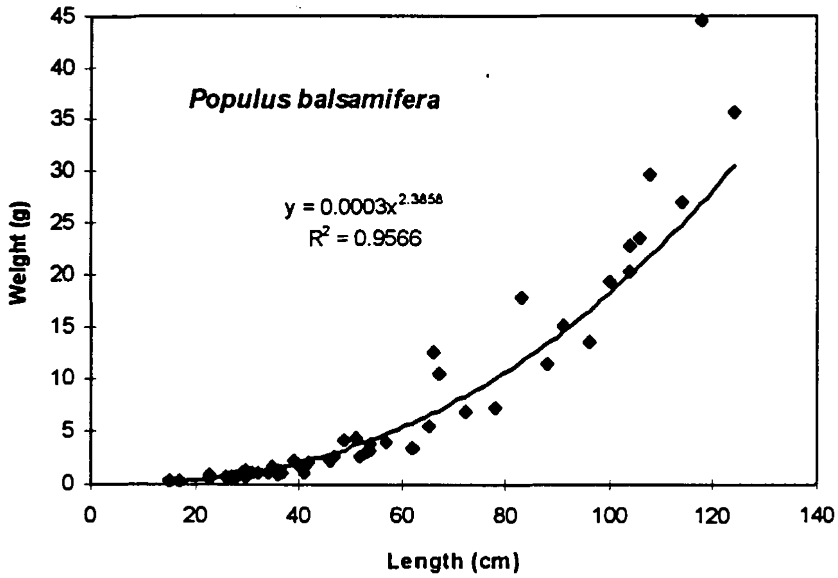


Figure 13. Relationship between length and weight of current annual twigs of balsam poplar.

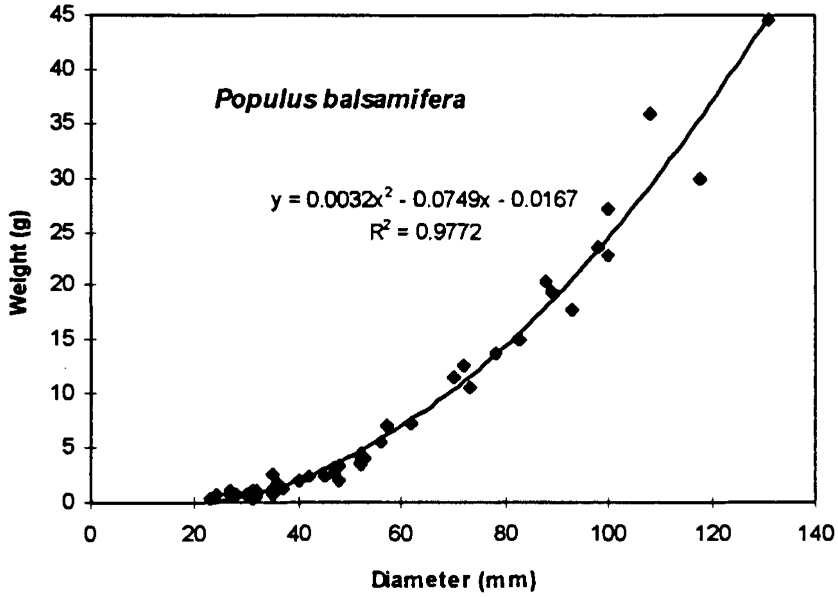


Figure 14. Relationship between diameter and weight of current annual twigs of balsam poplar.

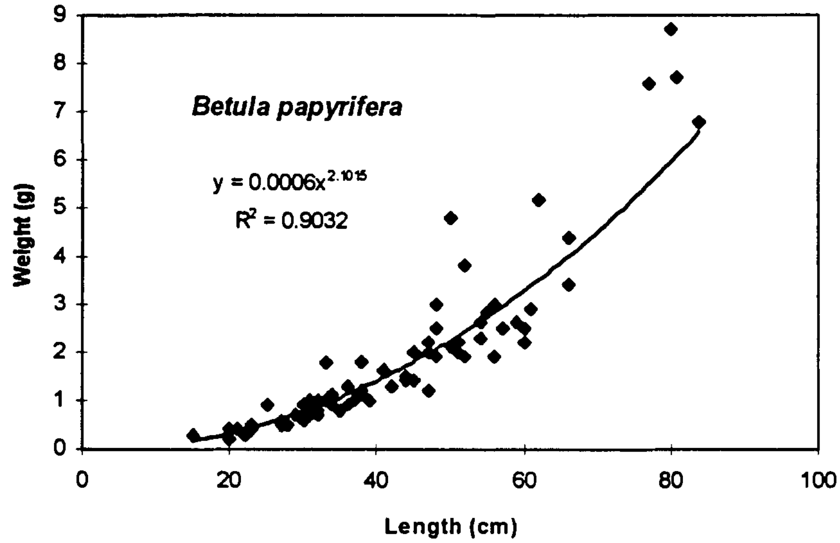


Figure 15. Relationship between length and weight of current annual twigs of paper birch.

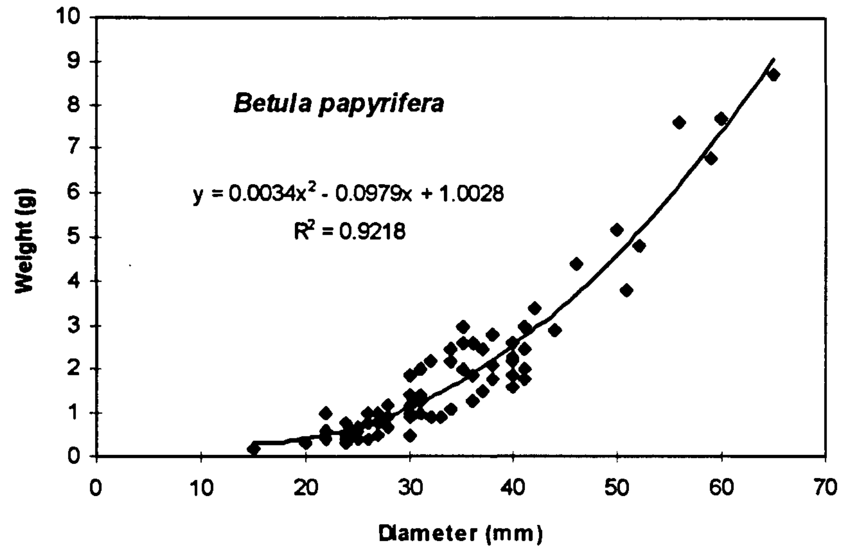


Figure 16. Relationship between diameter and weight of current annual twigs of paper birch.

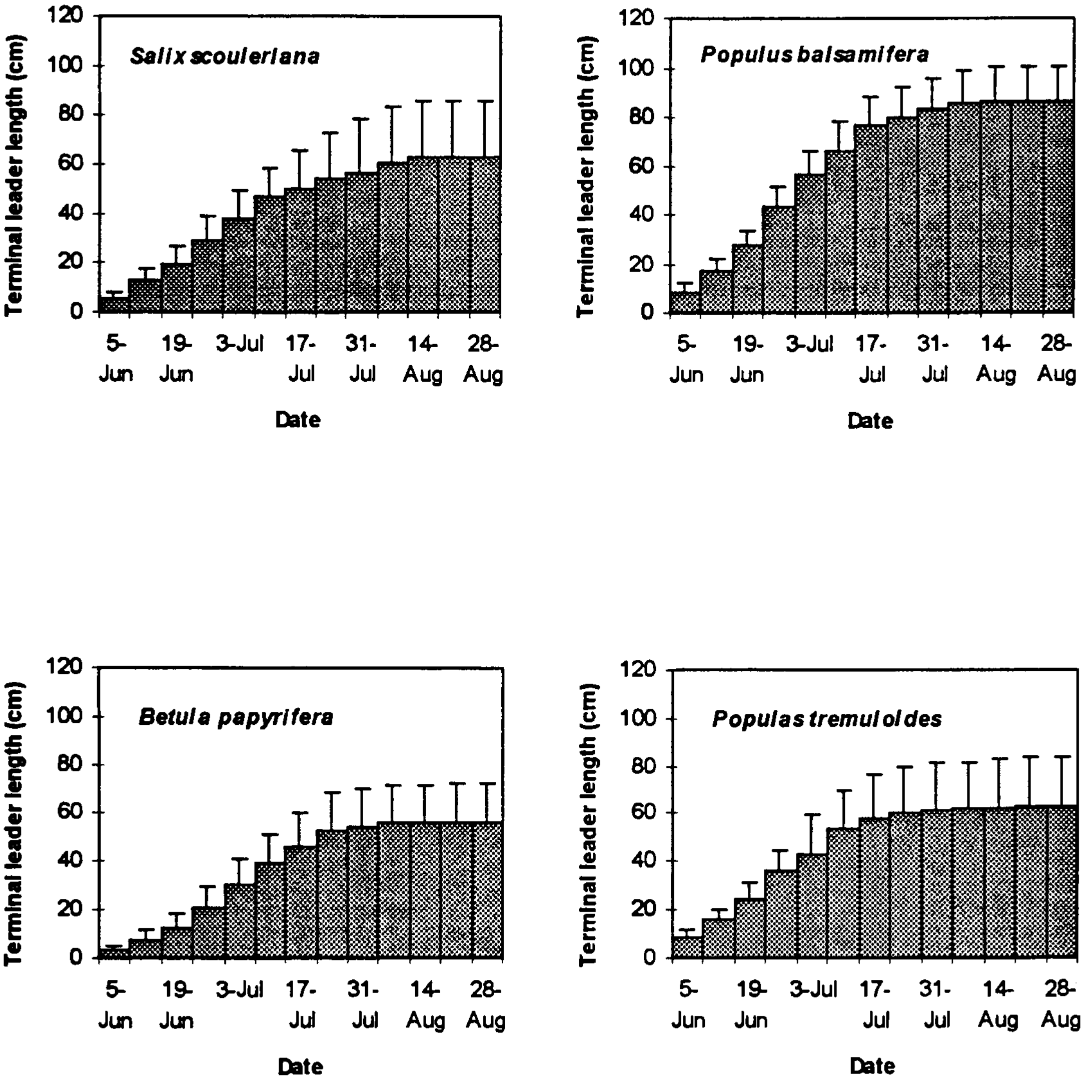


Figure 17. Timing of terminal leader growth in 4 browse/tree species important to moose. Total length of marked leaders (N = 30) were measured weekly through the growing season.

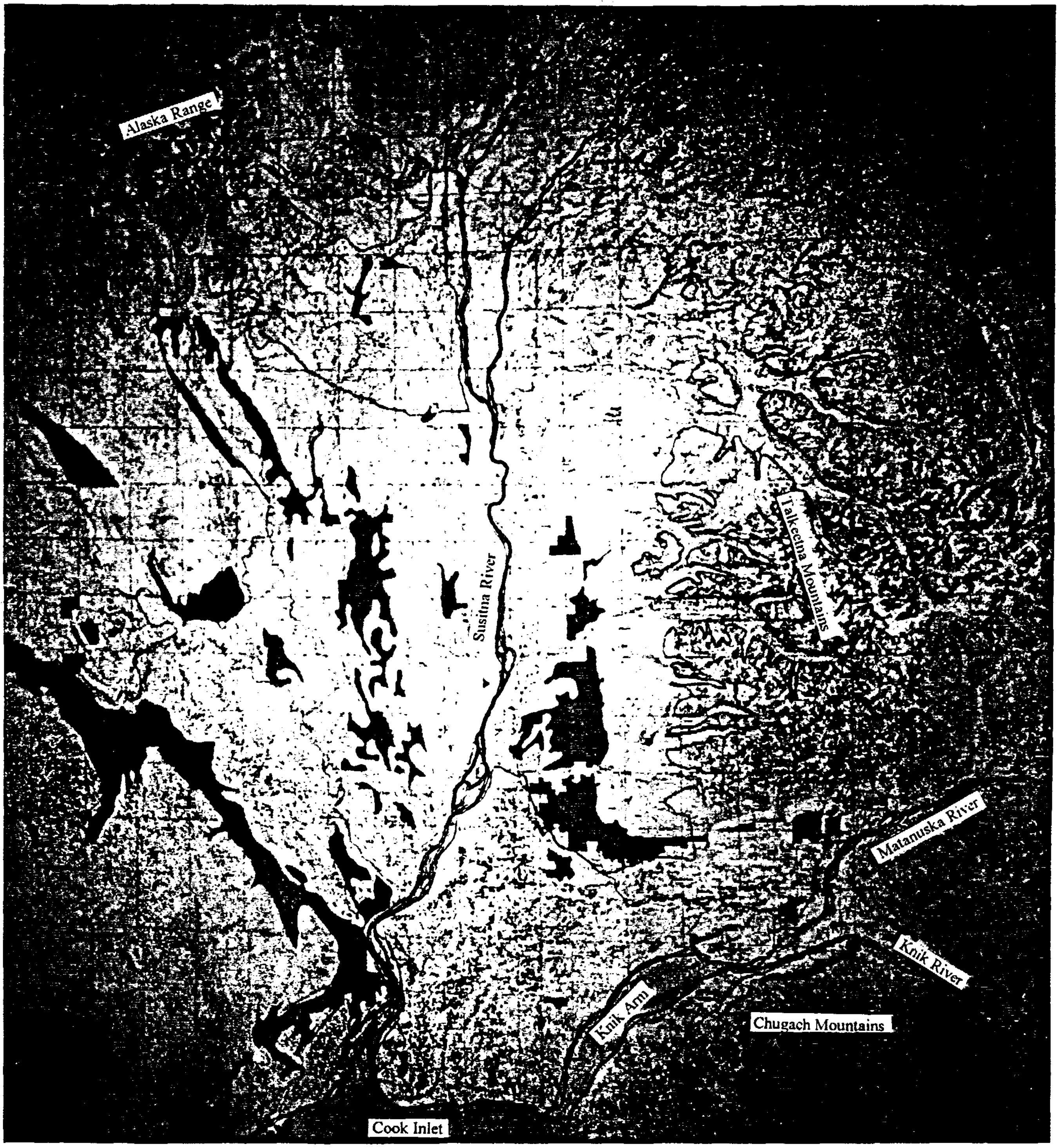


Figure 18. Areas of Matanuska and Susitna Valleys (black polygons, representing 15% of the total area below 300m elevation) where wildlife habitat enhancement is legally acceptable.

Table 1. Location, vegetation, management history and hardwood regeneration of logged sites within the Matanuska and Susitna Valleys.

Latitude:longitude	Vegetation[1]	Soil H_2O[2]	Harvest method	Date	Season	Scarifi cation		Year(s) lapse[3]	Seedlings	Sprouts	Total stems
						Method	Date				
61° 34.82 148° 59.19	Bepa-Pigl-Poba	M	selective	1985-1987	winter	none			50	350	400
61° 34.60 148° 59.32	Bepa-Pigl-Poba	M	selective	1987-1988	winter	none			100	350	450
61° 36.07 149° 01.06	Bepa-Pigl-Poba	M	selective	1993-1994	winter	none			0	400	400
61° 40.35 149° 12.37	Bepa-Pigl	M	clear cut	1981-1982	winter	flat blade	summer 1983	1	2,200	400	2500
61° 40.50 149° 12.27	Bepa-Pigl	M	clear cut	1981-1982	winter	flat blade	summer 1983	1	2,500	500	3000
61° 40.77 149° 12.21	Potr-Bepa-Pigl	D	clear cut	1983-1984	winter	none			1,000	4,500	5500
61° 40.79 149° 11.94	Bepa-Pigl	M	clear cut	1982-1983	winter	flat blade	1983	0	3,600	400	4000
61° 40.97 149° 11.87	Bepa-Potr-Pigl	D	clear cut	1982	winter	chain	winter 1982	0	1,700	300	2000
61° 41.18 149° 12.40	Bepa-Pigl	M	clear cut	1983-1984	winter	none			0	300	300
61° 41.25 149° 12.35	Bepa-Pigl	M	clear cut	1983-1984	winter	root rake	fall 1985	1	20,000	400	20400
61° 41.27 149° 11.94	Bepa-Pigl	M	clear cut	1983-1984	winter	none			0	300	300
61° 40.46 149° 08.85	Potr-Bepa	D	clear cut	1985-1986	winter	none			1,500	4,500	6000
61° 40.57 149° 08.51	Potr-Bepa	D	clear cut	1985-1986	winter	none			500	3,000	3500
61° 40.77 149° 08.18	Bepa-Potr	D	clear cut	1985-1986	winter	none			1,500	1,500	3000
61° 40.90 149° 07.98	Bepa-Potr-Pigl	D	clear cut	1985-1986	winter	none			0	500	500
61° 40.66 149° 07.27	Bepa-Pigl	M	clear cut	1982-1983	winter	none			500	4,000	4500
61° 40.49 149° 08.26	Bepa-Pigl	M	clear cut	1989	fall	root rake	fall 1989	0	5,000	0	5000
61° 40.44 149° 08.43	Bepa-Potr	M	clear cut	1988-1989	winter	none			800	3,000	3800
61° 40.25 149° 08.25	Bepa-Potr	M	selective	1985-1986	winter	none			800	5,500	6300
61° 40.80 149° 10.03	Bepa-Pigl-Potr	M	clear cut	1985-1994	all	disk	summer 1994	0	4,500	1,500	6000
61° 40.78 149° 09.73	Bepa-Pigl-Potr	M	clear cut	1985-1994	all	disk	summer 1994	0	4,000	2,000	6000
61° 40.83 149° 09.50	Bepa-Pigl	M	clear cut	1985-1994	all	disk	summer 1994	0	3,000	0	3000
61° 40.81 149° 09.07	Bepa-Pigl	M	clear cut	1985-1994	all	disk	summer 1994	0	4,000	0	4000
61° 40.84 149° 08.78	Bepa-Pigl	M	clear cut	1987-1988	winter	root rake	summer 1989	1	5,000	500	5500

Table 1. (continued)

Latitude:longitude	Vegetation[1]	Soil H_2O[2]	Harvest method	Date	Season	Scarification Method	Scarification Date	Year(s) lapse[3]	Seedlings	Sprouts	Total stems
61° 41.21 149° 07.80	Bepa-Pigl	M	clear cut	1989-1990	winter	none			500	400	900
61° 41.25 149° 07.97	Bepa-Pigl-Potr	M	clear cut	1989-1990	winter	none			400	300	700
61° 41.41 149° 08.10	Bepa-Pigl	M	clear cut	1989-1990	winter	none			300	300	600
61° 41.36 149° 08.44	Bepa-Pigl	M	clear cut	1989-1990	winter	flat blade	summer 1990	0	3,500	500	4000
61° 41.25 149° 08.66	Bepa-Pigl	M	clear cut	1989-1990	winter	none			100	400	500
61° 41.14 149° 08.39	Bepa-Pigl-Poba	M	clear cut	1989-1990	winter	none			200	300	500
61° 41.15 149° 08.63	Bepa-Pigl-Potr	M	clear cut	1989	summer	none			400	500	900
61° 41.29 149° 09.81	Pigl-Bepa	M	selective	1985-1988	winter	none			0	100	100
61° 41.23 149° 09.42	Pigl-Bepa	M	selective	1985-1988	winter	none			0	100	100
61° 41.19 149° 09.15	Bepa-Pigl	M	clear cut	1985-1987	summer	flat blade	summer 1987	0	6,000	500	6500
61° 41.11 149° 09.06	Bepa-Pigl	M	clear cut	1989	summer	none			100	200	300
61° 41.09 149° 09.26	Bepa-Pigl	M	clear cut	1989	summer	none			100	200	300
61° 40.11 149° 25.54	Bepa-Pigl	W	clear cut	1988-1989	winter	flat blade	spring 1989	0	30	45	75
61° 40.17 149° 09.25	Bepa-Pigl	W	clear cut	1988-1989	winter	flat blade	spring 1989	0	25	35	60
61° 40.21 149° 25.43	Bepa-Pigl	W	clear cut	1988-1989	winter	flat blade	spring 1989	0	35	35	70
61° 46.88 149° 53.45	Bepa-Pigl	M	clear cut	1988-1989	winter	root rake	summer 1991	2	8,000	500	8500
61° 47.05 149° 52.97	Bepa-Pigl	M	clear cut	1988-1989	winter	root rake	summer 1991	2	10,000	500	10500
61° 47.27 149° 52.95	Bepa-Pigl	M	clear cut	1988-1989	winter	root rake	summer 1991	2	18,000	500	18,500
61° 47.35 149° 52.86	Bepa-Pigl	M	clear cut	1988-1989	winter	root rake	summer 1991	2	17,000	500	17,500
61° 47.65 149° 52.77	Bepa-Pigl	M	clear cut	1989-1990	all	none			2,000	400	2400
61° 47.52 149° 52.74	Bepa-Pigl	M	clear cut	1990-1991	all	none			4,000	400	4400
61° 47.69 149° 51.77	Bepa-Pigl	M	clear cut	1990-1991	all	none			500	500	10000
61° 48.02 149° 51.34	Bepa-Pigl	M	clear cut	1990-1991	all	none			500	400	900
61° 44.23 150° 07.11	Potr-Pigl	D	ag clearing	1988-1989	all	flat blade	all 1988-1989	0	12,000	30,000	42000
61° 43.60 150° 10.74	Bepa-Pigl	M	clear cut	1988-1989	winter	none			300	350	650
61° 43.60 150° 11.14	Bepa-Pigl-Potr	D	clear cut	1984-1989	all	flat blade	summer 1989	0	2,500	300	2800

Table 1. (continued)

Latitude:longitude	Vegetation[1]	Soil H_2O[2]	Harvest method	Date	Season	Scarification Method	Scarification Date	Year(s) lapse[3]	Seedlings	Sprouts	Total stems
61° 43.38 150° 08.78	Bepa-Potr-Pigl-Poba	M	ag clearing	1988-1989	all	flat blade	summer 1989	0	18,000	8,000	26000
61° 57.75 150° 04.74	Bepa-Pigl-Potr	D	clear cut	1987-1988	all	none			300	23,000	23300
62° 11.47 150° 11.30	Bepa-Pigl	M	selective	1989-1990	all	none			0	50	50
62° 10.39 150° 09.74	Bepa-Pigl	M	clear cut	1989-1990	winter	none			0	150	150
61° 41.06 149° 05.46	Potr-Bepa-Pigl	M	clear cut	1982	all	none			1,500	4,500	6000
61° 41.22 149° 04.85	Bepa-Potr-Pigl	M	clear cut	1982	all	none			1,500	3,000	4500
61° 42.15 149° 07.82	Bepa-Pigl	W	clear cut	1983	winter	flat blade	winter 1983	0	40	5	45
61° 41.97 149° 03.65	Bepa-Pigl-Poba	M	clear cut	1992	summer	none			100	200	300
61° 41.46 149° 02.63	Bepa-Pigl-Poba	M	clear cut	1990	summer	root rake	summer 1990	0	1,400	1,600	3000
61° 44.16 148° 44.66	Bepa-Poba-Potr	M	select	1978-1980	all	none			0	3,400	3400
61° 41.55 149° 01.92	Bepa-Pigl-Poba	M	clear cut	1992	summer	whole tree	summer 1990	0	6,500	0	6500
61° 41.64 149° 01.44	Bepa-Pigl-Poba	M	clear cut	1989	summer	none			200	300	500
61° 41.46 149° 02.63	Bepa-Pigl-Poba	M	clear cut	1990	summer	root rake	summer 1990	0	0	1,400	1,600
61° 44.16 148° 44.66	Bepa-Poba-Potr	M	select	1978-1980	all	none			0		3,400
61° 41.55 149° 01.92	Bepa-Pigl-Poba	M	clear cut	1992	summer	whole tree	summer 1990	0	0	6,500	6500
61° 41.64 149° 01.44	Bepa-Pigl-Poba	M	clear cut	1989	summer	none			0	200	300

[1] Bepa = *Betula papyrifera*, Pigl = *Picea glauca*, Poba = *Populus balsamifera*, and Potr = *Populus tremoloides*.
[2] D = dry, M = mesic, and W =wet.
[3] Year(s) lapse refers to the number of years lapse between cutting and scarification.

Table 2. Mean concentrations of phosphorus (P), potassium (K), ammonia (NH_4), and nitrate (NO_3) in upper 10 cm of scarified soil at different distances from edge. Standard deviations are parentheses.

Distance (cm) from edge	P	K	NH_4	NO_3
0	6.5 (3.94)	125.7 (50.89)	12.7 (9.69)	2.8 (3.54)
50	3.2 (1.17)	105.5 (45.04)	7.7 (3.72)	1.5 (0.84)
100	3.3 (1.21)	67.5 (42.45)	3.5 (1.97)	1.2 (0.41)
150	2.5 (0.55)	65.5 (21.14)	4.2 (2.79)	1.2 (0.41)
200	3.2 (0.75)	52.0 (19.72)	3.2 (0.75)	1.0 (0.00)

Table 3. Differences in birch seed germination under different site preparation treatments. Contrasts are based on a MSE of 3.772 with 41 df.

Contrast	df	MS	F	P
Low vs High Conc. Herb.	1	0.0	0.00	1.0000
Med. vs High Conc. Herb.	1	0.0	0.00	1.0000
High Herb. vs High Herb/Disk	1	1600.0	424.2	0.0001
High Herb. vs High Herb/burn	1	0.0	0.00	1.0000
High Herb/Disk vs Disk	1	480.0	127.26	0.0001

Table 4. Forage production (dry weight, kg/ha) in wet birch-spruce sites which had been clearcut logged, grazed under a high-intensity, short-duration regime for 4 years, then rested 1 year. Means are followed by standard deviations in parenthesis.

species	Paddock 1		Paddock 2	
	Control	Grazed/rested	Control	Grazed/rested
Calamagrostis canadensis	1344(1002.8)	1580(643.6)	2084(1204.0)	2327(662.4)
Epilobium angustifolium	1580(1187.2)	134(106.0)	1334(1111.2)	200(158.6)
Equisetum pratense	274(208.4)	958(387.6)	179(274.0)	154(96.9)
Rosa acicularis	109(129.6)	30(78.0)	21(77.2)	53(105.1)
Gymnocarpium dryopteris	50(94.4)	14(23.6)	2(4.8)	43(100.8)
Streptopus amplexifolius	0	5(15.6)	137(208.2)	0

Table 5. Characteristics of upland black spruce forest floor before and after burning. Means are followed by standard deviations in parenthesis.

site	preburn			postburn	
	% fuel moisture[a]		depth	moss/duff	depth
	moss	duff	moss/duff (cm)	consumed (cm)	killing heat (cm)
crushed (1 day before)	17 (2.6)	110 (15.4)	11.8 (3.2)	7.6 (3.1)	1.6 (0.6)
crushed (1 year before)	5 (0.3)	21 (1.6)	11.9 (3.7)	8.4 (3.2)	2.4 (1.6)
standing forest (hot fire)	20 (1.9)	110 (11.2)	11.3 (4.4)	7.3 (3.8)	1.5 (0.7)
standing forest (creeping fire)	nd	nd	11.3 (3.6)	4.4 (4.9)	2.3 (2.3)

[a] % moisture = fuel water content / ovendry fuel weight x 100 (Schroeder and Buck 1970).

Table 6. Percent cover by species in upland black spruce forest--unburned, burned, and crushed and burned--August 1995. Trees or vegetation above 1 m are not included in cover estimates. Means are followed by standard deviations in parenthesis.

species or material	unburned	burned	crushed-and-burned
total bare soil[1]	0	24.1 (2.5)	36.2 (3.2)
bare soil (not over-topped by other covers)	0	18.3 (2.2)	25.0 (2.8)
litter	6.3 (1.7)	1.0 (0.5)	5.4 (0.5)
wood	2.9 (3.4)	8.4 (1.8)	17.4 (2.8)
dead moss	0	50.7 (0.2)	22.3 (6.9)
Marchantia polymorpha	0	0	6.2 (4.0)
Peltigera apthosa	1.6 (1.7)	0	0
Nephroma arcticum	5.0 (3.4)	0	0
Polytrichum strictum	4.7 (1.7)	1.7 (0.2)	1.5 (0.2)
Pleurozium schreiberi	57.4 (1.7)	0.5 (0.4)	0
Hylocomium splendens	3.9 (3.4)	0	0
Moss spp	0	3.3 (0.9)	4.5 (2.1)
Equisetum silvaticum	+[2]	0	0
Cornus canadensis	13.8 (1.7)	2.1 (1.5)	1.2 (1.7)
Geocaulon lividum	0.3 (1.7)	0	0
Ledum groenlandicum	0.3 (0.3)	0	0
Vaccinium vitis-idaea	3.4 (3.4)	0	0
Rosa acicularis	+	+	+
Pyrola asarifolia	0.3 (0.6)	0	0
Corydalis sempervirens	0	0.2 (0.1)	0.7 (1.0)
Epilobium angustifolium	0	7.9 (2.0)	12.4 (3.8)
Carex spp	0	+	0.8 (0.7)
Betula papyrifera	+	+	0.7 (0.9)
Salix scouleriana	+	+	+
Populus tremuloides	0	1.6 (4.7)	1.8 (5.5)

[1] Total bare soil includes bare soil which was overtopped by downed woody material, litter, and aerial portions of pioneering plants at the time of cover measurement. All other cover values in this table represent "single hit" cover measurement.

[2] + indicates trace amount present.

APPENDIX A. Moose (*Alces alces*) Habitat Relative to Riparian Succession in the Boreal Forest

William B. Collins[1] and D. J. Helm[2]

[1]Alaska Department of Fish and Game, 1800 Glenn Hwy., Palmer, Alaska 99645

[2]Agricultural and Forestry Experiment Station, University of Alaska, Fairbanks, 533 E. Fireweed, Ave., Palmer, Alaska 99645.

ABSTRACT: We documented moose habitat characteristics relative to boreal forest succession in the Susitna River floodplain, Alaska. Early shrub and old balsam poplar (*Populus balsamifera*) stands were most important to wintering moose. Browse availability was the principal factor affecting winter habitat selection by moose. Feltleaf willow (*Salix alaxensis*), a species found most abundantly in early shrub stands was the mainstay browse species, producing approximately 101 kg/ha available browse. Approximately 76% of available feltleaf willow was utilized. Other important species, high bushcranberry (Viburnum edule) and rose (Rosa acicularis) were abundant in old balsam poplar and birch-spruce (Betula papyrifera-Picea glauca) stands, but were virtually unavailable during winters of deeper than normal snow accumulations. Slightly deeper than normal snow triggered dramatic reductions in browse availability, greatly limiting the long-term carrying capacity of the floodplain. Non-vegetated sites, dry sloughs and frozen river channels had significantly less ($P < 0.05$) snow accumulation than other sites, making them preferred travel corridors for moose during periods of deep snow. The only other apparent effect vegetation cover had on habitat selection was observed during sunny, warm days in late winter when moose tended to bed within the shade of white spruce. Wind speed did not vary significantly ($P < 0.05$) between successional phases older than early shrub, and it did not appear to be a factor in any habitat use. While biologically feasible, enhancement of browse production in the Susitna River floodplain appears logistically impractical and of wrong priority. Habitat enhancement should be focused on upland sites where resources management has limited natural ecosystem functions, rather than in the floodplain where uninterrupted flow of the river naturally continues to maintain a constant supply and diversity of successional conditions important to moose and other wildlife.

Canadian Field-Naturalist (in review)

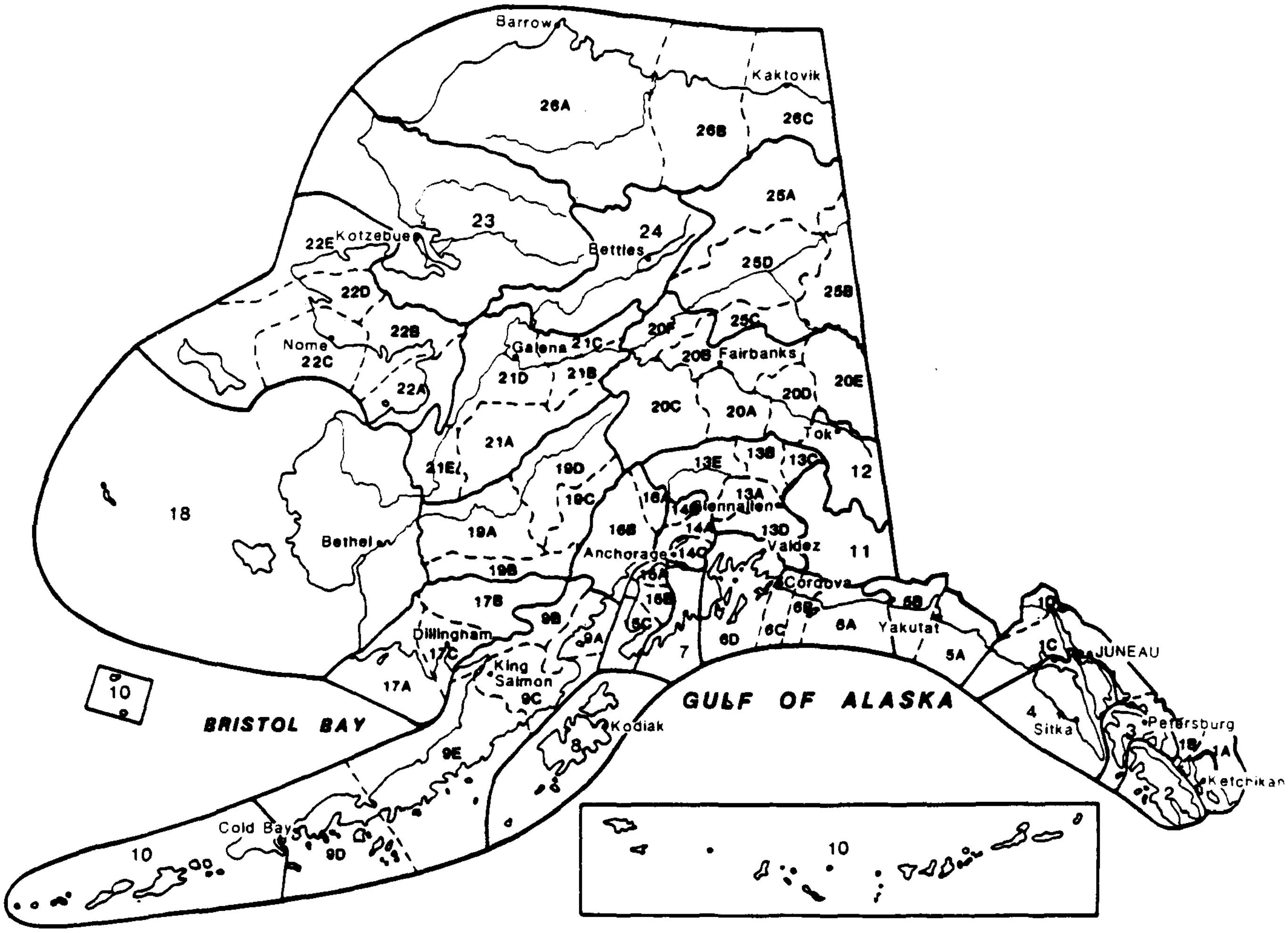
APPENDIX B. Measurement of the Horizontal Component of Wildlife Cover

William B. Collins, Alaska Department of Fish and Game, 1800 Glenn Hwy., Palmer, AK 99645.

ABSTRACT: A method for point sampling lateral profiles of vegetation and physiography was developed to provide biologists with an objective and efficient means for describing the horizontal component of wildlife cover. The staff-ball method resulted in estimates which were significantly ($P < 0.05$) less variable than those obtained by the checkerboard method. Depending on observation distances and whether or not binoculars were necessary for the staff-ball method, use of the staff-ball was 1.6-5.1x, 1.8-7.0x, and 10.5-14.5x significantly ($P < 0.01$) faster than profile board, cover tube, and checkerboard techniques, respectively. Important considerations in measurement of horizontal cover are discussed.

J Wildl Manage (in review)

Alaska's Game Management Units



The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program allots funds back to states through a formula based on each state's geographic area and number of paid hunting license holders. Alaska receives a maximum 5% of revenues collected each year. The Alaska Department of Fish and Game uses federal aid funds to help restore, conserve, and manage wild birds and mammals to benefit the public. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes for responsible hunting. Seventy-five percent of the funds for this report are from Federal Aid.

Craig Gardner

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-6077, (TDD) 907-465-3646, or (FAX) 907-465-6078.