Forest Succession and Wildlife Abundance Following Clear-cut Logging in West-Central Alberta

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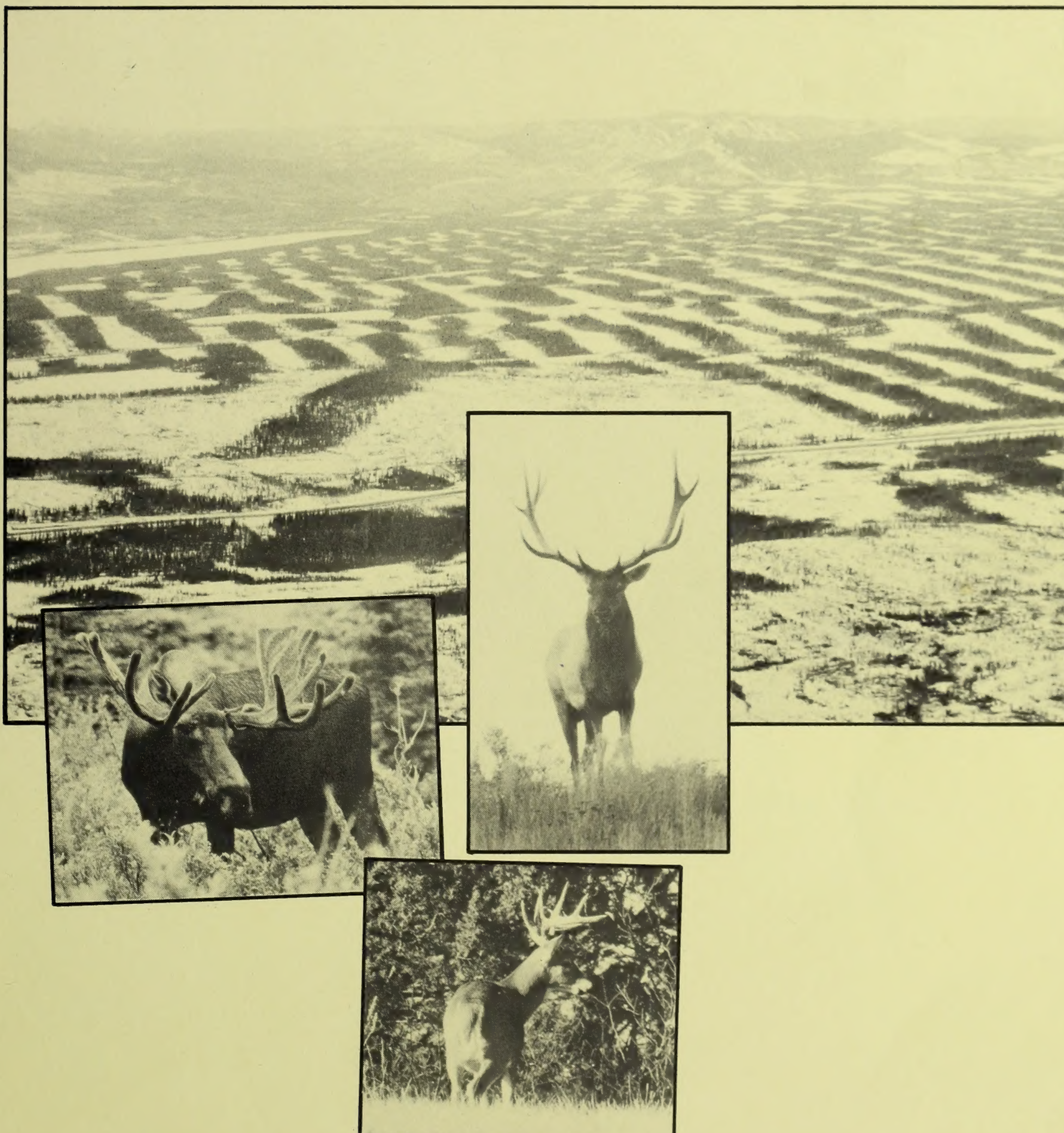

J.G. Stelfox
Wildlife Ecologist
15 December 1988

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FOREST SUCCESSION AND WILDLIFE ABUNDANCE FOLLOWING

CLEAR-CUT LOGGING IN WEST-CENTRAL ALBERTA

John G. Stelfox, Ph.D.
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philadelphicum), asters, thin-leaved ragwort, and hedysarum.

At Year 26, big game use of forbs averaged 2.8% in mixedwood and 0.1% or less in spruce and pine clear-cuts. Comparable values for big game use of grasses were <0.1% in mixedwood, 0% in spruce, and 0.1% in the pine clear-cuts. There was a significant difference ($p<0.01$) in forb use among the three forest types, with pine treatments tending to be higher in scarified but lower in unscarified clear-cuts compared with the other two forests (Stelfox 1984).

At Year 32, big game use of forbs and grasses was similar to that recorded in Year 26.

4.3.3 **Winter Forest/Wildlife Interactions** - Security (hiding) and thermal cover was a greater determinant of habitat use of clear-cuts by deer, elk and moose than forage availability, as shown in earlier sections. Mature coniferous blocks, at least 100 m wide, were essential for winter thermal and security cover during the first 15-20 years following logging of the pine forest and the first 25 years following logging of spruce and mixedwood forests. Where these latter forests were scarified following logging, mature residual blocks interspersed throughout the clear-cuts were required for at least 30 years after initial logging.

There was a strong negative correlation ($r = -0.77$) between wildlife abundance and wind chill, indicating that winter residents avoid clear-cuts with poor shelter values (Fig. 15). Wildlife abundance represents the sum of all direct and indirect observations using an identical survey technique and time period for all blocks. (Stelfox 1984). There was also a negative correlation ($r = -0.72$) between animal visibility and wildlife abundance. The correlation between crown closure and wildlife abundance was strongly positive in spruce but less positive in pine and mixedwood clear-cuts.

At Year 26, winter wildlife stocking rates were greatest in mixedwood treatments where they were twice as great as in spruce and 1.5 times greater than in pine treatments. Critical cover values of about 50% for each of security and coniferous canopy are needed before intensive yearlong use of clear-cuts by big game will occur (Fig. 15). The greatest diversity of animal species was in unscarified clear-cuts of all forests, then scarified clear-cuts, and lastly in mature blocks.

There was a positive correlation between abundance (winter

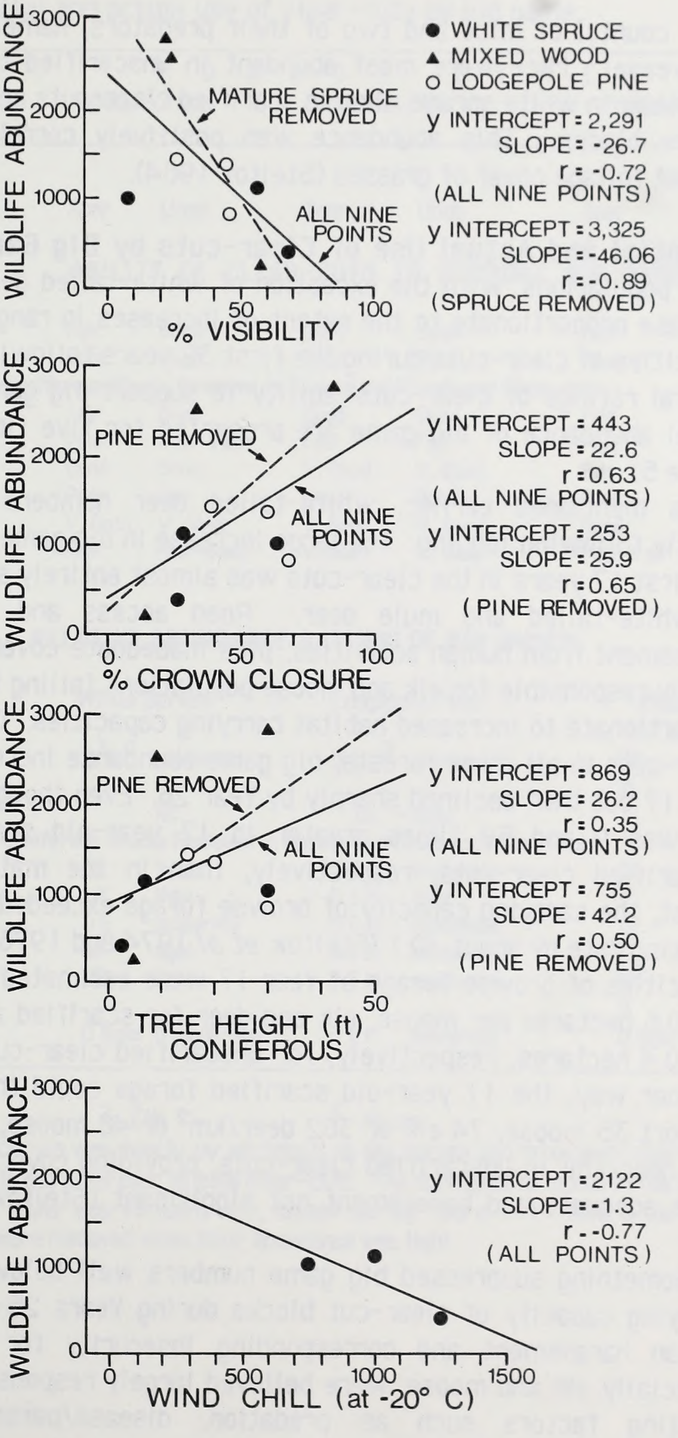

Figure 15. Correlations between winter wildlife abundance and security cover (% visibility), conifer crown closure, conifer height and wind chill.

ABSTRACT

Studies of forest succession, wildlife and habitat changes for a 32 year period following clear-cut logging were conducted in white spruce, lodgepole pine and mixedwood forests of west-central Alberta.

Increases in biomass and diversity of grasses and forbs during the Grass-forb stage (1-10 years) caused an increase in summer use by cervids, especially white-tailed deer and elk plus non-game species such as sparrows, thrushes, swallows, flycatchers and hawks compared to unharvested forests. Conversely, wildlife species of mature-old growth forest disappeared, especially in scarified clear-cuts. Spruce and ruffed grouse disappeared following logging while light use by sharp-tailed and blue grouse occurred. The presence of snags in unscarified clear-cuts resulted in the retention of snag-dwelling birds that were absent in scarified clear-cuts.

During the Shrub stage (11-20 years), cervid use was higher in clear-cuts, especially those unscarified, than in unlogged mature forests. A further increase was possible if residual blocks, interspersed among the clear-cuts had not been removed before adequate wildlife cover was available in the young clear-cuts. Adequate winter cover for cervids occurred 15-20 years post-logging in pine and 25-30 years in spruce and mixedwood clear-cuts. For scarified clear-cuts, this occurred at 15-20 years in pine and after 32 years in spruce and mixedwood clear-cuts.

Coniferous regeneration in spruce and mixedwood unscarified clear-cuts was advanced 5-10 years over scarified counterparts. Spruce seedlings, not destroyed in unscarified clear-cuts, had a major start over seedlings originating after scarification.

During the Pole sapling stage (15-25 years for mixedwood and pine, 20-40 years for spruce), improved wildlife habitat components (forage, thermal and security cover, nesting and brooding cover) resulted in increased abundance and species diversity of many non-game wildlife groups. Use by elk and moose declined whiledeer use increased. The former two species are more sensitive to human harassment than are deer. The abundance of five furbearer species (red squirrel, weasel, lynx, coyote, wolf) in mature forests was 3 and 17 times greater than in 26 year-old unscarified and scarified clear-cuts, respectively.

During the Immature stand stage (25-60 years), a rich diversity of wildlife species existed in all clear-cuts, especially those unscarified. Bears were common in all clear-cuts 25-32 years post-logging when there was an abundance of insect food in rotted stumps and logs. plus berries such as buffaloberries, and adequate escape cover.

A study of the role of native nitrogen-fixing plant species for wood fibre production and wildlife habitat and forage is recommended. Other recommendations are provided to assist land managers in developing forest-wildlife and timber harvesting plans.

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ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

A study was initiated in the foothills of west-central Alberta in 1956 to examine the impact of clear-cut logging on wildlife and their habitats within three forest types (white spruce, lodgepole pine, and mixedwood). Trends in wildlife numbers, coniferous regeneration, forage production, wildlife habitat ratings, and habitat preferences were compared among mature, logged/scarified, and logged/unscarified treatments in each forest type throughout a 32-year period. The main objectives of the study were:

(1) To determine if there were major differences in wildlife densities and habitats between areas scarified and those unscarified following clear-cut logging or between clear-cut and mature uncut blocks;

(2) To examine differences in wildlife abundance and habitat quality among clear-cut spruce, pine, and mixedwood cover types;

(3) To examine the relative importance of forest components in contributing to the three major wildlife habitat requirements namely food, shelter from inclement weather, and security (escape) cover. To determine the degree to which these three habitat requirements are met at various seral stages after logging;

(4) To compare levels of post-cut conifer regeneration between scarified and unscarified clear-cuts over time;

(5) To determine the effects of post-logging human activities on wildlife species.

Information on seasonal habitat requirements for wild ungulates in northern latitudes is scant. However, studies have shown that food supplies generally increase following logging, but that thermal and security cover is often lacking during early post-logging periods. For this reason cervids fail to exploit increased forage in young clear-cuts (Lyon and Jensen 1980, McNicol and Gilbert 1980). Winter thermal cover encompasses the variables of temperature, wind speed, precipitation and shade, and serves to maintain homeothermy and reduce energy expenditure of ungulates (Thomas 1979). In temperate regions, adequate winter thermal cover is provided by mature, dense-canopied conifer forests (Telfer 1974, 1978). Thomas (1979) defines minimal deer winter thermal cover as pole-sapling stage conifers with a canopy closure of 75%. He states that elk require dense conifer stands at least 12.2 m (40 ft) in height with 75% canopy closure. Wind and precipitation penetration is reduced in proportion to tree height (Jeffrey 1970, Bergen 1971, Raynor 1971, Moen 1973, Berglund and Barney 1977). Larger tree crowns and denser canopies also intercept more solar energy (Miller 1964, Moen 1973). By moderating inclement weather, coniferous cover reduces metabolic rate (MR) of white-tailed deer by a factor of 2.0 and deciduous cover reduces MR by a factor of 0.5 (Stevens 1972). Thus coniferous cover is four times as effective as deciduous cover for energy maintenance.

Summer thermal cover is usually provided by deciduous and coniferous trees greater than 1.5 m in height with a canopy closure of at least 60% (Thomas 1979). However, security is needed for concealment from predators, including man. Cervids will generally not venture far from security cover. Cover was expected to influence wildlife use of clear-cuts and the validity of this belief was examined during this study. Studies in the U. S. Northwest have shown that human harassment is largely responsible for the failure of elk to use suitable habitat (Lyon and Jensen 1980).

The reader is referred to the glossary (Appendix 12) for definitions of terms used in this report.

2.0 STUDY AREAS

Studies were conducted in three boreal forest cover-types (spruce, mixedwood and pine) within the foothills of west-central Alberta near Hinton (53° latitude and 117° longitude). Old (125-140 yr) white spruce (*Picea glauca)* and the mature (80-100 yr) mixedwood forests fall within the Boreal Mixedwood ecoregion of the Cordilleran region of Canada (Strong and Leggat 1981). The young-mature (60-70 yr) lodgepole pine (*Pinus contorta*) forest lies within the Boreal Foothills region.

The study areas have a continental subhumid climate, with long, cold winters modified by short periods of chinook (fohn wind) conditions and short, cool summers. Average annual precipitation is 330-390 mm at spruce and mixedwood forests (elevation 1000 m) and 450 mm at the pine forest (elevation 1350 m). Rainfall accounts for about 70% of precipitation and snowfall 30%. Mean yearly temperature at Hinton (elevation 1000 m) is 3.9°C while at the higher pine forest mean temperature is about 0°C. The study area is generally snow covered from early November until mid/late April (Powell and McIver 1976, Powell 1977, Hillman *et al* 1978).

Soils of the study area have been described by Dumanski *et al* 1972, Corns and Annas 1983. Soil beneath the spruce forest is dominated by well drained Cumulic Regosols with Orthic Brunisols and Degraded Brunisols with a pH of 8.2 and good drainage. All horizons are weakly structured silt loams. The mixedwood soil is well drained and dominated by Orthic Gray Luvisols with Degraded Eutric Brunisols. The surface horizon is sandy loam and the subsurface a coarse, sandy clay loam with a pH of 6.6. Soil beneath the pine forest is dominated by Orthic Gray Luvisols with Brunisolic Gray Luvisols and good drainage. The clay/loam clay soil is friable and moderately stoney with a strongly acidic pH of 5.3. This soil is overlain by a 0-2.5 cm layer of semi-decomposed litter

Understory vegetation of mature white spruce forests prior to logging resembled the shrub-herb faciation described by Moss (1953). The overstory was a dense stand of white spruce 30-40 m tall and 35-70 cm diameter at breast height (dbh), with a scattered distribution of mature balsam poplar (*Populus balsamifera*) in mesic sites. Sparse deciduous tree and shrub strata included willow (*Salix* spp.), dogwood (*Cornus stolonifera*), honeysuckle (*Lonicera dioica* and *L. involucrata*), low bush cranberry *(Viburnum edule)*, buffalo-berry *(Shepherdia* *canadensis),* shrubby cinquefoil (*Potentilla fruticosa),* birch (*Betula* spp.), prickly rose (*Rosa acicularis),* ground and creeping juniper (*Juniperus communis* and *J. horizontalis*) and saskatoon (*Amelanchier alnifolia*). The herb strata was characterized by twin-flower (*Linnaea borealis*), bunch-berry (*Cornus canadensis*), horsetail (*Equisetum* spp.), coltsfoot (*Petasites* spp.), northern bedstraw (*Galium boreale),* hedysarum (*Hedysarum mackenzii and H. lanatum),* tall mertensia (*Mertensia paniculata),* wintergreen (*Pyrola* spp.), miterwort (*Mitella* spp.), Solomon's seal (*Smilacina* spp.), baneberry (*Actaea rubra)* and club-moss (*Lycopodium* and *Selaginella* spp.). There was generally a floor carpet of mosses (*Sphagnum* and *Dicranum* spp.). The only graminoids of significance were hairy wildrye (*Elymus innovatus*) and sedges (*Carex* spp.) with small amounts of rushes (*Juncus* spp.), bromegrass (*Bromus* spp.), bluegrass (*Poa* spp.) and bluejoint (*Calamagrostis canadensis*).

Vegetation of the mature (80-100 yr) mixedwood forest seemed intermediate between Montane Forest and Poplar Associations (Moss 1955). White spruce dominated this community, though balsam poplar and lodgepole pine were common. Characteristic lesser tree and shrub species were aspen (*Populus tremuloides),* twining honeysuckle, buffalo-berry, prickly rose, snowberry (*Symphoricarpos albus*), willow, common bearberry (*Arctostaphylos uva-ursi)* and saskatoon. The herb layer was characterized by wild strawberry (*Fragaria vesca*), northern bedstraw, Solomon's seal, American vetch (*Vicia americana),* milk vetches (*Astragalus* spp.), showy loco-weed (*Oxytropis splendens),* groundsels (*Senecio* spp.), tall mertensia, and fireweed (*Epilobium angustifolium*). Graminoids were mainly hairy wildrye, bromegrass and bluejoint.

The lodgepole pine association was a dense stand of young to mature pine with a sparse deciduous tree and shrub strata of a few clones of balsam and aspen poplar plus small amounts of green alder (*Alnus crispa*), prickly rose, low-bush cranberry, willow, mountain ash (*Sorbus scopulina),* wild red raspberry (*Rubus strigosis),* wild gooseberry (*Ribes oxyacanthoides),* blueberries and bilberries *(Vaccinium* spp.), honeysuckle and elderberry (*Sambucus racemosa).* The herb stratum consisted mainly of bunchberry (*Cornus canadensis),* bedstraws (*Galium* spp.) horsetail, twin-flower, and palmate-leaved coltsfoot (*Petasites palmatus).* Two graminoids dominated, hairy wildrye and to a lesser extent bluejoint. There were traces of bluegrasses, sedges, timothy *(Phleum pratense)*, wood rush *(Luzula* spp.), northern bent grass *(Agrostis borealis)* and slender wood grass *(Cinna latifolia)*.

Major big game and fur-bearer species included moose (*Alces alces*), elk (wapiti) (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), coyote (*Canis latrans*), wolf (*Canis lupus*), grizzly and black bear (*Ursus arctos* and *U. americanus*), lynx (*Lynx canadensis*), cougar (*Felis concolor*), red fox (*Vulpes vulpes*), mink (*Mustela vison*), ermine and least weasel (*Mustela erminea* and *M. nivalis*), marten and fisher (*Martes americana* and *M. pennanti*), and red squirrel (*Tamiasciurus hudsonicus*). Estimated big game population densities prior to logging of the white spruce forest were 0.8 deer, 0.6 moose, 0.4 elk, 0.1 black bear, and <0.1 grizzly bear per km^2 (Stelfox 1962). Snowshoe hare (*Lepus americanus*) and rodent (*Clethrionomys, Phenacomys, Microtus* spp.) populations experienced marked population fluctuations regardless of the forest age.

Common winter resident birds prior to logging were spruce grouse (*Dendragopus canadensis*), ruffed grouse (*Bonasa umbellus*), chickadee *(Parus atricapillus* and *P. gambelli)*, pine siskin and common redpoll (*Carduelis pinus* and *C. flammea*), snow bunting (*Plectrophenax nivalis*), gray jay (*Perisoreus canadensis*), three-toed, hairy and downy woodpeckers (*Picoides tridactylus, P. villosus,* and *P. pubescens*), pine grosbeak (*Pinicola enucleator*), white-winged crossbill (*Loxia leucoptera*), Bohemian waxwing (*Bombycilla garrulus*), magpie (*Pica pica*), raven (*Corvus corax*), great horned owl (*Bubo virginianus*), boreal owl (*Aegolius funereus*), great gray owl (*Strix nebulosa*) and northern goshawk (*Accipiter gentilis*).

3.0 METHODS

3.1 Harvest and Silvicultural Techniques

The spruce forest was clear-cut into rectangular blocks (201 x 805 m) at right angles to the prevailing westerly winds. One third of the mature forest, originally left as intervening blocks (101 x 805 m) between clear-cuts, was removed 12-13 years after the original harvesting. Less than 10% of clear-cut blocks were left unscarified.

One-half of the pine forest was scarified after an area of 283 ha was logged. For the mixedwood forest, residual blocks (100 x 100 m) of mature timber were left interspersed throughout the clear-cut for the first 10-15 years after logging to serve as conifer seed sources. About one-half of the original clear-cut area was left unscarified.

Clear-cutting was accomplished by woodcutters using chain-saws, who cut and piled spruce and pine trees to be used for pulp wood. Logs were skidded to truck roads with horses. Scarification was achieved using large Caterpillar tractors (D7 and D9) equipped with rippers or rakers attached to the lower edge of the blade. Virtually all deciduous trees and shrubs were removed and the herb, grass and moss layers were mixed with the upper 25-50 cm of soil. For the pine clear-cut, scarification consisted of merely pushing down any standing pine snags and crushing the slash with Caterpillar tractors.

Unscarified blocks after logging retained standing snags and unmerchantable trees and shrubs. Soil disturbance was negligible and those blocks were not really "clear-cut" in the modern sense.

For all study areas, logging and scarification occurred during 1956 and 1957. Details on the silvicultural methods used during the 1950s within the St. Regis (Alberta) lease area are provided by Clark (1960).

3.2 Vegetation and Wildlife Plots

The sampling design and terminology for this study are displayed in Fig. 1. Sample and plot sizes were originally (1950's) based on imperial units that were later converted to metric measures. Both measures are presented in this introductory section for the sake of clarification.

Two samples were established within each treatment (mature, scarified, and unscarified) for each of the three areas to encompass topographic and soil variability. Each sample was 54.9 x 320.0 m (180 x 1050 ft) and randomly located a minimum distance of 30.48 m (100 ft) from the forest edge to eliminate edge effect.

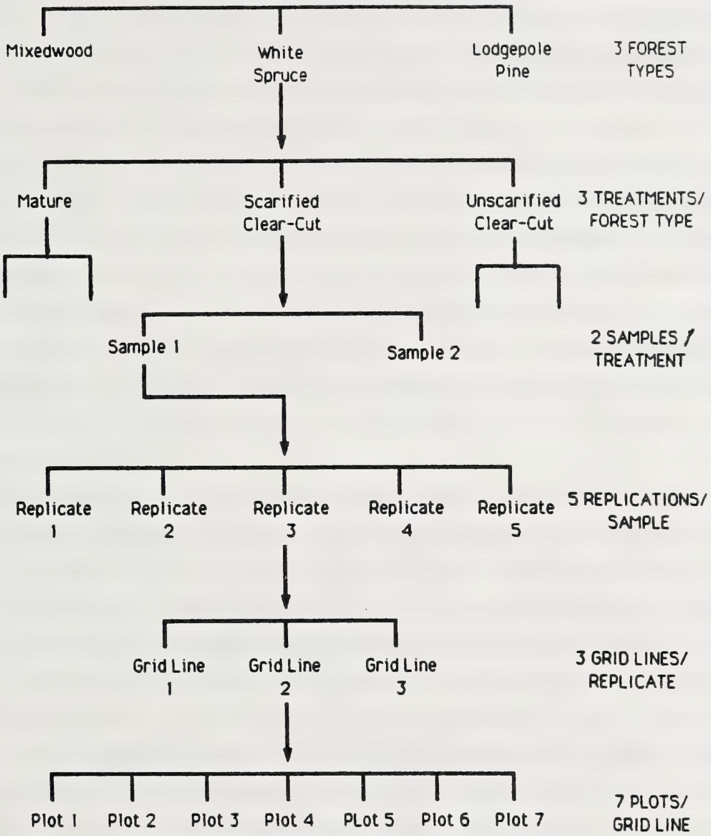

Figure 1a. Diagram of a sampling design within each of three forest types.

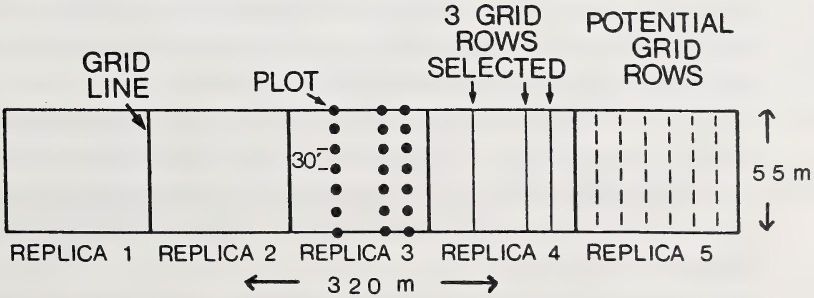

Figure 1b. Diagram of a sampling design and plot arrangement within each sample area.

Details of sampling methods, descriptions of angle point directions along transect axis, exact locations of samples and plots (including photoplots) and maps are provided in a separate operational report submitted to Alberta Fish and Wildlife Division, Edson office.

Each sample consisted of five replications, each containing six grid rows (from which three rows were randomly selected). Each of the 15 selected grid rows contained seven sample plots (0.89 m^2 or 9.6 ft^2) spaced 9.14 m (30 ft) apart in a straight line (Fig. 1). Thus, each sample contained 105 plots, yielding 210 plots for each treatment (mature, scarified, and unscarified) in each forest type. Sampling intensity was chosen following a pilot study to determine the number of plots required to adequately sample browse heights, using the formula

$$n = \frac{2S^2}{0.10\bar{x}}$$

where "S" is standard deviation, "$\bar{x}$" is mean height, and 0.10 is the desired limit of the confidence interval expressed as a proportion of the mean (Stelfox 1963). A square plot frame, of 1 cm thick round rod, open on one side to facilitate placing it in brushy vegetation. was used to obtain foliage cover and tree density data. To increase accuracy in estimating foliage cover, a 0.09 m^2 (1 ft^2) plot frame, divided into sixteenths, was hand-held over each plant species. In 1988, the 105, 0.89 m^2 plots were replaced by 100, 1.0 m^2 plots to conform with metric units. The first 100 of the previous 105 plot stakes were used and by increasing the plot size from 0.89 m^2 to 1.0 m^2 the area sampled actually increased from 93.4 m^2 to 100.0 m^2 per sample. Within each plot, data was collected on the following floral and faunal attributes:

a) Foliage cover for grass and forb species, to the nearest 0.006 m^2 until 1988 when it was to the nearest 0.01 m^2;
b) Densities of deciduous and coniferous tree and shrubs;
c) Species composition for grass, forb, and browse vegetation groups;
d) Foliage cover for each deciduous tree and shrub species was also obtained from clear-cut plots for Years 1 to 5;
e) Heights of browse plants were recorded to the nearest 1.25 cm until plants reached 2.44 m after which the height was estimated to the nearest 0.15 m. In 1982 and 1988, deciduous and coniferous tree and shrub heights were recorded under 12 height classes as shown in Appendix 1;
f) Big game utilization of plant species was recorded as either summer or winter use. Utilization classes were: 0% = none; 1-25%

= light; 26-50% = moderate; 51-75% = heavy; and 76-100% = very heavy. Percent use of total current years biomass was determined using the ocular-estimate-by-plot method (Pechanec and Pickford, 1937). For browse species this technique considers leaves and green stems up to a thickness of 0.75 cm;

g) Utilization of browse species was also estimated from 20 clip-plots per sample. Browse refers to all deciduous or coniferous tree and shrub species observed to be eaten by wild ungulates. Browse species utilized by cervids are presented in Appendix 8. All live browse under 2.44 m in height was clipped. Clipped forage was placed in cotton bags and weights of both leaves and stems were recorded immediately. Forage was then air-dried to a constant weight. Browse forage production per unit area was then calculated (Appendix 9);

h) Big game, grouse and hare abundance was determined from fecal pellet group counts within a 9.3 m^2 (100 ft^2) circular plot. A 1.72 m rod served as the plot radius with permanent plot stakes serving as the center of the circle. For Years 17 and 26, pellet group counts were made from within the 0.89 m^2 plots. During 1988, pellet group counts were made within 10 m^2 or 25 m^2 circular plots.

After each regular survey, a thorough investigation was made of the entire treatment and all direct and indirect observations of wildlife were recorded. As the same amount of time was spent in each of the study blocks, the results were considered comparable.

During Years 1-6, 9, 17, and 27, at least two winter track counts were conducted after fresh snowfall and all sets of tracks recorded by species, probable age, and sex classes (young of the year, adult, and large males). Direct wildlife observations were made using aerial (helicopter) and ground (drive and track) counts (Stelfox 1984).

Scientific and common names in this report conform to Flora of Alberta (Moss 1983) for plants, The Mammals of Canada (Banfield 1977) for mammals, and American Ornithologists' Union (1983) for birds. See Appendix 2 for complete lists.

Results during the 1950's and 1960's were presented earlier (Stelfox and Cormack 1962, Stelfox *et al* 1973).

3.3 Photo Points

Photo points were established in 1957 to monitor gross floral changes over time in scarified and unscarified clear-cuts. Black and white photographs were taken by placing a 35 mm (single reflex) camera on top of a 1.5 m high metal stake and centering the photo on a conspicuous permanent feature.

3.4 Conifer Regeneration and Growth

Conifer stocking rates (% of plots occupied), density and height data for regenerating spruce and pine were obtained from 210 plots per treatment until 1988 when this was reduced to 200 plots because of the larger plot size (1 m^2). Spatial distribution, height, and wildlife damage of the nearest conifer to each of the first 200 plot stakes were recorded for the spruce forest during Years 9, 17, 26 and 32 and for the other two forest types during Years 26 and 32.

3.5 Habitat Quality

Measures of seasonal habitat quality (security and thermal cover) were obtained by three techniques:

a) Wind chill was determined in mid-winter with a thermometer, and a hand-held anemometer at chest height (1.2 m). Ten wind velocity readings were taken, each for a duration of one minute, and the average of ten readings used as a measure of average wind velocity. Wind chill factors for each site were expressed in watts/m^2 (Canada Atmospheric Environment Service 1981). This information was obtained for the spruce forest type at Year 16 (January 1972) and Year 27 (January 1983).

b) Conifer canopy cover was determined for mature plus 25, 27 and 32 year-old clear-cuts (scarified and unscarified) for each forest type. This was achieved by estimating canopy diameter (cm) of the first four conifers within each circular plots. Average canopy diameter was calculated and then the average tree canopy was determined using the formula: Area = $.7854D^2$ where "D" is the average canopy diameter. Tree area values were then multiplied by conifer density.

c) Security cover was estimated for mature, 27 and 32 year-old clear-cut blocks using a 0.3 x 2.5 m vegetation profile board divided horizontally into five strata above ground level as follows:

1 = <0.5 m; 2 = 0.5-1.0 m; 3 = 1.0-1.5 m; 4 = 1.5-2.0 m; 5 = 2.0-2.5 m. The profile board was held vertically at a location 20 m due northwest of the plot stake. The percent of each segment that was visible was recorded. Observations were made at 30 locations within each sample. Visibility classes were coded as a percentage of the coloured rectangle: 1 = 0-20%; 2 = 21-40%; 3 = 41-60%; 4 = 61-80% (ave. = 70%); and 5 = 81-100%.

Values for visibility (security cover) and thermal cover (windchill plus density, canopy closure, and height of conifers) were combined to evaluate many aspects of cover. Winter cover values were derived from percent canopy cover. Conifer canopy closure was determined by the Alberta Department of Energy and Natural Resources Inventory Section using standard photogrammetric forestry inventory procedures. Combined cover was determined as:

$$\left(\frac{\Sigma \text{ canopy closure} + \text{\% security cover}}{2}\right).$$

d) Snags (dead or decadent) with diameters at least 15 cm, diameter at breast height (dbh), were counted within the first 100 plots (50 m^2 circular). Data were recorded on snag density, height, dbh, condition, presence and size of cavities, and presence of snag-dwelling wildlife. Snag condition classes were: sound, decadent, decayed.

3.6 Statistical Analyses

Analyses of mean plant height, density, cover, and utilization were conducted using 1-way or 2-way ANOVAs.

Differences in number of big game observations between treatments were analysed using the Wilcoxan signed rank test (Daniel 1978).

During 1988 statistical differences among the three forest types and the three treatments (mature, logged-scarified, logged-unscarified) were calculated using an MTS ANOVA analysis.

Computer tapes of all data recorded and analyses conducted have been submitted to Alberta Fish and Wildlife Division, Edson.

4.0 RESULTS AND DISCUSSION

4.1 Physiognomic Forest Changes

Clear-cut logging of mature forests produced open "Grass-forb" communities during the first 10 years (Figs. 2-4). This early successional community was interspersed with residual mature forest blocks in spruce and mixedwood clear-cuts until Years 12 and 13 when these residuals were removed. During Years 10-20, the "Shrub-seedling" community was dominated by a conspicuous stand of poplar, willow and rose while grass cover declined. Young growth of pine became conspicuous in both pine clear-cuts by Year 15 (Fig. 4). During Years 20-32 the "Young growth" community in pine clear-cuts was dominated by rapidly growing pine, with strips of alder, poplar and willow along old logging roads (Fig. 4). Spruce and mixedwood clear-cuts (unscarified) were dominated by a mixture of poplar, willow and spruce while in scarified clear-cuts conifers were not conspicuous (Figs. 2 and 3).

Blocks left unscarified in mixedwood and spruce clear-cuts contained many large poplar (including snags), young and dead spruce, and some willow (Figs. 2 and 3). Only a few pine snags remained in the unscarified pine clear-cut (Fig. 4). Some security (escape) cover remained for wild ungulates in unscarified spruce and mixedwood clear-cuts compared with little or none in scarified clear-cuts (Figs. 2-4). Desirable mosaics of open clear-cuts and mature forest (Thomas 1979, Stelfox 1984) were destroyed during Years 12 and 13 when mature residual blocks were removed within spruce and mixedwood forests.

A pronounced physiognomic change occurred in vegetation between Years 15 and 26 (Figs. 2-4). Within spruce and mixedwood forests, Shrub-sapling communities in scarified clear-cuts provided suitable cover and shelter during summer, but not winter. However, immature deciduous/coniferous trees in unscarified clear-cuts were, at Year 25, providing winter cover for wildlife. (Figs. 2-4).

Variability among plant density, height, percent cover and species richness was generally too great to show statistical differences ($p<0.05$) between treatments, years, and forest types. However, trends over time were usually consistent, indicating that reported differences did exist but were not highly significant.

SCARIFIED | UNSCARIFIED

YEAR 4

YEAR 5

YEAR 16

YEAR 16

YEAR 25

YEAR 25

Figure 2. Forest succession in white spruce clear-cuts following logging.

SCARIFIED
Year 1: August 1957

UNSCARIFIED
Year 3: December 1959

Year 16: August 1972

Year 16: August 1972

Year 32: July 1988 (Note gravel pit operation)

Year 32: July 1988

Figure 3. Forest succession in mixedwood clear-cuts following logging.

Year 1: August 1957

Year 9: August 1965

Year 16: August 1972

Year 32: July 1988

Figure 4a. Forest succession in an unscarified pine clear-cut following logging.

SCARIFIED
Year 1: August 1957

UNSCARIFIED
Year 6: August 1962

Year 16: August 1972

Year 25: August 1981

Year 32: July 1988

Year 32: July 1988

Figure 4b. Forest succession in lodgepole pine clear-cuts following logging.

4.2 Plant Density, Cover, Height, and Species Richness

4.2.1. Herbaceous Cover - A major difference following clear-cut logging was the pronounced increase in foliage cover of both grasses and forbs during the first six years, followed by a decline to near pre-logging values by Year 26 (Figs. 5 and 6, Appendix 4). Cover values for grasses decreased from an average of 17% for mature forests to 15% one year after logging, then rose to 63% by Year 6 and declined to 22% and 19% at Years 26 and 32. Scarification following logging further reduced grass cover to 8% one year after logging, followed by a rapid increase to an average of 54% by Year 6 and a decline to 23% and 18% at Years 26 and 32. Although grass cover increases following logging were large in all three forests, they were greatest in pine, then spruce and least in mixedwood clear-cuts. By Year 32, grass cover values were only slightly higher than those in mature forests (Appendix 4). Changes in cover of native grass species, in particular major ones such as hairy wild rye, bromegrass, sedge, and reedgrass, are presented in Fig. 7, Appendices 3 and 4. Introduced species that increased temporarily following logging and the use of horses included oats *(Avena sativa* and *A. fatua),* timothy, bluegrass and fescue (*Festuca* spp.).

No significant differences ($p<.05$) existed in total grass cover of 32 year-old clear-cuts among the three forests, although two genera did show significant differences (Appendix 3). Bromegrass was common in mixedwood (5.1%), less common in spruce (2.3%) and almost absent in pine (0.01%) clear-cuts. Reedgrass was abundant in pine (8.7%), scarce in spruce (0.2%) and absent in mixedwood forests.

Changes in forb cover followed the same trend as for grasses except that cover values were higher in scarified than in unscarified clear-cuts at Year 6 (Figs. 5 and 6, Appendix 4). In the spruce forest, forb cover declined from 16% prior to logging, to less than 5% one year after logging, then peaked near Year 6 at about 25% (Appendix 4). Forb cover was almost 50% lower in mixedwood than in spruce and pine clear-cuts at Year 6 (Fig. 6). At that time, forb cover in the three forests averaged 39% higher in scarified than in unscarified clear-cuts (Fig 5). During Years 26 and 32, values were similar in both clear-cut treatments (Fig. 5. Appendix 4).

At Year 32, forb and mat-like low shrub cover averaged 26% higher than grass cover and there were no significant differences

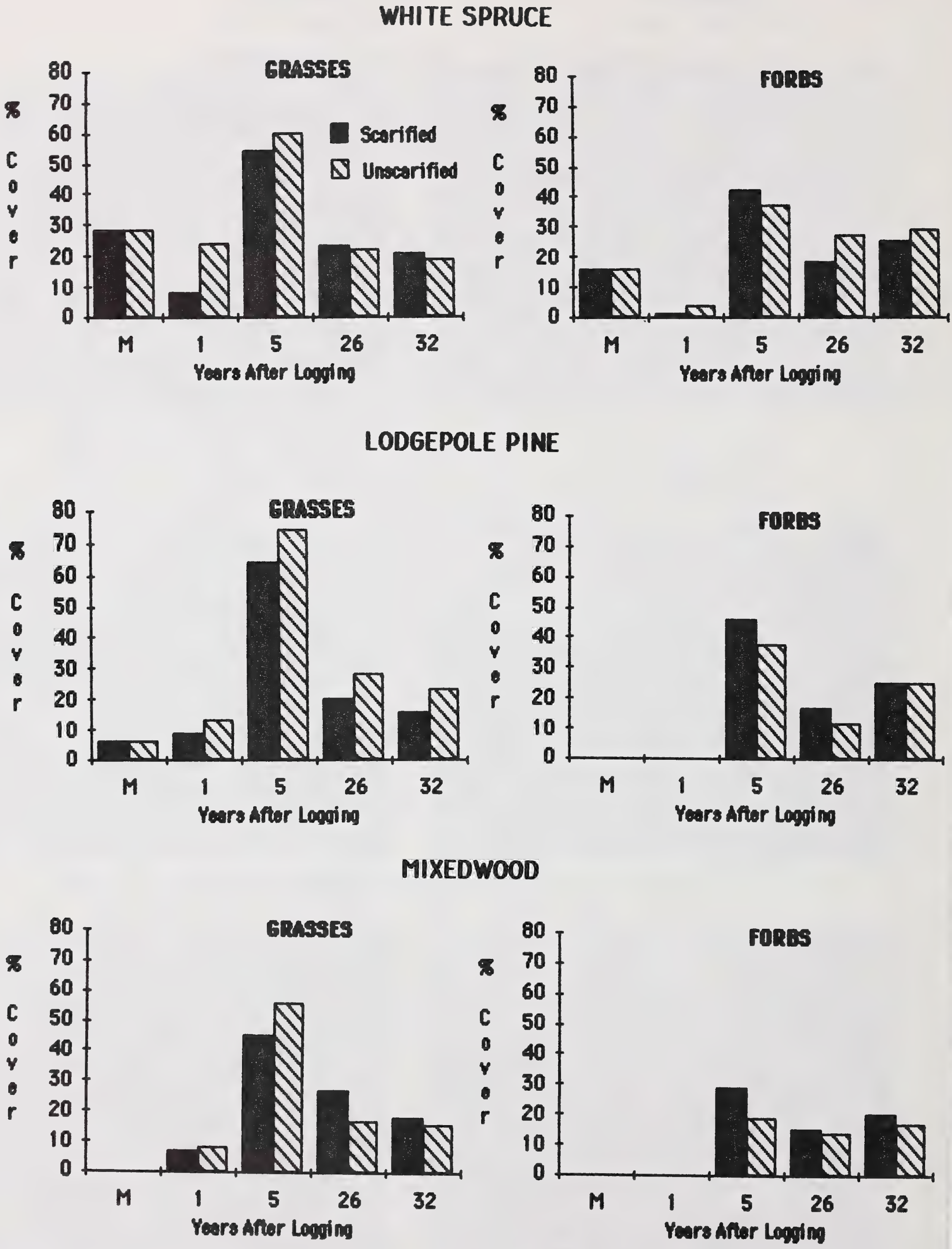

Figure 5. Comparison of grass and forb cover between scarified and unscarified clear-cuts.

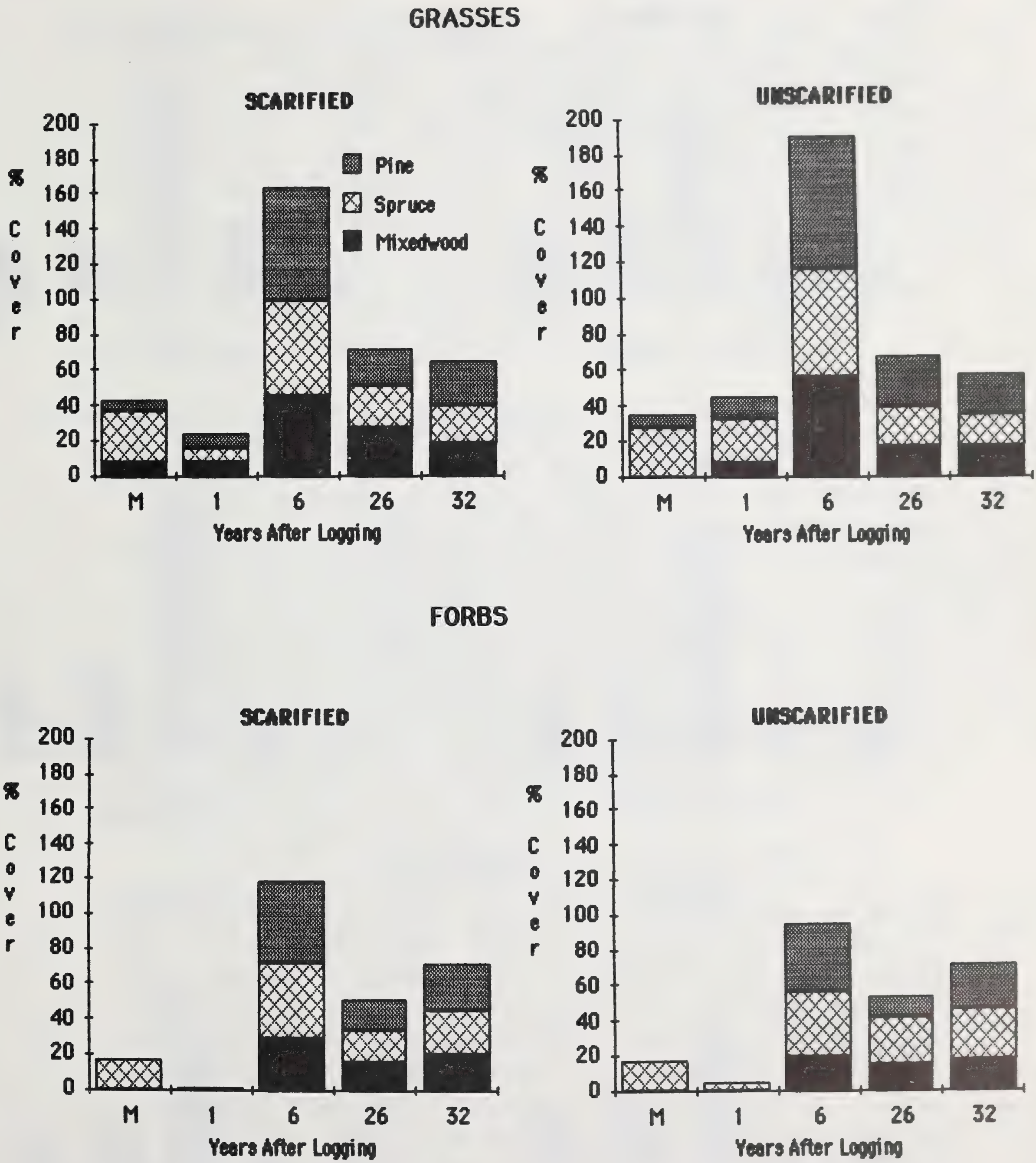

Figure 6. Comparison of grass and forb cover following logging among three forest types.

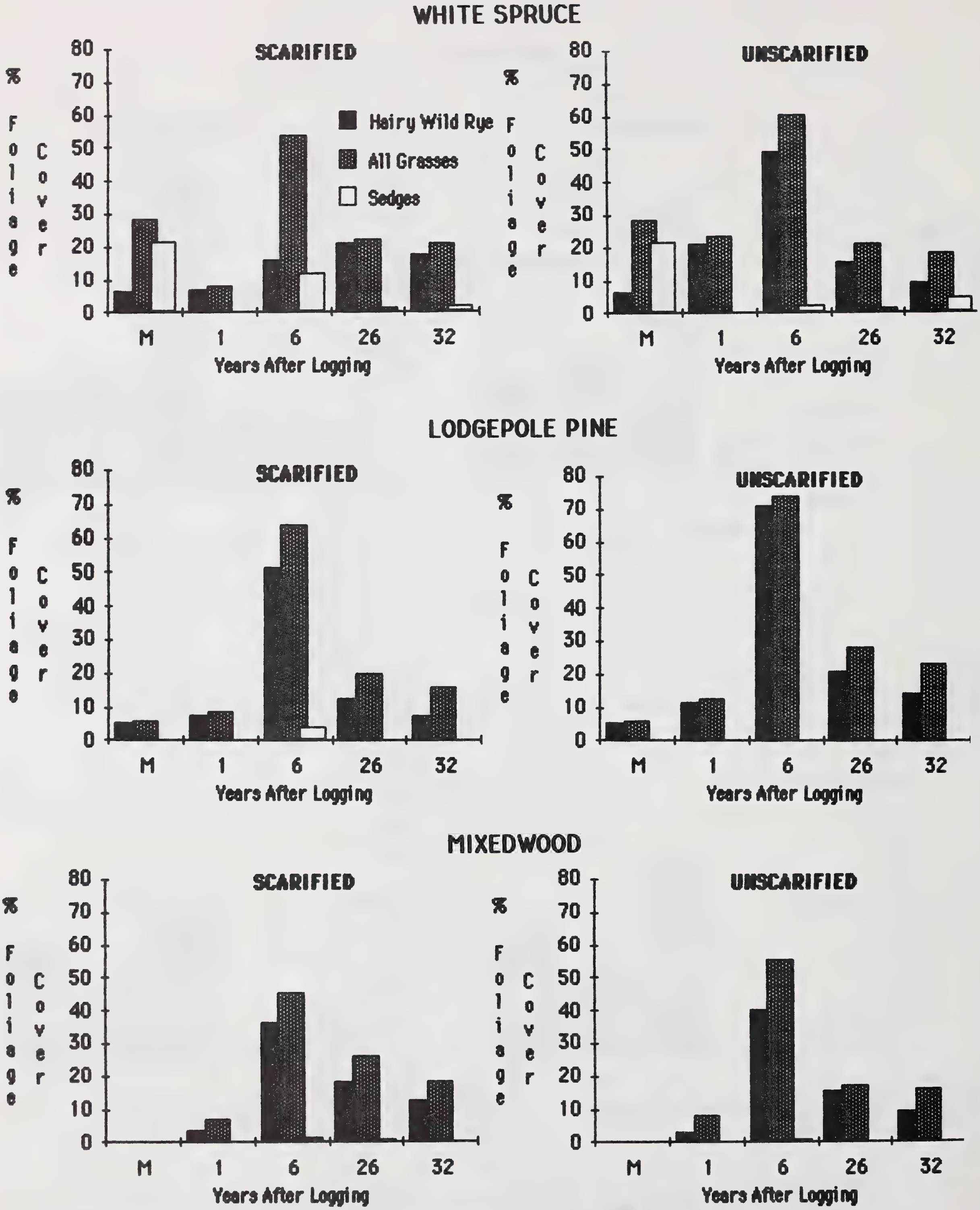

Figure 7. Trends in foliage cover of sedges and grasses following logging.

($p<.05$) among forests (Appendix 3). However, some genera and groups of forbs were significantly different among forest types. Bearberry was highest in spruce (12.5%), next in mixedwood (6.3%) and least in pine (0.2%) clear-cuts. Three nitrogen-fixing legumes: milkvetch, loco-weed, and Indian potatoe (*Hedysarum* spp.), had highest cover in spruce (3.1%), next in mixedwood (0.8%) and none in pine clear-cuts. Two other nitrogen-fixing legumes: peavine (*Lathyrus ochroleucus)* and vetch were common in mixedwood (1.6%), scarce in pine (0.1%) and absent in spruce clear-cuts. Fireweed was significantly higher in pine (8.0%) than in mixedwood (0.5%) or spruce (0.2%) clear-cuts (Appendix 3).

4.2.2. Species Diversity - There was a pronounced increase in species diversity during the first 5 years following logging. At Year 5 in spruce clear-cuts, 26 forb species were recorded that were not found in the mature block (Stelfox 1963 and 1981). Aster (*Aster* spp.), Indian potatoe, groundsel, fleabane (*Erigeron* spp.), fireweed, tall mertensia, and white camas (*Zygadenus elegans)* comprised most of forb cover in spruce clear-cuts (Appendix 4). For the mature spruce forest they were northern bedstraw , Indian potatoe, asters, tall mertensia, and groundsels (Appendix 4, and Stelfox 1963). Forb species richness continued to increase to Year 26 at which time there were about twice as many forb species in spruce and mixedwood clear-cuts as in corresponding mature forests. At that time there were 30-40 forb species present in pine clear-cuts compared with only 4 in mature pine.

The number of grass species declined following logging in the spruce forest but not in pine and mixedwood forests. By Year 26, the number of grass species was similar in both logged and mature blocks of the spruce forest. Between Years 5 and 32, in pine and mixedwood forests, there were 2-5 times as many grass species in logged as in mature blocks. Following logging in the spruce forest, there was no discernable difference in grass species diversity between scarified and mature blocks, but an increase in the number of grass species in unscarified blocks, during this same period.

There was a small increase in the number of grass and forb species present in spruce and pine clear-cuts between Years 26 and 32 while in mixedwood clear-cuts species diversity remained similar (Table 1).

Table 1. Species richness in mature forests and various age-classes of scarified (SC) and unscarified (UN) clear-cuts.

Forest age	Number of Species							
	Browse		Forbs		Grasses		Total	
	SC	UN	SC	UN	SC	UN	SC	UN
WHITE SPRUCE FOREST								
Mature	15		28		13		56	
1	9	10	9	12	5	7	23	20
5	5	7	25	26	11	7	41	29
26	13	12	53	50	8	12	74	74
32	10	9	58	59	10	13	78	81
LODGEPOLE PINE FOREST								
Mature	13		4		2		19	
1	5	5	5	6	2	2	12	13
5	11	10	20	21	11	9	42	40
26	14	15	38	31	7	7	59	53
32	12	11	40	34	9	8	61	53
MIXEDWOOD FOREST								
Mature	9		17		4		30	
1	9	9	-	-	3	2	-	-
5	9	9	16	17	8	4	33	30
26	10	10	37	39	10	10	57	59
32	7	8	37	39	10	8	54	55
THREE FORESTS (AVES.)								
Mature	12		16		6		34	
1	8	8	-	-	3	4	-	
5	8	9	20	21	10	7	38	37
26	12	12	43	40	8	10	63	62
32	-	-	45	44	10	10	64	63

Numbers of woody browse species declined following logging in spruce and pine forests (Table 1). By Years 26 and 32, species diversity was similar in clear-cuts and their corresponding mature forests.

4.2.3 **Deciduous Tree and Shrub Density** - For all forest types, the trend was a decrease in density following logging/scarification (Fig. 8). For spruce and mixedwood forests, logging/scarification reduced the density of deciduous trees and shrubs by 43%. In pine clear-cuts, where scarification merely involved leveling unmerchantable trees and trampling slash with caterpillar tractors, density of deciduous trees and shrubs was not reduced. One year after logging, densities in scarified clear-cuts were 60% lower than in unscarified clear-cuts for all forest types. At Year 6, scarified clear-cuts were 15% lower than unscarified clear-cuts while at Year 26, densities were similar in both clear-cuts. At Year 32, scarified clear-cut densities averaged 10% lower than those in the unscarified clear-cuts (Fig. 8, Appendix 5). Densities appeared to peak at about Year 17 in spruce clear-cuts and to be still increasing in pine and mixedwood clear-cuts at Year 32 (Fig. 8).

Prickly rose increased 4 to 7 fold between Year 1 and Years 17-32 when it peaked. Average densities following logging were similar in scarified and unscarified clear-cuts of pine and mixedwood forests but noticeably higher in unscarified than in scarified spruce clear-cuts.

Poplar and willow densities peaked near Year 9 in scarified clear-cuts of the spruce forest and about Years 26-32 in the other two forest types (Fig. 9). Results for unscarified clear-cuts are less clear but suggest that both poplar and willow peaked about Year 9. Densities of poplar and willow were significantly higher in spruce than in pine and mixedwood clear-cuts throughout the 32 year period following logging (Appendix 5). Changes in species densities are presented in Figs. 8 and 9, Appendices 3 and 5.

Another deciduous woody species that changed noticeably in the pine forest following logging was green alder (*Alnus crispa)* Increases were somewhat higher in the scarified clear-cut during Years 26 and 32 (Appendix 5). This species was not present in spruce and mixedwood forests. This is an important species to consider in forest-wildlife management of pine forests because of its nitrogen-fixing capability. Studies in North America and

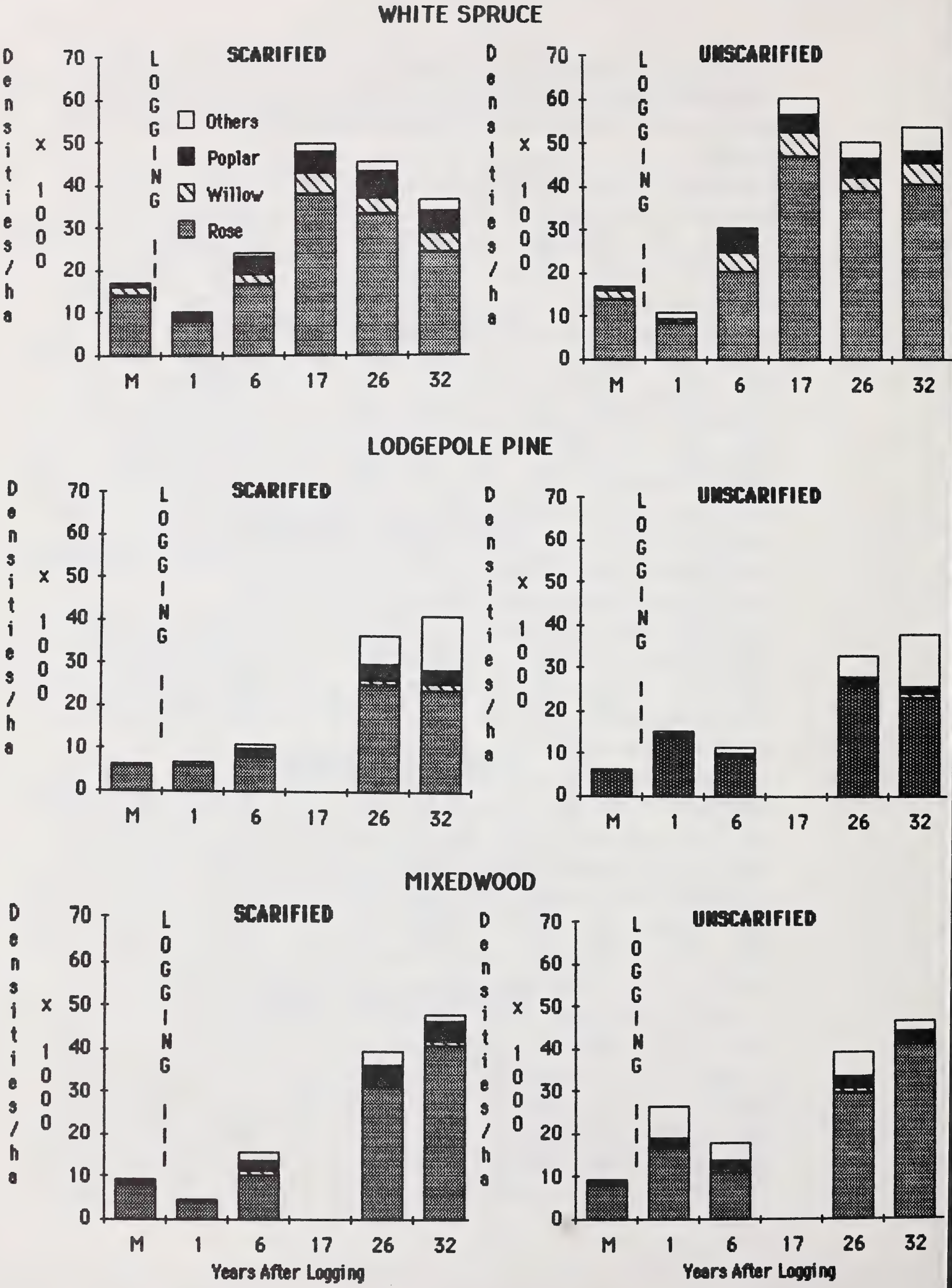

Figure 8. Trends in woody deciduous densities following logging.

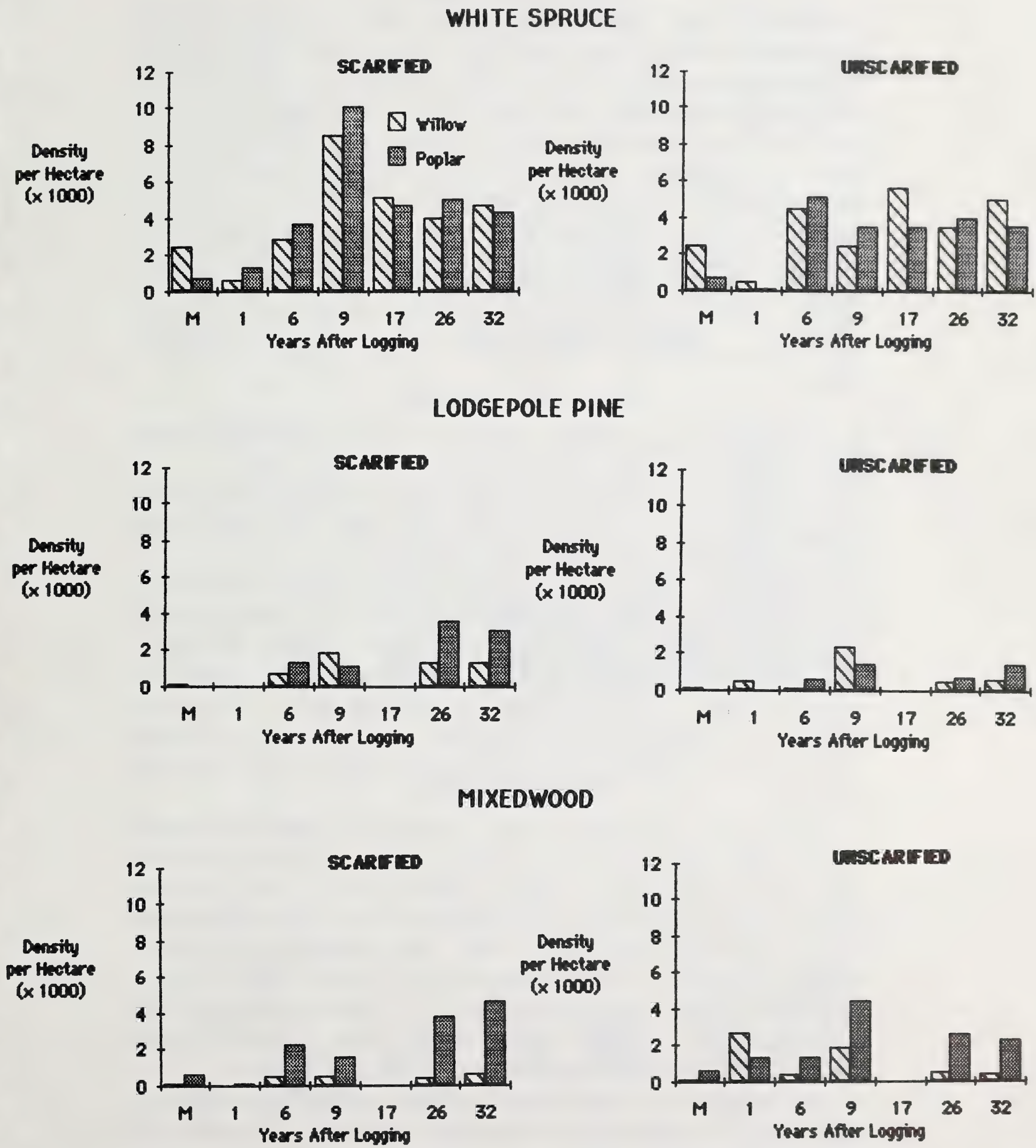

Figure 9. Trends in densities of poplar and willow following logging.

Scandinavia have demonstrated that alder is an important contributor to soil nitrogen (Lawrence 1958, Virtanen 1962, Becking 1970). Greater heights of pine, poplar and willow in the scarified pine clear-cut may have been largely due to the higher density of alder and a corresponding higher nitrogen yield compared with values in the adjacent unscarified clear-cut (See section 4.2.4). Other species that increased significantly in density during the first 32 years following logging were saskatoon, birch, honeysuckle, shrubby cinquefoil and buffalo-berry in spruce clear-cuts and gooseberry, raspberry and low-bush cranberry in pine clear-cuts. In the mixedwood forest, major changes in density following logging were with prickly rose, poplar and willow species as discussed earlier.

4.2.4 **Deciduous Tree and Shrub Height** - Mean heights decreased more noticeably following logging in scarified clear-cuts.

Prickly rose attained a maximum height at about Year 6 with average heights greater in unscarified clear-cuts during Years 6-32 in spruce and pine forests (Fig. 10, Appendix 6).

During the first six years post-logging, poplar and willow heights remained below 0.7 m in scarified and 1.2 m in unscarified clear-cuts, providing inadequate escape cover for wild ungulates, except, perhaps, white-tailed deer. Mean heights were greater in unscarified than in scarified clear-cuts during Years 1-32 in both spruce and mixedwood clear-cuts. The converse was true in pine clear-cuts with heights being somewhat greater in the scarified clear-cut.

By Year 26, in the spruce forest, 20 and 34% of poplar and 14 and 18% of willow exceeded 2.4 m in height, in scarified and unscarified clear-cuts, respectively. Stems above 2.4 m are generally unavailable as browse for cervids except where moose break down young trees (Telfer and Cairns 1978). This partially explains why browse production (<2.4 m height) declined during Years 17-32 in unscarified clear-cuts (see section 4.3.2). Browse reductions had not occurred by Year 26 in the scarified clear-cut as few trees exceeded 2.4 m in height (Appendix 6).

Poplar and willow heights were greater in unscarified clear-cuts during Years 1-26 except in the logged pine forest (Appendix 6). They increased most rapidly in pine clear-cuts, next in mixedwood,

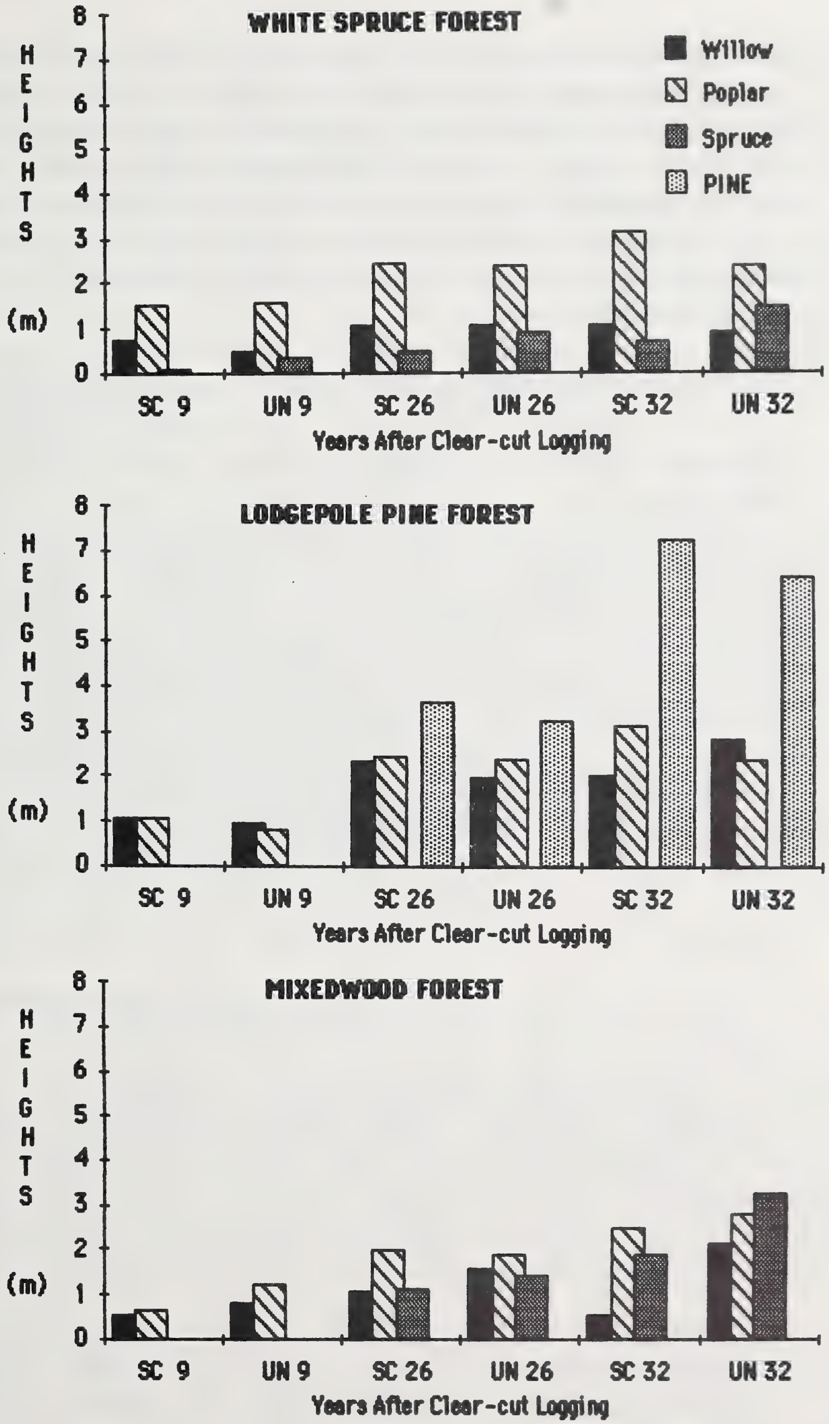

Figure 10. Changes in heights of coniferous and deciduous tree and shrub species following logging.

and least in spruce clear-cuts. Most poplar forage was unavailable to big game in pine and mixedwood clear-cuts, while in spruce clear-cuts most poplar was still available, especially within the scarified clear-cut. Even willow species were growing beyond reach of big game animals by Year 26, especially in pine clear-cuts where almost two-thirds had reached or exceeded 2.4 m. Details of deciduous and coniferous heights at Year 32 in each sample area are presented in Appendix 6.

4.2.5 **Coniferous Regeneration and Growth** - Coniferous growth and anticipated harvest volumes were reduced by scarification in spruce and mixedwood clear-cuts but were increased in pine clear-cuts.

In the spruce forest, conifer growth was higher in unscarified clear-cuts throughout the 32 year post-logging period (Table 2). By Year 32, comparable heights were 1.5 and 0.7 m (Appendix 6). Stocking rate (% of plots stocked with at least 1 conifer), annual growth rate and percent of trees taller than 5.6 m were also considerably higher in unscarified blocks (Table 2, Fig. 10, Appendices 5 and 6). By Year 32, there were 2.3 times more spruce/ha in scarified (9479) than unscarified (4036) clear-cuts but most were less than 1 m tall (Table 2, Appendix 5). Density of spruce >2 m was 760 and 309/ha in unscarified and scarified

Table 2. Trends in coniferous (spruce and pine) densities (per ha) following logging.

AGE OF	**SPRUCE FOREST**		**PINE FOREST**		**MIXEDWOOD FOREST**	
CLEARCUT	SCARIFIED	UNSCAR.	SCARIFIED	UNSCAR.	SCARIFIED	UNSCAR.
1	1730	180	2783	0	0	2345
6	363	1043	3080	619	118	73
9	-	-	-	-	-	-
17	22460	7575	-	-	-	-
26	22355	6858	3894	2574	1759	4941
32	9479	4036	1354	1272	3130	2573

clear-cuts; indicating a stocking rate 2.5 times greater in unscarified than in scarified blocks of well- established spruce.

Within mixedwood clear-cuts, density of spruce in stocked plots was similar between treatments but stocking rates were 3 times higher in unscarified clear-cuts at Year 26 (Appendix 5). Annual growth rates were 1.3 times greater in unscarified clear-cuts. At Year 32, the stocking rate of conifers was 1.7 times higher in the unscarified block clear-cut, for well established spruce and pine (Appendix 5). Some conifer seedlings were planted in the scarified clear-cut so the densities and height data presented here are somewhat inflated.

Both pine clear-cuts were adequately stocked (988 seedlings/ha and $\geq$1 seedling in 8.9% of the 0.89 m^2 plots) by Year 26 (Appendix 5) with mean heights greater in scarified (3.6 m) than unscarified (3.2 m) clear-cuts (Appendix 6). By Year 32, comparable heights were 7.2 and 6.4 m indicating rapid growth during that 6 year period. Density of pine declined by 65 and 51% in scarified and unscarified clear-cuts between Years 26 and 32, respectively. At Year 32, there were 1080 and 815 pine/ha in scarified and unscarified clear-cuts that exceeded 6 m in height (Appendices 5 and 6).

All clear-cuts were adequately stocked with conifers at Year 26. At Year 32, all clear-cuts were still adequately stocked and average heights of spruce were significantly higher in unscarified than in scarified clear-cuts of both spruce and mixedwood forests (Fig. 10, Appendices 3, 5 and 6). The converse was true in pine treatments.

4.3 Habitat and Wildlife Abundance

4.3.1 Cover and Wildlife Use of Clear-cuts - Results indicated that deer, elk and moose prefer some optimum combination of cover and forage. Cover (security and thermal) appeared to be a greater determinant of habitat use than forage availability (Stelfox 1984). Other studies in Alberta (Tomm *et al.* 1981, Holroyd and Van Tighem 1983, Westworth *et al.* 1984) and in Saskatchewan (Hunt 1976) have shown the importance of cover and forage for deer and moose during winter.

The three mature forests provided adequate winter thermal and security cover for wild ungulates with the best cover provided by mature mixedwood, then spruce and finally pine forests (Figs. 10 and 11, Appendix 7). They were, however, largely devoid of forage with the result that big game abundance was low as indicated by

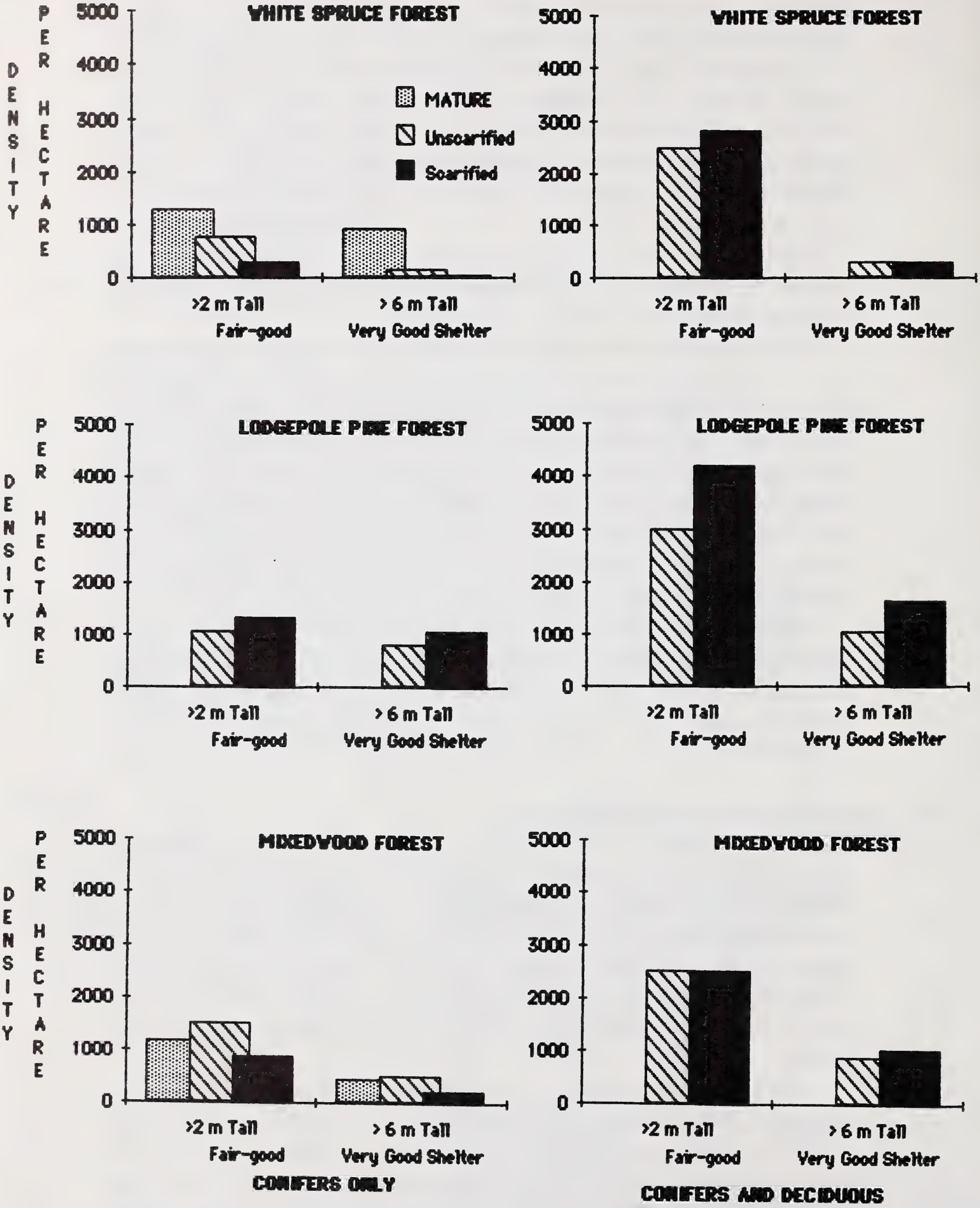

Figure 11. Winter and summer thermal shelter for wild ungulates in 32 year-old clear-cuts and mature forests.

pellet groups/ha of 15, 0, and 15 for mature mixedwood, pine and spruce forests prior to logging compared with 100, -, and 28, respectively, 32 years later when adjacent clear-cuts were available for food.

During the first five years post-logging, shrubs and trees were too low to provide ungulate cover although unscarified clear-cuts provided minimum security for deer and elk in summer because of residual trees and shrubs (Figs. 2-4). The 100 m wide (5 chains) residual blocks, left interspersed throughout spruce and mixedwood clear-cuts for the first 12 years, although too narrow to provide good cover, were apparently providing some cover (thermal and security) because elk and moose use of clear-cuts declined sharply after the mature blocks were removed.

By Year 9, deciduous cover was adequate to provide summer security cover in spruce and mixedwood unscarified clear-cuts and in both pine clear-cuts (Figs. 2-4). Removal of mature, residual blocks at Years 12-13 in spruce and mixedwood clear-cuts decreased summer security cover and eliminated all winter thermal cover because conifer heights in the young clear-cuts were inadequate to meet minimum winter thermal cover requirements (Thomas *et al* 1979). Winter thermal cover is considered minimal for deer when 75% of the area is covered by conifers at least 2 m tall. Adequate thermal cover does not necessarily imply adequate security cover e. g. mature-old aged conifer forests, or those with the understory deliberately removed, that provide ideal thermal cover but where cervids are conspicuous.

By Year 17, dense pine regeneration and rapid tree growth of both coniferous and deciduous plants in both pine clear-cuts resulted in moderate winter thermal/security cover for big game. The 26 year-old unscarified spruce and mixedwood clear-cuts were providing minimum winter cover at a time when browse forage was abundant and available above snow. Scarified clear-cuts lagged 5-10 years behind the unscarified clear-cuts in meeting wildlife cover requirements and at Year 26 were inadequate for winter cover but were providing adequate summer cover (Fig. 11).

By Year 26, both pine and unscarified mixedwood clear-cuts provided acceptable winter thermal/security cover plus adequate summer cover.

By Year 32, winter cover values in all clear-cuts had increased over those present in Year 26, but only pine clear-cuts were providing adequate winter cover (Appendices 5 and 7).

Security or hiding cover in the summer of Year 32 was best in unscarified clear-cuts, next in mature forests and lowest in scarified clear- cuts (Fig. 12, Appendix 7). Big game were 45% more visible in scarified than in unscarified clear-cuts, especially for portions of the body >0.5 m above ground. For 32 year-old scarified clear-cuts, big game were most visible in mixedwood, then spruce and lastly pine. In unscarified clear-cuts, they were most visible in white spruce then mixedwood and lastly pine. Even under the mature forest canopy, they were 41% more visible than in 32 year-old unscarified clear-cuts. Mature conifers lose needles on their lower branches and become "leggy" thus providing less security cover than under younger conifers. However, animals bedded down with none of their body above 0.5 m above ground were only about 50% as visible as those standing (Appendix 7).

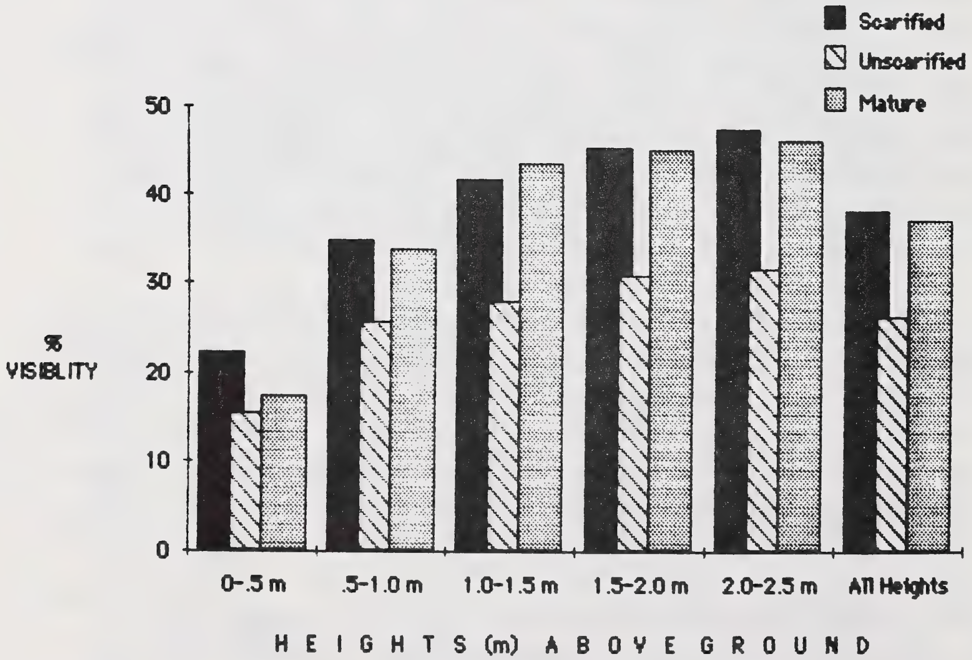

Figure 12. Summer visibility values for 5 heights above ground, averaged from spruce, pine and mixedwood forests for mature and 32 year-old clear-cuts.

In response to these changes in quantity and quality of wildlife habitat during logging and for 32 years after, there were major changes in big game species' diversity and abundance. Big game (deer, moose elk) densities in the spruce forest, as determined from helicopter and ground surveys, declined from 1.5/km^2 in the mature forest to 0.8/km^2 in summer and 0/km^2 in winter one year after logging in scarified clear-cuts (Stelfox 1983). By Year 5, corresponding values were 3.5 and 0 indicating that virtually all big game use during the first five years was summer use. White-tailed deer quickly moved into the clear-cuts whereas they were not observed in mature forests prior to logging. Most use during the first ten years was summer use by deer and elk with summer use increasing rapidly, especially during the period 5-10 years after logging. At Year 6, big game use was 7 and 13 times greater in mixedwood than in spruce and pine clear-cuts (Fig. 13).

During the first 17 years in spruce clear-cuts, big game use was 2.7 times greater in unscarified than in scarified clear-cuts. At Year 17, big game use was considerably greater in clear-cuts than in mature spruce although most use of clear-cuts was still summer use due to a lack of winter cover. Big game use was 59 and 9 times greater in 17 year-old unscarified and scarified clear-cuts, respectively, than in the mature spruce forest. During Years 1-27, deer, elk and moose sign (combined direct and indirect observations) was significantly greater in unscarified than scarified clear-cuts for all three forest types (Appendix 8, Stelfox 1984). For the time periods: Years 1-9, 17, 26-27, unscarified treatments had 2-27 times more big game sign than scarified treatments, when differences were significant. Unscarified spruce clear-cuts had more big game sign during Years 1-17, but not Years 26-27, than in scarified clear-cuts (Appendix 8). Within the pine forest, the unscarified clear-cut had significantly more big game use than the scarified clear-cut during Years 26-27 and 32, but not Years 1-9 (Fig. 13, Appendices 3 and 8). Because all cervids exhibited similar responses to changing habitat conditions, it suggests they reacted to the same or related habitat factors (Appendix 8).

Pine clear-cuts received considerably more use by moose than did spruce and mixedwood clear-cuts (Fig. 13). Some reasons may be greater cover (security and thermal) in 10-32 year-old pine clear-cuts compared with those in the other two forest types and a correspondingly lower harassment from human activities in pine

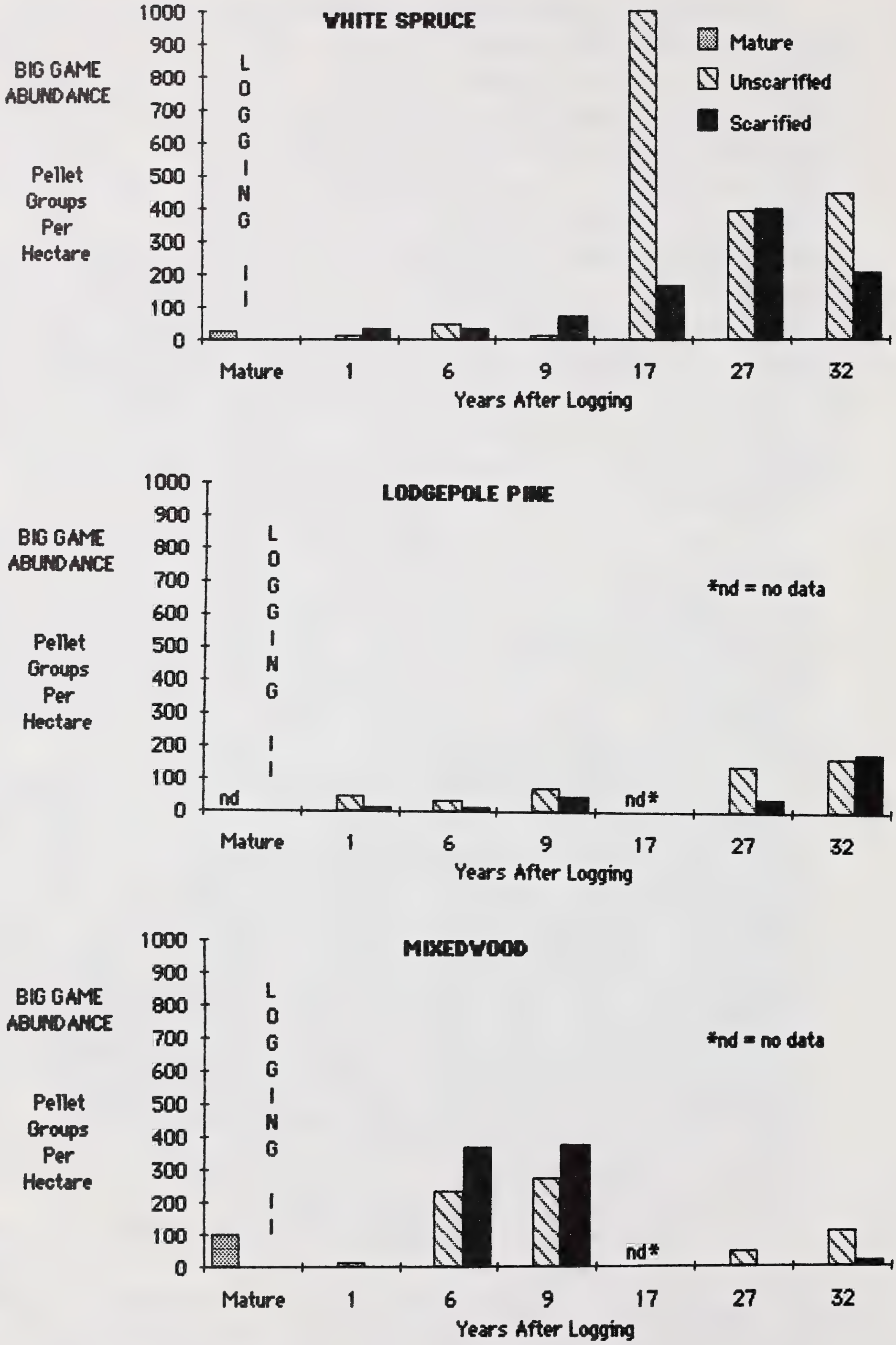

Figure 13. Changes in big game abundance following logging.

clear-cuts. Also, abundance of alder in the pine may have enhanced habitat and increased protein content of browse forage as well as nitrogen content of the soil (Becking 1970, Virtanen 1962). Big game use of pine clear-cuts was greatest in the unscarified clear-cut during the first 32 years (Table 3, Appendix 8).

During Year 32, abundance of big game, based on pellet-group counts, was 5.7, 0.9 and 2.1 times greater in unscarified spruce, pine and mixedwood clear-cuts than in their respective scarified blocks. Deer, moose and elk use was greatest in spruce, then pine and lastly mixedwood clear-cuts (Tables 3, Fig. 13, Appendix 8). Deer and elk abundance was significantly higher in spruce and pine than in mixedwood clear-cuts (Appendix 3). Most big game use was by deer with winter use 1.9 times greater than summer use. This was the converse of Year 1 when all use was in summer. Elk use was only about 10% of that by deer. Moose did not use the spruce and mixedwood clear-cuts although in pine clear-cuts use by moose was about 28% as great as that by deer. Big game use of mature forest blocks increased 2 and 7 fold in spruce and mixedwood forests, respectively, between 1956 (prior to logging) and 1988 when forage was available in adjacent clear-cuts. Complete details of winter versus summer wildlife abundance and population trends during the first 32 years following logging are presented in Appendix 8.

The problem of human harassment was more evident in the mixedwood clear-cuts because they were interlaced with accessible roads and trails. Big game use actually declined after Year 9 even though forage, cover and shelter conditions continued to improve. This easy accessibility for humans caused an almost complete evacuation of the area by elk, and to a lesser extent by deer, within a week of the opening of the fall big game season. Large mammals continued to largely avoid these clear-cuts until spring when they returned to forage on new grass and forb growth. However, they were again forced from the area by continued human harassment. Use of clear-cuts by elk in Montana was also reduced by the presence of roads (Lyon and Jensen 1980). In west-central Alberta, harassment was found to be a major factor affecting the use of clear-cuts by moose (Tomm *et al.* 1981).

Black bears apparently require a combination of cover and food which includes an abundance of insects in rotting wood material and berry-producing shrubs (Lindsey and Meslow 1977). These were not

Table 3. Wildlife abundance in mature forests and 32 year-old clear-cuts based on pellet groups/hectare, 1988.

BLOCK	SAMPLE	DEER W*	DEER S*	DEER Total	ELK W	ELK S	ELK Total	MOOSE W	MOOSE S	MOOSE Total	HARE	GROUSE●	COYOTE
MIXEDWOOD FOREST													
SCAR	1	0	20	20	0	0	0	0	0	0	0	50	0
UNSC	1	180	20	200	20	0	20	0	0	0	0	370	0
	2	4	4	8	0	0	0	0	0	0	4696	32	0
AVE.UNSC		92	12	104	10	0	10	0	0	0	2348	201	0
MATURE	1	44	48	92	8	0	8	0	0	0	28	56	4
LODGEPOLE PINE FOREST													
SCAR	1	70	50	120	0	10	10	20	20	40	5220	1320	0
	2	50	80	130	10	0	10	30	20	50	3110	50	0
AVE.SCAR		60	65	125	5	5	10	25	20	45	4165	910	0
UNSC	1	80	60	140	0	0	0	36	8	44	196	52	0
	2	124	16	140	0	0	0	12	4	16	628	132	0
AVE.UNSC		102	38	140	0	0	0	24	6	30	412	92	0
WHITE SPRUCE FOREST													
SCAR	1	108	60	168	20	24	44	0	0	0	16	36	0
	2	104	48	152	32	24	56	0	0	0	0	8	0
AVE.SCAR		106	54	160	26	24	50	0	0	0	8	22	0
UNSC	1	360	180	540	30	10	40	0	0	0	290	0	0
	2	228	44	272	20	20	40	0	0	0	4	0	0
AVE.UNSC		294	112	406	25	15	40	0	0	0	147	0	0
MATURE	1	12	12	24	0	0	0	4	0	4	220	0	4

* W = Winter S = Summer

● Ruffed grouse in scarified spruce and mixedwood clear-cuts. Spruce grouse in mature forests and both pine clear cuts. Both species in the unscarified clear-cuts.

common in clear-cuts until after Year 17. Studies in northern California (Kelleyhouse 1977) and in spruce-fire associations of Montana (Jonkel and Cowan 1971) showed that all recently logged areas were either avoided or minimally used by black bears. Kelleyhouse (1977) concluded that extensive logging has at least a short-term (1-10 yr) adverse impact on black bear populations. However, mixed conifer habitat was used continually. Other studies have shown that black bears are attracted to recently burned or clear-cut areas because of increased berry production (Scotter 1964, Jonkel and Cowan 1971). Bears, primarily black bears, began using clear-cuts extensively 17-25 years after logging in all three forest types. At that time rotten logs and stumps were producing an abundance of insect food, especially ants, while other important foods, such as hedysarum and buffalo-berry, were becoming more abundant. Taller deciduous and coniferous trees and shrubs were then providing adequate cover and cooler summer conditions than were younger clear-cuts. Cursory observations from this study indicated that productive bear habitat was associated with two important habitat attributes:

(1) Adequate summer cover (security and thermal) which existed when aspen, willow, alder, spruce and/or pine vegetation reached a height of at least 3 m. Hot, open cover existing during Years 1-16 was unsuitable while taller and more dense canopy cover during latter years provided cooler conditions and adequate security cover;

(2) Abundance of food, especially ants and other preferred insects, berries such as buffalo-berries and fleshy underground plant material (hedysarum). At Year 32, use of clear-cuts by bears was similar to that observed during Years 25-27.

4.3.2 **Forage Production and Use** - Deciduous browse use in summer was greatest where coniferous canopy cover was lightest while during winter the converse occurred. Browse production decreased with increasing canopy closure. Scarification increased production in mixedwood and spruce clear-cuts but decreased production in pine clear-cuts. Browse production (≤2.4 m in height) peaked at about Year 17 in unscarified spruce and mixedwood clear-cuts and about Year 26 in scarified blocks (Table 4, Appendix 9). Peak production (kg/ha dry weight) was about 1240, 1070 and 420 in unscarified pine, spruce and mixedwood clear-cuts. Comparable

Table 4a. Browse forage production (green weight kg/ha) in clear-cut blocks following logging.

CLEAR-CUT BLOCK	MATURE FOREST	YEARS AFTER LOGGING 1	5	9	17	26	32
WHITE SPRUCE FOREST							
Scarified	592	113	966	1615	1911	2074	1662
Unscarified		210	999	1935	2272	1838	1523
MIXEDWOOD FOREST							
Scarified	-	-	-	1154	-	1302	739
Unscarified		-	-	750	-	398	158
LODGEPOLE PINE FOREST							
Scarified	-	-	-	-	-	2057	1624
Unscarified		-	-	-	-	2436	2113

Table 4b. Dry weight browse forage production (kg/ha) in clear-cut blocks following logging.

CLEAR-CUT BLOCK	MATURE FOREST	YEARS AFTER LOGGING 1	5	9	17	26	32
WHITE SPRUCE FOREST							
Scarified	278	51	433	727	858	934	906
Unscarified		99	470	909	1068	866	834
MIXEDWOOD FOREST							
Scarified	-	-	-	635	-	610	406
Unscarified		-	-	418	-	190	88
LODGEPOLE PINE FOREST							
Scarified	-	-	-	-	-	1019	927
Unscarified		-	-	-	-	1195	1235

values for corresponding scarified clear-cuts were 1020, 930 and 630 kg/ha (Table 4). These values included both leaf and twig weights. Within some Alberta aspen forests, the annual biomass yield of browse decreased with age from 210 kg/ha at age 14 to 40 kg/has at age 30 and 20 kg/ha at age 60 (Westworth *et al.* 1984).

Both browse biomass and winter cover interacted to influence cervid browse use. ANOVA statistics indicated that both forest type and forest type-treatment interactions accounted for differences in browse use. At Year 26, pine clear-cuts had the greatest total summer plus winter consumption followed by scarified mixedwood, unscarified spruce, scarified spruce, and unscarified mixedwood (Appendix 9). Total browse consumption coincided more with degree of cover than with stem plus leaf browse production (Stelfox 1984). When only summer use is considered, the highest browse consumption occurred in both mixedwood, both pine, unscarified and then scarified spruce clear-cuts, in that order.

In summer, cervids utilized browse resources more fully where coniferous canopy closure and security cover values were low (Stelfox 1984). This was probably due to improved nutrition of plants in the sun compared with those in the shade (Cowan *et al.* 1950).

The large difference in yearlong use between clear-cut pine and other clear-cuts indicates that a critical combined cover value of about 50% is needed before intensive utilization takes place. It is evident that extremely low cover values result in little or no use of browse resources (e.g., Year 5, Appendix 9). Mean and total browse utilization increased over time in the spruce clear-cuts as better cover became available (Apppendix 9, Stelfox 1984). Although browse production decreased by Year 26 in unscarified clear-cuts, browse consumption was greater than in scarified clear-cuts because of superior cover.

In general, browse densities (or production) and use by big game were greater in unscarified treatments, except for Years 26 and 32 when scarified spruce and mixedwood produced more browse. This indicates that total consumption averaged greater in unscarified treatments during Years 1-26 in all forest types.

Of the main browse species, use by big game animals was heaviest on rose, willow, and poplar in that order of decreasing use (Appendix 9). Utilization was heaviest in mixedwood, then pine and least in spruce clear-cuts. Two highly preferred species present in low densities in the pine forest were mountain ash (*Sorbus scopulina)* and alpine fir as shown in Fig. 14. Big game use of mountain ash had removed 75% of new leaf and stem growth by late August in 32 year-old pine clear-cuts. By that time, at least 50% of new growth of young alpine fir seedlings and saplings had also been consumed by moose, deer and elk. This strong preference for these two species has prevented them from achieving normal density and growth in the young pine forest and has resulted in what could be termed a "zootic-impaired" tree community. Mountain ash and alpine fir were not found on low-elevation spruce and mixedwood clear-cuts. Alder was only present in pine clear-cuts and there it received an average utilization of 11.1% by big game, somewhat more than for poplar but less than for willow (Stelfox 1984). Utilization of less than 5% for poplar, willow and rose (Appendix 9) at Year 26 supports the contention that browse forage was under-utilized and the range stocking rate of moose, deer and elk well below the range carrying capacity from a food availability perspective.

Grass and forb cover and species diversity increased significantly, especially in scarified blocks, during the first six years resulting in increased summer use of clear-cuts by deer and elk. Only light use of grasses occurred during Years 1-32 with greatest use during Years 1-6. Preference of the most abundant grasses during Years 1-6 in spruce clear-cuts, in decreasing order of preference were timothy, rush, bromegrass, sedge and hairy wild rye. Use of grasses and forbs in mature forests was negligible prior to logging. Deer and elk in summer used the diverse and abundant growth of forbs within clear-cuts during these early years. Of 26 forb species present in clear-cuts but not in mature blocks, many were eaten by deer and elk. Seven species or genera that comprised 90% of forb diet (cover x ave. use) in spruce clear-cuts during Years 1-5 were hedysarum 27.9 %, fringed gentian *(Gentianella crinata)* 14.0%, tall mertensia 13.4%, asters 12.1%, blue columbine (*Aquilegia brevistyla)* 7.8%, thin-leaved ragwort (*Senecio pseudaureus*) 7.7%, and smooth camas 7.3%. However, the ten most highly preferred forbs, in decreasing order of preference were: lamb's quarter (*Chenopodium album),* harebell (*Campanula rotundifolia),* blue columbine, fringed gentian, indian paint-brush (*Castilleja* spp.), smooth camas, western wood lily (*Lilium*

Mountain Ash (*Sorbus scopulina*) Alpine Fir (*Abies lasiocarpa*)

Figure 14. Preferred big game browse species, mountain ash and alpine fir, being suppressed in a 32 year-old lodgepole pine forest.

philadelphicum), asters, thin-leaved ragwort, and hedysarum.

At Year 26, big game use of forbs averaged 2.8% in mixedwood and 0.1% or less in spruce and pine clear-cuts. Comparable values for big game use of grasses were <0.1% in mixedwood, 0% in spruce, and 0.1% in the pine clear-cuts. There was a significant difference ($p<0.01$) in forb use among the three forest types, with pine treatments tending to be higher in scarified but lower in unscarified clear-cuts compared with the other two forests (Stelfox 1984).

At Year 32, big game use of forbs and grasses was similar to that recorded in Year 26.

4.3.3 **Winter Forest/Wildlife Interactions** - Security (hiding) and thermal cover was a greater determinant of habitat use of clear-cuts by deer, elk and moose than forage availability, as shown in earlier sections. Mature coniferous blocks, at least 100 m wide, were essential for winter thermal and security cover during the first 15-20 years following logging of the pine forest and the first 25 years following logging of spruce and mixedwood forests. Where these latter forests were scarified following logging, mature residual blocks interspersed throughout the clear-cuts were required for at least 30 years after initial logging.

There was a strong negative correlation ($r = -0.77$) between wildlife abundance and wind chill, indicating that winter residents avoid clear-cuts with poor shelter values (Fig. 15). Wildlife abundance represents the sum of all direct and indirect observations using an identical survey technique and time period for all blocks. (Stelfox 1984). There was also a negative correlation ($r = -0.72$) between animal visibility and wildlife abundance. The correlation between crown closure and wildlife abundance was strongly positive in spruce but less positive in pine and mixedwood clear-cuts.

At Year 26, winter wildlife stocking rates were greatest in mixedwood treatments where they were twice as great as in spruce and 1.5 times greater than in pine treatments. Critical cover values of about 50% for each of security and coniferous canopy are needed before intensive yearlong use of clear-cuts by big game will occur (Fig. 15). The greatest diversity of animal species was in unscarified clear-cuts of all forests, then scarified clear-cuts, and lastly in mature blocks.

There was a positive correlation between abundance (winter

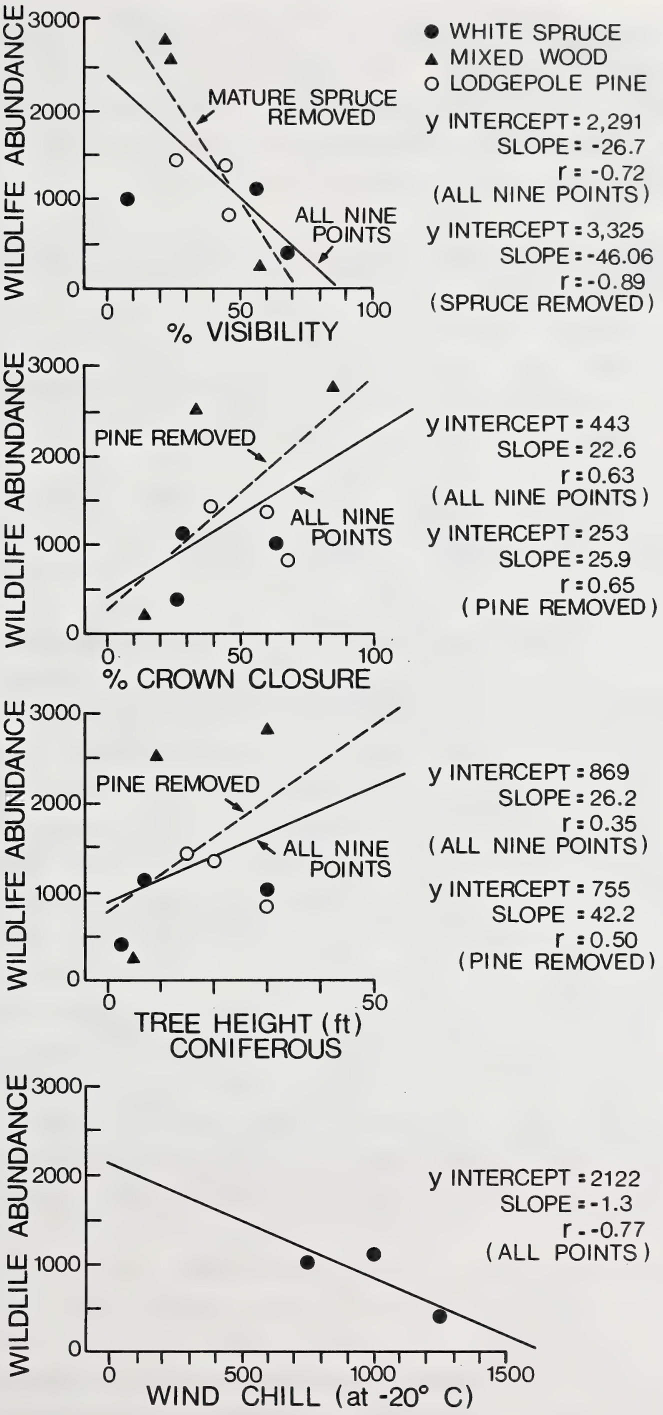

Figure 15. Correlations between winter wildlife abundance and security cover (% visibility), conifer crown closure, conifer height and wind chill.

track counts) of mice and two of their predators, namely coyotes and weasel. Mice were most abundant in unscarified clear-cuts, especially in white spruce, then in scarified clear-cuts and lastly in mature blocks. This abundance was positively correlated with percent foliage cover of grasses (Stelfox 1984).

4.3.4 **Potential and Actual Use of Clear-cuts by Big Game** - Big game populations, with the exception of white-tailed deer, did not increase proportionate to the extent of increases in range carrying capacities of clear-cuts during the first 32 years following logging. General ratings of clear-cuts' ability to support big game and the actual abundance of big game are presented for five time periods (Table 5).

As mentioned earlier, white-tailed deer numbers increased quickly following logging. The large increase in big game use during the first 17 years in the clear-cuts was almost entirely summer use by white-tailed and mule deer. Road access and continuous harassment from human activities, plus inadequate cover, appeared mainly responsible for elk and moose populations failing to increase proportionate to increased habitat carrying capacities. Considering clear-cuts in all three forests, big game abundance increased up to Year 17 but then declined sharply by Year 26. Even though big game use was 9 and 59 times greater in 17 year-old scarified and unscarified clear-cuts, respectively, than in the mature spruce forest, the carrying capacity of browse forage exceeded the actual stocking rate by about 40:1 (Stelfox *et al* 1974 and 1976). Carrying capacities of browse forage at Year 17 were estimated at 6.7, 2.8 and 0.6 hectares per moose, elk and deer for scarified and 4.4, 2.1 and 0.4 hectares, respectively, for unscarified clear-cuts. Stated another way, the 17 year-old scarified forage could theoretically support 35 moose, 74 elk or 382 deer/km^2 or 48 moose, 103 elk or 536 deer/km^2 in unscarified clear-cuts, providing cover conditions were adequate and harassment not significant (Stelfox *et al* op. cit).

Something suppressed big game numbers well below the range carrying capacity of clear-cut blocks during Years 25-27 and 32. Human harassment and corresponding insecurity for big game, especially elk and moose, were believed largely responsible. Other limiting factors such as predation, disease/parasitism and inclement weather were not believed to be significant mortality

Table 5. Potential and actual use of clear-cuts by big game.

YEARS AFTER LOGGING		White Spruce		Lodgepole Pine		Mixedwood	
		Scar	Unsc	Scar	Unsc	Scar	Unsc
		ABILITY OF CLEAR-CUTS TO SUPPORT BIG GAME					
1-11	Summer	Fair	Good	Good	Good	Fair	Good
	Winter	Poor	Poor	Poor	Poor	Poor	Poor
12 & 13	Residual Coniferous Blocks Removed in Spruce and Mixedwood Clear-cuts						
14-17	Summer	Fair	Good	Good	Good	Fair	Good
	Winter	Poor	Poor-Fair	Fair	Fair	Poor	Poor-Fair
18-25	Summer	Good	Good	V. Good	V. Good	Fair	Good
	Winter	Poor	Fair	Good	Good	Poor	Fair
26-32	Summer	V. Good	V. Good	V. Good	V. Good	Good	V. Good
	Winter	Fair	Fair-Good	V. Good	V. Good	Poor-Fair	Good
		RELATIVE ABUNDANCE RATINGS OF BIG GAME*					
		White Spruce		Lodgepole Pine		Mixedwood	
1-11	Summer	D[1]E[2]	moderate	D E M[3]	moderate	DE	moderate
						M	nil
	Winter		nil	nil	- light		nil
12 & 13	Residual Coniferous Blocks Removed in Spruce and Mixedwood Clear-cuts						
14-17	Summer	DE	light	D E M	moderate	DE	light
	Winter	nil	light	D E M	light		nil
18-25	Summer	D E	moderate	D E M	moderate	DE	light
	Winter	nil	light	D E M	moderate		nil
26-32	Summer	DE	light	D E M	moderate	EM	nil
						D	light
	Winter	D light	D moderate	D E M	moderate	D light	D light

[1] Deer [2] Elk [3] Moose

* Deer use of clear-cuts was mostly by whitetails in the spruce and mixedwood clear-cuts and by both whitetails and mule deer in pine clear-cuts. The abundance of moose in the spruce and mixedwood clear-cuts was virtually nil, except during Years 1-11 before the coniferous residual blocks were removed when their abundance was light.

factors during this study. Hunting may have suppressed moose and elk populations (Regional Biologist K. G. Smith pers. comm.) As stated earlier, security cover and winter shelter attributes were inadequate for the first 15 years at least, especially in scarified blocks. However, these requirements were being met to a greater degree each year so moose, deer and elk populations should have increased correspondingly but didn't (Table 3, Figs. 10-13, Appendix 7 and 8), except for pine clear-cuts (Fig. 13). For spruce and mixedwood clear-cuts there was a decrease in big game abundance between Years 26 and 32, in both scarified and unscarified clear-cuts.

The recent, large gravel pit operation within the mixedwood clear-cut (Fig. 16) undoubtedly affected big game use of both clear-cuts during Years 25-32. During Years 26 and 27, summer and winter studies showed negligible big game sign within 335 m of gravel pit activities. Old logging trails remained passable for motorized vehicles throughout Years 1-32 and received increased use by various vehicles during summer and winter. During the summer of Year 32, when gravel pit operations were still active, mixedwood clear-cuts were being used by less than six whitetails and no elk or moose. Conversely, in spruce clear-cuts along the same valley where vehicular use was denied, 6-12 whitetails, 3-5 mule deer and 5-6 elk were using a similar sized area during the summer of Year 32.

4.3.5 **Upland Game-bird Trends** - Grouse were absent or scarce during Years 1-15 (Grass-forb and Shrub-seedling stages). Only 25% of grouse observations during the first 27 years occurred during Years 1-15 compared with 75% during Years 16-27 (Pole-sapling stage) as shown in Appendix 10. Mixedwood clear-cuts were most productive (59% of observations), then white spruce, (32%), and lastly lodgepole pine (9%), during Years 16-27. More grouse were observed in unscarified clear-cuts (86%) compared with 14% for scarified.

Spruce grouse were not seen in any clear-cuts during the first 15 years although they were common in all three mature forests. A small summer population of ruffed grouse was observed in unscarified mixedwood as were blue grouse in scarified spruce and sharp-tailed grouse in scarified pine clear-cuts, during Years 1-15. The first spruce grouse observed in the clear-cuts was Year 17

Figure 16. Gravel pit operations in scarified and unscarified mixedwood clear-cuts, 26-32 years after logging.

in unscarified spruce, Year 26 in unscarified mixedwood and Year 27 in unscarified pine. They comprised only 10% of the grouse seen during Years 1-27. Most (86%) were in unscarified clear-cuts.

In Year 32, spruce grouse were abundant in both pine clear-cuts (Table 3) while ruffed grouse were observed in the transitional zone between these pine clear-cuts and the open, deciduous cover adjacent to the perimeter road. Grouse were more abundant in the scarified pine clear-cut. In mixedwood clear-cuts, ruffed grouse were found in scarified, both spruce and ruffed grouse in unscarified clear-cuts, and only spruce grouse in the adjacent mature forest. In spruce clear-cuts, no spruce or ruffed grouse sightings or signs were observed in the unscarified block while three broods of ruffed grouse were seen in the scarified clear-cut, in addition to an average of 22 faecal groups/ha (Table 3, Appendix 10).

The most abundant grouse for all clear-cuts was ruffed grouse which accounted for 72% of all grouse seen during Years 1-27. During Years 1-15, they accounted for only 44% of the grouse compared with 81% during Years 16-27. No ruffed grouse were seen in the unscarified pine clear-cut during Years 1-32 while 2 were seen in the scarified clear-cut during Years 16-27 (Table 3, Stelfox 1984).

Sharp-tailed grouse were only observed in the scarified pine clear-cut at Year 3 during the Grass-forb forest successional stage.

Blue grouse summered only in the spruce scarified clear-cut near the mountains during Years 1-26. They did not occur in the adjacent unscarified and mature spruce blocks nor in the mixedwood and pine blocks that were more than 15 km from the mountains. One brood was seen in the summer of Year 3 and three single adults were seen during the summers of Years 25 and 26 (Stelfox 1984). None were seen in winter.

During Years 1-27, only 11% of the grouse were observed during winter indicating that these young clear-cuts were generally not providing adequate winter cover. However, in Year 32, both pine and spruce clear-cuts appeared to be supporting grouse equally well in winter and summer.

During Years 25-27 and 32, unscarified spruce and pine clear-cuts had 10% or less as much grouse sign as did their scarified counterparts (Table 3, Stelfox 1984). In mixedwood clear-cuts, abundance of grouse was 4 times greater in unscarified than in scarified and mature clear-cuts (Table 3).

4.3.6 Tree Cavity-Dwelling Wildlife - At least 38 cavity-dependent species on the Weldwood lease rely on snags for nesting (McCallum 1984). Their association with snags of various diameters and the abundance of snags in three mixedwood forest blocks are present in Table 6 and Appendix 11). This group of wildlife disappeared from the scarified clear-cuts following logging as no trees with cavities remained. Within the unscarified clear-cuts, only a small portion of decadent and dead trees were removed during logging. Large poplar trees, in particular, were essential for maintaining populations of woodpeckers (pileated, hairy, downy, northern three-toed, yellow-bellied sapsucker, flicker), nuthatches (red-breasted, white-breasted), chickadees (boreal and black-capped), mountain bluebird, starling, swallows (tree and violet-green), house wren, kestrel, saw-whet owl and ducks (bufflehead, goldeneye and hooded merganser) as well as flying squirrels and big brown bats. The red squirrel and marten also disappeared while such species as short-tailed weasel and least chipmunk were undoubtedly affected because of the loss of trees and logs with cavities that result from scarification following logging. The density of trees with cavities after logging was much higher in mixedwood, then spruce, and lastly pine clear-cuts. Correspondingly, 84% of woodpecker and 79% of chickadee sightings were in the unscarified mixedwood clear-cut during Years 1-27 (Appendix 10). Three hawks (goshawk, merlin and sharp-shinned) were seen only in unscarified and mature treatments. Dickson *et al* (1983) found bird species richness, abundance and diversity were significantly higher in plots with snags than in snagless plots. They also found that many non cavity-nesting birds used snags for foraging and perching and were more abundant on plots with snags. A study in Oregon and Washington determined that 39 bird and 23 mammal species used snags for nesting or shelter and that a direct relationship existed between the number of snags and the number of snag-dependent wildlife in the forest (Thomas *et al* 1979).

In Year 32, the density of tree snags in unscarified clear-cuts was highest in pine (43/ha), next in mixedwood (23/ha) and then in spruce (22/ha) forests (Appendix 11). However, the greatest density of snags with cavities was in mixedwood (17), then pine and spruce (7) unscarified clear-cuts. Almost 75% of snags in mixedwood unscarified clear-cuts contained cavities compared with only 32% in spruce and 16% in pine unscarified clear-cuts. The

Table 6a. Density of snags, percent with cavities and percent being used by wildlife in three mixedwood forest blocks.

		MATURE	32 YEAR OLD UNSCARIFIED	32 YEAR OLD SCARIFIED
Snag Density/Hectare		76	23	0
Wildlife Use	a) Woodpecker[1]	0	3	1
	b) Flicker	0	2	0
	c) Chickadee	0	1	0
	d) Starling	0	2	0
	Total Wildlife	0	8	1
% of Snags	10-20 cm DBH	5.3 (0)	14.3 (7)	0 (0)
with Cavities	20-30 cm DBH	2.3 (0)	58.3 (17)	0 (0)
and % of Snags	30-35 cm DBH	0 (0)	66.7 (100)	0 (0)
Being Used	35-50 cm DBH	0 (0)	50.0 (33)	0 (0)

[1]Pileated and northern three-toed woodpeckers

Table 6b. Wildlife species that will use tree snags of various diameters.

SNAG DIAMETERS IN CENTIMETRES 15-20	20-30	30-35	35-50	>50
Chickadees Downy Woodpecker	Yellow-bellied Sapsucker Hairy Woodpecker Tree Swallow Violet-Green Swallow House Wren Bluebird Starling Short-tailed Weasel Chipmunk Deer Mouse	Kestrel Saw-whet Owl Northern 3-Toed-Woodpecker Nuthatch (white & redbreasted) Red Squirrel Flying Squirrel Big Brown Bat	Bufflehead Duck Hooded Merganser Marten	Goldeneye Duck Pileated - Woodpecker

density of snags was 2-3 times greater in mature unlogged forests than in adjacent unscarified clear-cuts (Table 6, Appendix 11). Snags were absent in scarified clear-cuts of mixedwood and spruce forests while there was a density of 15/ha in the scarified pine clear-cut (Appendix 11). It is expected that under a timber management rotation cycle of 80-90 years, decadent and dead snags with diameters greater than 30 cm dbh will be virtually non-existent. That will result in a major decline in those 15 bird and mammal species that use decadent and dead trees with diameters >30 dbh (Table 6b). The exception could be the red squirrel and marten that probably exist without snags.

4.3.7 Avifauna General - Considering all bird species, 54% of bird observations were in mixedwood, 25% in spruce, and 21% in pine clear-cuts. Hawks (*Accipiter* and *Buteo* spp.) and falcons (*Falco* spp.) predominated in mixedwood clear-cuts, especially in the unscarified clear-cut. Sparrows (*Passerculus*, *Spizella*, *Zonotrichia* and *Melospiza* spp.), siskins and juncos (*Junco hyemalis)* were present in similar abundance in all three forest types (Stelfox 1984 and Appendix 10). The results are consistent with the findings of Welsh (1981) who concluded that population density and diversity of bird populations was greater within boreal mixedwood than within pine and spruce forests. The greater diversity of plant communities and plant species within the mixedwood forest provides more resources for more bird species than do forests dominated by one tree species (e.g. white spruce or lodgepole pine). The abundance and diversity of resources for birds are further enhanced in unscarified clear-cuts especially those containing unmerchantable trees such as aspen and balsam poplar of various sizes. Although the number of bird species seen in scarified and unscarified clear-cuts was similar, 21 and 22, respectively, there were major differences in species associated with each treatment. Ten species were observed only in unscarified clear-cuts: hairy woodpecker, yellow-bellied sapsucker (*Sphyrapicus varius)*, goshawk, merlin (*Falco columbarius)*, sharp-shinned hawk (*Accipiter striatus)*, cedar waxwing, common snipe *(Gallinago gallinago)*, upland sandpiper *(Bartramia longicauda)*, mountain bluebird (*Sialia currucoides)*, and starling (*Sturnus vulgarus)*. The seven species seen only in scarified clear-cuts were sharp-tailed and blue grouse, Swainson's hawk (*Buteo swainsoni)*, white-crowned (*Zonotrichia leucophrys*, and song sparrows (*Melospiza melodia*), hummingbirds (*Selasphorus* and *Stellula* spp.) and red-eyed vireo (*Vireo olivaceus*).

4.3.8 **Furbearing Mammals and Prey Species** - Furbearer numbers were depleted following clear-cut logging although weasels, coyotes and lynx appeared to respond somewhat to increased densities of mice and hares between Years 6 and 17. Furbearer numbers remained scarce to Year 17 but by Year 26, red squirrels were common in all unscarified but scarce in scarified clear-cuts. For all forest types, at Year 26, red squirrels were 31 and 4 times more abundant in mature forests than in scarified and unscarified clear-cuts, respectively (Fig. 17). Considering all five species (squirrel, weasel, lynx, coyote and wolf), their abundance in mature forests was 17 and 3 times greater than in scarified and unscarified clear-cuts, respectively. In mixedwood treatments (all three combined), the abundance of furbearers was 9 and 7 times greater than in spruce and pine forest treatments, respectively, at Year 26. Red squirrels were especially more abundant in mature forests while weasels and lynx were more abundant in clear-cuts (Fig. 17).

At Year 26 in the pine forest, snowshoe hare abundance was greatest in scarified, then unscarified clear-cuts (Stelfox 1984). At Year 32, abundance was 10 times greater in the scarified clear-cut. The converse was true in mixedwood and spruce forests where hares were abundant in unscarified, but absent or scarce in scarified clear-cuts which had inferior thermal and security cover (Table 3, Figs. 11 and 12). Recent girdling of conifers was light at Year 32 compared to Years 25-27 although the abundance of hares was still high in pine and mixedwood forests (Table 3). Hare girdling of 25-27 year-old pine was 41% higher in the scarified pine clear-cut and this was correlated with higher hare abundance (15%), coniferous density (64%), deciduous tree/shrub density (6%), and heights of pine, poplar and willow compared with the unscarified clear-cut (Table 7). These results agree with other studies showing hares preferred dense coniferous cover near a diverse food source (Poll 1981, Sullivan and Sullivan 1982). Deciduous browse forage biomass was 17% greater in the unscarified clear-cut and this greater food source may have also contributed to the lighter damage to pine (Table 7).

Pine trees girdled more than 40% will usually die (Radvanyi 1987). About 28 % of pine in scarified and 23% in unscarified

Table 7. Snowshoe hare damage to 26 year-old pine trees correlated to coniferous and deciduous tree densities and heights.

	26 YEAR-OLD SCARIFIED	CLEAR-CUTS UNSCARIFIED
% All Pine Girdled	67.0	47.5
% Pine Girdled 1-50%	38.0	24.5
% Pine Girdled 51-100%	28.5	23.5
% Pine With No Girdling	33.0	52.5
Ave. Pine Height (m)	6.2	4.6
Ave. Poplar Height (m)	3.8	3.3
Ave. Willow Height (m)	3.0	2.8
Deciduous Browse Biomass (kg/ha)	1019	1190
Deciduous Tree/Shrub Density/ha	39960	37530
Hare Density (Pellets/ha)	24950	21750
Coniferous Density/ha	3995	2430
Alder Density	2592	1835

clear-cuts will likely die because they were girdled more than 50% (Table 7). The number of trees girdled more than 40% increased by 9.5% between Years 26 and 27 in scarified compared with 0.5% in unscarified clear-cuts.

Vitality of pine trees girdled at least 75%, as measured by percent of needles that were red, was greater for tall (>6 m) than for small trees (Fig. 18). A higher mortality rate of severely girdled (>75%) trees can thus be expected for small trees (<6 m tall).

Pine trees were not only damaged by snowshoe hares but also by red squirrels (Fig. 19). Rather than girdling the trunk near its base, squirrels stripped bark from the stem to feed on the cambium and sapwood. Not only were strips of bark removed at distances of 2-5 m above ground but frequently the stem was completely girdled.

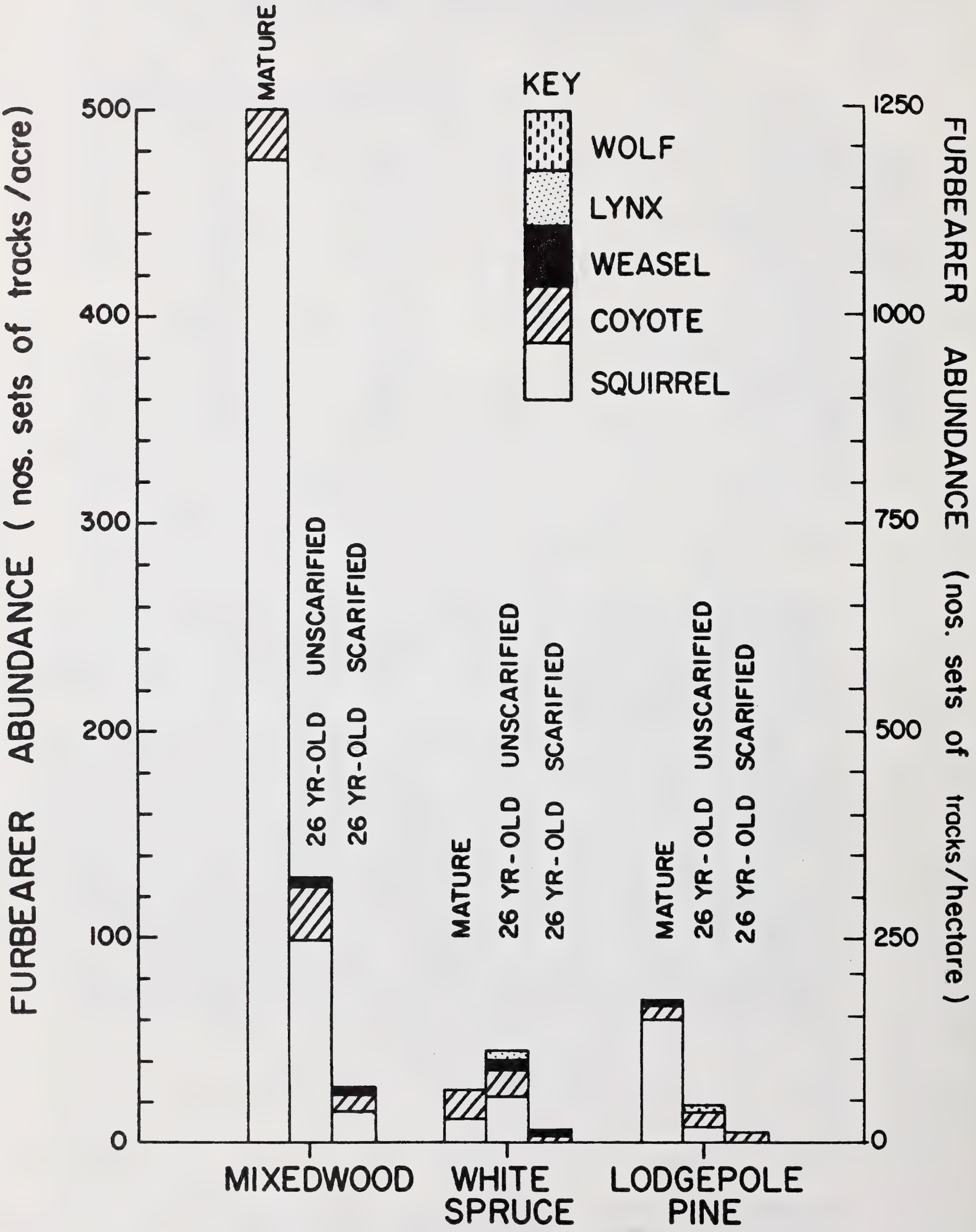

Figure 17. Furbearer abundance in mature and 26 year-old clear-cuts, based on winter track counts.

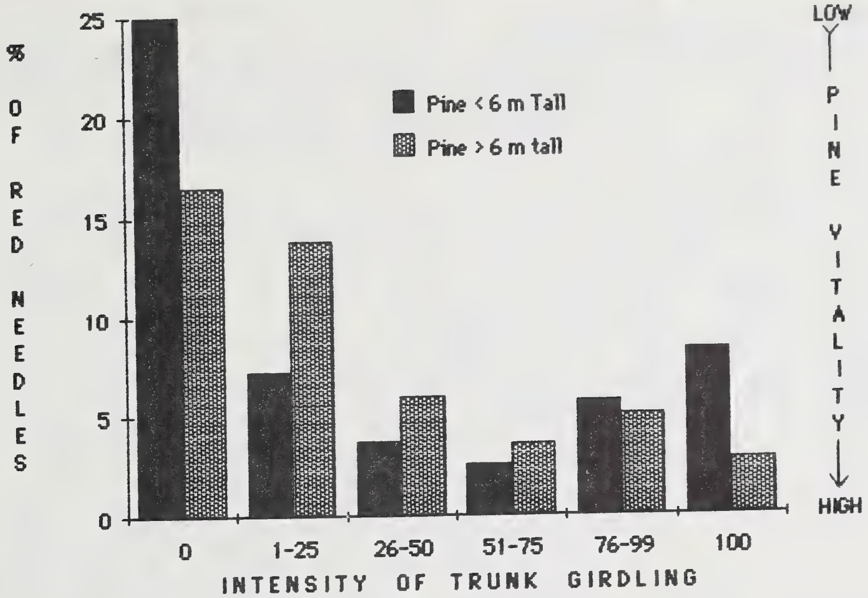

Figure 18. Vitality of girdled pine trees less than and greater than 6 metres in height.

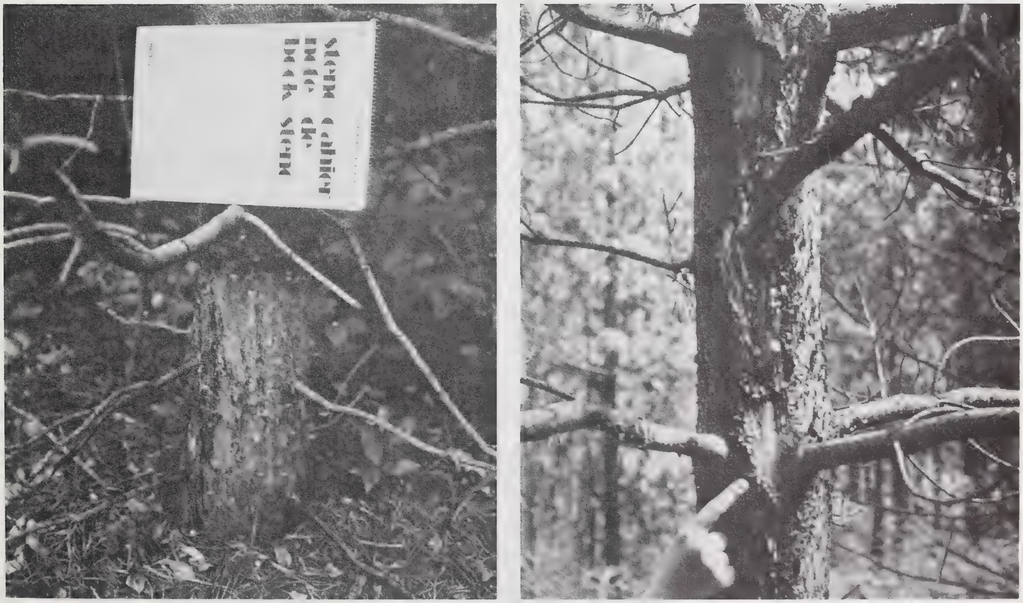

Figure 19. Girdling of 26 year-old pine by snowshoe hares (left) and damage by red squirrels (right).

6.0 SUMMARY AND CONCLUSIONS

Studies of forest succession, wildlife and habitat changes were conducted over a 32 year period (1956-1988) following clear-cut logging in white spruce, lodgepole pine and mixedwood forests in west-central Alberta.

Following logging, one-third of the old age spruce remained as intervening blocks between clear-cuts until 12-13 years after initial logging when they were removed. About 20% of the mature mixedwood forest was also left as residual blocks for the first 10-15 years after logging. None of the 283 ha logged pine forest contained mature unlogged blocks although about one-half of the area was left unscarified, as it was in the mixedwood clear-cut. In the spruce clear-cut only one block was left unscarified and reserved. Scarification consisted of using Caterpillar tractors equipped with rippers attached to the lower edge of the blade. Unmerchantable trees and shrubs were pushed down and the herb, grass and moss layers mixed with the upper 25-50 cm of soil. For the pine clear-cut, scarification consisted of merely pushing down all unmerchantable trees and shrubs and crushing the slash with Caterpillar tractors. For all study areas, logging and scarification occurred during 1956 and 1957.

Major differences occurred in wildlife densities and habitats, between scarified and unscarified, between clear-cuts and unlogged mature forests, and among the three forest types. Major differences in relation to forest succession stages were:

<u>Grass-forb (Herb-dwarf shrub) stage</u> (1-10 years)

Grass (grass and sedge) and forb (herb) biomass and species diversity increased significantly following logging, resulting in increased summer use by deer and elk that fed on this abundant forage. Grass cover increased 4 fold by Year 6 while the number of species also increased, compared with those in unlogged forests. Grass cover increases were greatest in pine, then spruce and least in mixedwood clear-cuts. Forb cover increased 2-3 fold after logging with greatest increases in scarified clear-cuts. At Year 5 in spruce clear-cuts, there were 26 forb species not evident in the mature forest, and many were preferred forages for elk and deer. By Year 32, grass and forb cover had declined to values somewhat higher than those in mature forests.

The open, low-growth plant communities favored ground nesting passerine birds but were unfavourable for tree nesting, perching, and tree cavity-dwelling avifauna. Light summer use by blue and sharp-tailed grouse occurred while spruce and ruffed grouse were absent.

Furbearer numbers were depleted following clear-cut logging although weasels, coyotes and lynx responded somewhat to increased densities of mice and hares, between Years 6 and 17. Snowshoe hare numbers remained low during this successional stage.

The overall abundance and diversity of resident wildlife species was scant in scarified clear-cuts because the three essential habitat requirements (forage, escape cover, shelter or thermal cover) were deficient. Winter forages for moose, deer and elk were too low to be available beneath the blanket of snow. Wind-chill conditions were unfavourable due to a lack of tall coniferous trees essential for thermal cover. Unscarified clear-cuts provided some forage plus winter cover and thus received light winter use by wildlife. However, most winter use occurred within mature residual blocks and in nearby unlogged forests. Tree cavity-dwelling bird species remained in unscarified clear-cuts where suitable tree snags remained but not in scarified clear-cuts, where snags had been removed.

Shrub Stage (11-20 years)

Poplar, willow and alder provided the conspicuous vegetative overstory at heights of 1.5-2.5 m and provided summer escape cover plus yearlong forage for big game animals, especially in unscarified clear-cuts. In pine, plus unscarified spruce and mixedwood clear-cuts, conifers were conspicuous. Conifers were still too small to provide adequate winter cover for big game, except in pine clear-cuts where their density and height were providing minimum winter cover during the later part of this period. During the first 17 years, big game use was 2.7 times greater in unscarified than in scarified spruce clear-cuts. This was mainly summer use by deer and elk due to a lack of winter cover. Big game use was 50 and 9 times greater in 17 year-old unscarified and scarified spruce clear-cuts, respectively, than in the mature spruce forest. Big game use declined temporarily following the removal of residual blocks of mature forest at Years 12-15 in spruce and mixedwood clear-cuts, because original clear-cuts were not providing adequate cover.

Ruffed grouse were common in unscarified spruce and mixedwood clear-cuts. Spruce grouse were absent in all clear-cuts during the first 15 years but were common in all three mature forests. They were first observed in the unscarified spruce clear-cut at Year 17, at Year 26 in unscarified mixedwood and at Year 27 in unscarified pine clear-cuts. Sharp-tailed grouse were absent during both the Shrub and Pole-sapling stages.

Tree cavity-dwelling wildlife, bears and most furbearing mammals remained scarce in scarified clear-cuts until after Year 17. Unscarified clear-cuts were superior to scarified ones for the above wildlife groups.

Snowshoe hare numbers remained low but somewhat higher than during the Grass-forb stage, especially in unscarified spruce and mixedwood clear-cuts.

Pole-sapling (young growth) Stage (15-25 years for Mixedwood and Pine, 20-40 years for Spruce clear-cuts)

Poplar and willow were still the conspicuous tree/shrub species in lowland spruce and mixedwood clear-cuts, especially the scarified ones. Conifer regeneration met provincial stocking rate standards in all clear-cuts by Year 26 although major differences existed in density, distribution and height between scarified and unscarified blocks. In the upland pine forest at Year 26, the density of conifers, tall enough to provide minimum winter thermal cover (>2 m) for cervids, was higher in scarified (1337/ha) than in unscarified clear-cuts (1084/ha). The converse was true in lowland spruce and mixedwood forests where densities were higher in unscarified (760 and 1491/ha, respectively) than in scarified (309 and 890) clear-cuts.

Greater density and height of conifers in pine compared with spruce and mixedwood clear-cuts resulted in superior winter cover and greater use by cervids in the former, at Year 26. Similar differences were observed in abundance of grouse and snowshoe hares. Adequate winter thermal cover occurred first in both scarified and unscarified pine clear-cuts 15-20 years after logging, then in unscarified spruce and mixedwood clear-cuts at Years 25-30. Scarified clear-cuts did not provide adequate winter cover for cervids during this stage.

Moderate use of clear-cuts by bears during the period 17-32 years post-logging was associated with an abundance of insect food in rotten stumps and logs, berries such as buffalo-berry, adequate escape cover, and probably cooler summer habitats than those in younger clear-cuts.

Browse forage production peaked at about Year 17 in unscarified spruce and mixedwood clear-cuts and about Year 26 in scarified ones. Thermal and security cover influenced cervid use of clear-cuts more than forage. Blocks of mature coniferous forest, at least 100 m wide and interspersed throughout clear-cut blocks, were essential for winter cover during the first 15-20 years following logging of the pine forest and the first 25-30 years in spruce and mixedwood clear-cut areas. Where these latter clear-cuts were also scarified, then mature residual blocks interspersed among clear-cuts were needed for at least 32 years after logging.

The return of spruce grouse to pine and mixedwood clear-cuts, with the exception of the scarified mixedwood, was apparent during Years 25-32. The tall, dense stand of lodgepole pine on pine clear-cuts was no longer suitable for ruffed grouse which were increasing in abundance in mixedwood and spruce clear-cuts.

Furbearing mammals, which were depleted following logging, were increasing in abundance, especially the red squirrel that was common in all unscarified clear-cuts by Year 26. The combined abundance of five furbearers (coyote, wolf, lynx, weasel, squirrel) was 17 and 3 times greater in mature forests than in 26 year-old scarified and unscarified clear-cuts. They were also 7-9 times more abundant in mixedwood than in spruce and pine forest blocks.

Snowshoe hare abundance was high in all clear-cuts by Year 25, especially in both pine and the unscarified mixedwood clear-cuts. Hares had girdled 66% and 48% of pine trees in scarified and unscarified pine clear-cuts, respectively, by Year 26. Girdling of conifers was not noticeable within spruce and mixedwood clear-cuts.

Immature Stand (25-50 years for Pine and Mixedwood, 30-60 years for Spruce clear-cuts)

At Year 32, in pine clear-cuts, a well stocked stand of lodgepole pine averaging 7.2 and 6.4 m in height was the dominant vegetative feature, in scarified and unscarified clear-cuts, respectively. Alder, poplar and willow dominated old skid roads. Average heights of pine, poplar and willow were greater in the scarified clear-cut and this was associated with a higher density of nitrogen-fixing green alder. Girdling of 25-27 year old trees by snowshoe hares was 41% higher in the scarified pine clear-cut and this was correlated with higher hare abundance (15%), greater coniferous density (64%) and deciduous tree/shrub density (6%), and heights of pine, poplar and willow compared with those in the unscarified clear-cut. Mortality of 28 and 23% of pine in scarified and unscarified clear-cuts, respectively, was expected because of trees girdled more than 50%. Very heavy big game use (summer and winter) of young mountain ash and alpine fir trees was preventing these species from becoming a conspicuous component of this Immature Stand.

Grass cover had declined to about one-third of that at Year 5 but was still 2-4 times greater than that in the mature pine forest.

Similarly, forb cover had declined to almost one-half of that at Year 5.

Abundance of cervids was higher than during previous stages with deer being most abundant, then moose and lastly elk. At Year 32, big game abundance was greatest in unscarified clear-cuts except for the pine forest where abundance was similar in both clear-cuts. Deer comprised 55 and 81% of big game use in scarified and unscarified clear-cuts, respectively, with elk and then moose being next in abundance. Moose were more common in upland pine than in lowland spruce and mixedwood clear-cuts. Cover and forage conditions were optimal for big game in both pine clear-cuts.

Grouse were more abundant than during earlier stages and were higher in scarified than in unscarified clear-cuts. Only spruce grouse occurred within pine clear-cuts, while some ruffed grouse existed in the more open habitat adjacent to perimeter roads. Red squirrels were more abundant in both pine clear-cuts than during earlier stages.

A marked contrast existed between scarified and unscarified clear-cuts of the mixedwood forest at Year 32. The scarified clear-cut supported an aspen poplar overstory (2.5 m tall) with a light density of spruce and pine averaging 1.9 m tall. The unscarified area supported a light density of tall aspen (>10 m) that remained after logging, a lower overstory of spruce (3.2 m tall) and a lower layer of aspen/willow that was taller than in the scarified clear-cut. Density and canopy cover values of conifers tall enough (>2 m) to provide minimum winter shelter were 149/ha and 25.3% in the unscarified clear-cut, which were 67 and 500% higher than those in the scarified clear-cut. For these reasons, winter cover for cervids was inadequate in scarified and only moderately adequate in unscarified clear-cuts. Superior cover conditions in the unscarified clear-cut were reflected in deer and elk use that was 6-fold greater than in the adjacent scarified block. It was also associated with a grouse abundance that was 4-fold greater than in the scarified block. The unscarified block also had a density of 23 tree snags/ha that supported several species of tree cavity-dwelling wildlife species, compared with none in the scarified block.

Differences were less pronounced in the 32 year-old spruce forest. The average height of spruce trees was 2.1 times greater in unscarified (1.5 m) than in scarified (0.7 m) clear-cuts. The density of shelter conifers (>2 m) was 2.5 times greater, and coniferous canopy cover 5.6 times greater, in unscarified than in scarified clear-cuts. Winter shelter conditions were still inadequate even in the unscarified clear-cut as density and canopy cover values of conifers >2 m tall were only 760/ha and 3.3%. Use of the unscarified clear-cut by deer and elk was 2.5 times greater than in the scarified clear-cut. Conversely, grouse were common in the scarified clear-cut during summer but absent in the unscarified clear-cut.

Aside from the above wildlife and habitat conditions associated with the four successional stages, there were several major biophysical and human land use results of significance. These can be listed as follows:

1. Unscarified clear-cuts supported higher use of big game, furbearer, insectivorous and tree cavity-dwelling wildlife than did scarified clear-cuts.
2. Negative correlations existed between winter wildlife abundance and both wind chill and animal visibility. Positive correlations existed between winter wildlife abundance and conifer tree height, and crown closure.
3. Thermal shelter and security cover were more important than forage in dictating big game use of clear-cuts during winter.
4. Adequate winter cover (thermal and security) did not occur in unscarified clear-cuts until at least 15-20 years post logging in pine and 25-30 years in spruce and mixedwood clear-cuts. In scarified clear-cuts, this occurred at 15-20 years in pine and after 32 years in spruce and mixedwood clear-cuts.
5. Positive aspects of clear-cut logging included an increase in wildlife species characteristic of open Herb-dwarf shrub and Pole-sapling stages such as sparrows, thrushes, swallows, flycatchers and hawks, white-tailed and mule deer, elk, rodents. Cervid (deer, elk and moose) use of 17 year-old scarified and unscarified clear-cuts was 9 and 59 times greater, respectively, than in nearby mature forests.
6. Big game use of clear-cuts could have been increased further by maintaining mature, residual blocks (at least 100 m wide) until 15-20 years after logging in pine, 25-30 years in unscarified and 35-40 years in scarified spruce and mixedwood clear-cuts.
7. Tree cavity-dwelling wildlife cannot be maintained in clear-cuts unless some old age-dead trees, especially aspen, are left standing following logging. A light density (24/ha) of standing snags was adequate to sustain a variety of cavity-dwelling wildlife species.
8. Black and grizzly bears avoided clear-cuts during the first 17 years. However, between Years 25 and 32, black bears were common in all clear-cuts and their use was associated with an

abundance of insect food in the rotted stumps and logs, berries such as buffalo-berry and adequate escape cover.

9. Densities of snowshoe hares and the degree of girdling damage to conifers in clear-cuts increased directly with the density of conifers and deciduous trees and shrubs, and heights of pine and willow.
10. Although unscarified clear-cuts were more beneficial to a variety of wildlife species than were scarified clear-cuts, results from scarification varied as a result of site-specific factors.
11. Yearlong human harassment of big game, especially elk, was a major factor in preventing big game from attaining population densities that clear-cut habitats were capable of supporting.
12. Coniferous regeneration in spruce and mixedwood unscarified clear-cuts was advanced about 5-10 years over their scarified counterparts. This was due to spruce seedlings present, but not destroyed, when unscarified clear-cuts were logged and which had a major start over spruce seedlings originating after scarification.

7.0 MANAGEMENT IMPLICATIONS

1. Where continuous populations of deer, elk and moose are a forest wildlife management objective, coniferous blocks at least 100 m wide (preferably 200 m), and interspersed at distances not exceeding 200 m throughout the clear-cuts should be retained until clear-cuts provide adequate winter cover for cervids. This will occur about 15-20 years post-logging in pine, 25-30 years in unscarified and 35-40 years in scarified spruce and mixedwood clear-cuts.
2. In order to retain viable populations of tree cavity-dwelling wildlife in clear-cuts, some decadent or dead tree snags, especially those exceeding 25 cm dbh, will have to be retained. Leaving residual strips at least 100 m wide bordering lakes and major streams will help to maintain viable populations of tree cavity-dwelling species as well as big game, grouse, furbearer and song-insectivorous birds in addition to meeting watershed needs. It will not correct this problem in areas deficient in water bodies.
3. Leaving small patches of critical wildlife cover within clear-cuts can maintain small populations of wildlife species that otherwise would disappear. It will be easier to save patches of wildlife cover

than a scattering of individual trees when a forest is being logged by large machinery. The study indicated that patches of mature aspen within coniferous forests were especially important to many wildlife species. However, there is a need for sound quantitative information on the role of mature aspen to the welfare of bird and mammal species in the Alberta foothills.

4. The conversion of large tracts of mature coniferous forests to a variety of age classes by clear-cut logging can greatly enhance the abundance and species diversity of wildlife. However, several wildlife species such as elk have a low tolerance for human harassment and quickly abandon otherwise favorable habitat if subjected to continuous harassment, especially by vehicles. Minimizing human activities within clear-cuts should be a forest management objective, especially during the critical winter period for areas otherwise favorable for high-priority wildlife species that are sensitive to human harassment.
5. Where spruce forests are well-stocked with spruce seedlings before logging, consideration should be given to saving them during logging and post-logging. This study showed that coniferous regeneration in spruce and mixedwood unscarified clear-cuts was advanced about 5-10 years over their scarified counterparts because of numerous spruce seedlings and saplings that remained after logging. By not scarifying such areas, benefits accrue for both wood fibre and wildlife production.
6. Although adequate quantitative data was not obtained, this study showed that growth rates of pine, poplar and willow appeared to be associated with the density of nitrogen-fixing green alder. Studies in Alaska and Scandinavia have shown the importance of alder and other native nitrogen-fixing plant species in increasing soil nitrogen. Information on the importance of native nitrogen-fixing plants for enhancing both wood fibre growth and wildlife habitat should be determined before definitive forest management guidelines are developed for suppressing deciduous plant species. Some species that should be evaluated are green alder, buffalo-berry, vetch, peavine, hedysarum, locoweed and milk vetch.

7.0 RECOMMENDATIONS

1. Because this study focused primarily on the effects of clear-cut logging on game species and their habitats, information on non-game species is inadequate and should be strengthened during future studies, especially for high-priority mammal and bird species expected to decline under an 80-90 year forest rotation cycle. These should include the great gray owl, pileated woodpecker, siskin, crossbill, marten, fisher and flying squirrel. A Research Advisory Board should review strengths and weakenesses of this study and determine how it can be improved, or supplemented by other studies. This long-term monitoring study with its permanent plots should be protected and continued at regular 5 or 10 year intervals throughout one forest logging cycle. Comparable results should be obtained from similar forest types logged by the newer, highly mechanized system to identify differences and similarities of floral/faunal changes during forest succession following logging.
2. The importance of native nitrogen-fixing plant species for wood fibre growth and wildlife forage/habitat enhancement should be determined.
3. The recent joint program of integrated forest/wildlife management within the Weldwood of Canada Forest Management area by this forest industry and the Alberta government is a major positive milestone that deserves the continued support of public, industry and government.

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APPENDICES

Appendix 1

Field Forms for Recording 1988 Forest-Wildlife Data

Hinton Forest/Wildlife Study   Form I: Vegetation Description and Utilization Data   Date 28

Forest Mixed   Block Scar.   Sample 1   Plot Size 1 m^2 Observers [illegible]   Month 06   Year 88

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Plot Location			Species				Cover		Species				Cover		Species				Cover		Species				Cover		Species				Cover	
	Repl	Grid	Plot	Genus		Species		# Cells		Genus		Species		# Cells		Genus		Species		# Cells		Genus		Species		# Cells		Genus		Species		# Cells	
1	1	5	2	F	R	V	I	0	1	S	Y	A	L	0	3	G	A	B	O	0	1	E	L	I	N	1	6	B	R	I	N	0	2
2				A	S	A	L	T	R																								
3	1	5	1	O	X	S	P	1	5	E	R	G	L	T	R	F	R	V	I	0	1	L	A	O	C	T	R	G	A	B	O	0	1
4				A	N	M	U	T	R	A	R	U	V	8	5	E	L	I	N	0	1	B	R	I	N	0	1	S	Y	A	L	T	R
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	34	35	36	37	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
	Species				Cover									WOODY PLANTS								WOODY PLANTS								REMARKS			
	Genus Species				# Cells								#/m2		% Use		S/W	Ht. Class #			Ht. Class #			Ht. Class #			Ht. Class #						
1																																	
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Hinton Forest/Wildlife Study Form 2: Wildlife Habitat Quality

Date 3/8/88 Forest SPRUCE Block UNSC. Sample 1 Observers Stelfox/Lapointe Plot Sizes 10m² for conifers, 25m² for pellets, 50m² for snags

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Plot				Pellet Groups					Tree Spp.				Coniferous Shelter (#/height class)												Shelter Canopy Diameter Class							
														cm 0-20	21-40	41-60	61-80	81-100	meters 1-2	2-3	3-4	4-6	6-8	8-10	>10								
	Rep	Grid	Plot	D	E	M	H	G	C	Genus		Species		1	2	3	4	5	6	7	8	9	10	11	12	Tree 1		Tree 2		Tree 3		Tree 4	
1	1	1	1	1				1		P	1	G	L		1	1	1	1	1		1					0.	5	1.	4	1.	0	0.	3
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	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
	Shelter		Cover Visibility									Trees					CAVITY-DWELLING WILDLIFE Snag Cavities											Wildlife Use				Remarks	
	# Conifers		1	2	3	4	5	Genus		Species		#	Height Class		Diameter cm		Condition	# Cav.	Height Class		Diameter cm		Height Class		Diameter cm		Y/N	Genus		Species			
1	0	4	2	3	2	3	5	none																									
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Hinton Forest/Wildlife Study Form 3: Browse Production and Use

Forest PINE Block SCAR. Sample 2 Observers Stelfox / Lapointe

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23		
	Date						Plot			Browse Species				Green Weight (gms)											
	Day		Month		Year		Rep	Grid	Plot	Genus		Species		Leaf			Stem			Total					
1	2	4	0	8	8	8	1	1	1	V	I	E	D			3			4				7		
2							1	1	6	R	O	A	C			1			1				2		
3							1	3	4	S	A	S	P	1	0	0		6	0		1	6	0		
4										R	O	A	C			1			1				2		
5										V	I	E	D			4			6			1	0		
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	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	Dry Weight (gms)										Utilization			Utilization (gms)									Remarks		
	Leaf			Stem				Total			Percent			Leaf		Stem				Total					
1															0			0				0			
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Appendix 2

Names and Symbols of Plant and Animal Species

on Forest/Wildlife Plots: 1956-1988

Common and Scientific Names Follow These References:

Plants: The Flora of Alberta, 2nd edition, 1983. by E. H. Moss and J. G. Packer.

Mammals: The Mammals of Canada. 1974 by A. W. F. Banfield. National Museum of Canada. Univ. of Toronto Press.

Birds: The American Ornithologist's Union Checklist of North American Birds, Sixth Edition. Allen Press, Inc. Lawrence, Kansas.

NAMES AND SYMBOLS FOR PLANT SPECIES ON HINTON FOREST/WILDLIFE PLOTS 1956-1988 (after Flora of Alberta, Moss, 1983).

SCIENTIFIC NAME	COMMON NAME	SYMBOL	LOCATION SP	LOCATION Pi	LOCATION Mi*	Months in Bloom	
		FORBS					
Achillea millifolium	Common Yarrow	AC MI	√		√	Jun	Jul
Actaea rubra	Red and White baneberry	AC RU		√		Jun	
Agoseris glauca	False Dandelion	AG GL	√	√	√	May	Jun
Alyssum murale	Alyssum	AL MU					
Anaphalis margaritacea	Pearly Everlasting	AN MA			√		Jul
Androsace chamaejasme	Sweet-scented Androsace	AN CH	√			May	Jun
Androsace spp.	Fairy Candelabra	AN SP					
Anemone multifida	Cut-leaved Anemone	AN MU	√		√	May	Jun
A. parviflora	Anemone	AN PA	√			May	Jun
Antennaria pulcherrima	Showy Everlasting	AN PU	√				Aug
Aquileja brevistyla	Blue Columbine	AQ BR	√		√	Jun	
Aralia nudicaulis	Wild Sasparilla	AR NU		√		May	Jun
Arnica spp.	Arnica	AR SP	√	√	√	Jun	Jul
Aster conspicuus	Showy Aster	AS CO	√		√	Jul	Aug
A. ciliolatus	Lindley's Aster	AS CI	√		√	Jul	Aug
A. sibiricus	Low Aster	AS SI	√			Jul	Aug
Aster spp.	Aster	AS SP	√				Aug
Astragalus alpinus	Alpine Milk Vetch	AS AL	√		√	May	Jun
A. drummondii	Drummond's Vetch	AS DR					
A. frigidus/americanus	American Milk Vetch	AS FR	√		√	Jun	Jul
A. striatus	Milk Vetch	AS ST	√			Jun	Jul
Botrychium boreale/lunaria	Moon Wort	BO BO	√		√	Jun	Jul
Braya richardsonii/humilus	Braya	BR RI					
Campanula rotundifolia	Harebell	CA RO	√	√	√	Jun	Jul
Castilleja miniata	Indian Paint-brush	CA MI	√	√	√	Jun	Jul
Cerastium spp.	Mouse-eared Chickweed	CE SP	√		√	Jun	
Chenopodium album	Lamb's quarter	CH AL					
Comandra pallida	Bastard Toad-flax	CO PA					
Cornus canadensis	Bunchberry	CO CA	√	√	√	Jun	
Cypripedium calceolus	Yellow Lady's Slipper	CY CA	√			Jun	
C. passerinum	Sparrow's Egg Lady's Slipper	CY PA	√	√		Jun	
Delphinium glaucus	Tall Larkspur	DE GL			√		
Disporum trachycarpum	Fairy Bells	DI TR		√		Jun	
Dodecatheon radicatum	Shooting Star	DO RA			√	Jun	
Draba sp.	Whitlow Grass	DR SP	√			Jun	
Epilobium angustifolium	Fireweed	EP AN	√	√	√	Jun	Jul
Equisetum arvense	Field Horsetail	EQ AR	√	√	√		
Equisetum spp.	Horsetail	EQ SP	√	√	√		
Erigeron caespitosus	Tufted Fleabane	ER CA	√		√	Jun	
E. glabellus	Smooth Fleabane	ER GL	√		√	Jun	
E. ochroleucus	Fleabane	ER OC					

E philadelphicus	Fleabane	ER PH					
Fragaria vesca/virginiana	Wild Strawberry	FR VI	√	√	√	Jun	
Galium boreale	Northern Bedstraw	GA BO	√		√	May	Jun
G. triflorum	Sweet-scented Bedstraw	GA TR		√		Jun	
Gentianella amarella	Felwort	GE AM				Jul	Aug
G. crinata	Fringed Gentian	GE CR		√	√	Jul	
Geocaulon lividum	Bastard Toad-flax	GE LI	√		√	Jul	
Geranium bicknellii	Crane's Bill	GE BI		√		Jun	Jul
Geum rivale	Purple Avens	GE RI		√		Jun	
Goodyera repens	Rattling Plantain	GO RE	√				Aug
Habenaria hyperborea	Northern Green Bog Orchid	HA HY	√			Jun	
H. obtusata	Blunt-leaved Orchid	HA OB	√				
H. viridus	Bracted Orchid	HA VI	√			Jun	
Hedysarum alpinum	Hedysarum	HE AL	√			Ju,	
H. mackenzii/boreale	Indian Potatoe	HE MA	√	√	√	May	Jun
Heracleum lanatum	Cow Parsnip	HE LN		√		Jul	
Heuchera flabellifolia/parvifolia	Alum-root	HE FL					
Hieraceum umbellatum	Narrow-leaved Hawkweed	HI UM					
Lathyrus ochroleucus	Wild Pea	LA OC			√	Jun	Jul
Lilium philadelphicum	Western Wood Lily	LI PH	√	√	√	Jun	
Linnaea borealis	Twin flower	LI BO	√	√	√	Jun	
Luzula parviflora	Wood Rush	LU PA	√			Jul	Aug
Maianthemum canadense	Wild Lily-of-the-Valley	MA CA		√		Jun	
Matricaria matricarioides	Pineapple Weed	MA MA					
Mertensia paniculata	Tall Mertensia	ME PA	√		√	Jun	
Mitella nuda	Bishop's-cap	MI NU		√			
Moneses uniflora	One-flowered Wintergreen	MO UN					
Orchis rotundifolia	Round-leaved Orchid	OR RO	√			Jun	
Orthilia secunda	One-sided Wintergreen	OR SE	√		√	Jun	
Oxycoccus microcarpus	Small Bog Cranberry	OX MI		√			
Oxytropis splendens	Showy Loco-weed	OX SP	√		√	Jun	
O. monticola	Late Yellow Loco-weed	OX MO	√			Jul	
Parnassus fimbreata	Grass-of Parnassus	PA FI	√		√	Jul	
Pedicularis bracteosa	Bracted Lousewort	PE BR		√		Jun	
Petasites spp.	Coltsfoot	PE SP					*
Petasites palmatus	Palamate-leaved Coltsfoot	PE PA	√	√		Jul	
Plantago major	Common Plantain	PL MA					
Polygonum viviparum	Bistort	PO VI	√				•
Potentilla anserina	Silverweed	PO AN	√			Jun	
P norvegica	Rough Cinquefoil	PO NO		√		Jun	Jul
Pulsatilla occidentalis	Chalice-flower	PU OC					
Pulsatilla spp.	Anemone	PU SP					
Pyrola asarifolia	Common Pink Wintergreen	PY AS	√	√		Jul	
Pyrola spp.	Wintergreen	PY SP	√	√		Jul	
Ranunculus acris	Tall Buttercup	RA AC		√		Jun	
Rubus acaulis	Dwarf Raspberry	RU AC		√		Jun	
R. pubescens	Dewberry	RU PU	√	√		Jun	
R. stigosus	Wild Raspberry	RU ST		√		Jun	
Senecio palustris	Marsh Ragwort	SE PA	√			Jun	
S. pseudaureus	Thin-leaved Ragwort	SE PS			√	Jun	
Senecio spp.	Groundsel	SE SP					
Sisyrinchium montanum	Blue-eyed Grass	SI MO			√	Jun	
Smilacina racemosa	False Solomon's-seal	SMRA					

S. stellata	Star-flowered Solomon's seal	SM ST*	√			Jun□
Solidago spp.	Goldenrod	SO SP	√			Jul Aug
S. decumbens/spathulata	Mountain Goldenrod	SO DE	√	√		Jun Jul
S. gigantea	Tall Smooth Goldenrod	SO GI	√			Jul Aug
Sonchus arvensis	Sow thistle	SO AR	√			Jul Aug
Spiraea lucida/betulifolia	White Meadowsweet	SP LU			√	Jun
Spiranthus romanzoffiana	Ladies'-tresses	SP RO				Jul
Stellaria longipes	Long-leaved Chickweed	ST LO				
S. longifolia	Long-stalked Chickweed	ST LF			√	Jun
Streptopus amplexifolius	Twisted-stalk	ST AM		√		Jun
Symphoricarpus albus	Snowberry	SY AL				
Taraxacum officianale	Dandelion	TA OF	√	√	√	May Jun
Thalictrum venulosum	Veiny Meadow Rue	TH VE		√		June
Tofieldia glutinosa	Sticky Asphosel	TR GL	√			Jul
Trifolium pratense	Common Red Clover	TR PR	√	√	√	Jun
T. repens	White Dutch Clover	TR RE			√	Jun
Veronica spp.	Speedwell	VE SP				May
Vicia americana	American Vetch	VI AM			√	Jun
Viola renifolia	Kidney-leaved Violet	VI RE		√		Jun
Viola spp.	Violet	VI SP			√	●
Zizia cordata	Heart-leaved Alexanders	ZI CO			√	Jun
Zygadenus elegans	Smooth Camas	ZY EL	√	√		Jun
Unknown Forb	Forb	UN FO				

* SP = Spruce Pi = Pine Mi = Mixedwood

• Persicaria natans is Polygonum viviparum

* Virtually all Petasites spp. in 1988 was P. palmatus

□ In Camp 9 this is actually Smilacina racemosa

● Includes both Viola canadense and V. renifolia

GRAMINOIDS (Grasses and Sedges)

Agropyron spicatum	AG SP	Deschampsia caespitosa	DE CA
A. subsecundum	AG SU	Elymus innovatus	EL IN
A. trachycaulum	AG TR	Festuca rubra	FE RU
Agrostis alba	AG AL	Festuca spp.	FE SP
A. scabra	AG SC	Glyceria striata	GL ST
Bromus inermis	BR IN	Juncus balticus	JU BA
Bromus spp.	BR SP	Juncus spp.	JU SP
Calamagrostis canadensis	CA CA	Phleum pratense	PH PR
C. montanensis	CA MO	P. alpinum	PH AL
Carex aurea	CA AU	Poa palustris	PO PA
C. capillaria	CA CP	P. spp.	PO SP
C. eburnea	CA EB	P. pratense	PO PR
Carex spp.	CA SP	Unknown grass	UN GR

TREES AND SHRUBS (Browse plants)

Abies lasiocarpa	AB LA	Potentilla fruticosa	PO FR
Alnus crispa	AL CR	Prunus pensylvanica	PR PE
Amelanchier alnifolia	AM AL	Ribes oxycanthoides	RI OX
Arctostaphylos uva-ursi	AR UV*	R. triste	RI TR
Betula glandulosa	BE GL	Rosa acicularis	RO AC
B. papyrifera	BE PA	Rubus acaulis	RU AC
B. occidentalis	BE OC	R. pubescens	RU PU *
Cornus stolonifera	CO ST	R. strigosus/idaeus	RU ST
Juniperus communis	JU CO*	Salix spp.	SA SP
J. horizontalis	JU HO	Sambucus racemosa	SA RA
Lonicera dioica	LO DI	Shepherdia canadensis	SH CA
L. involucrata	LO IN	Sorbus scopulina	SO SC
Picea glauca	PI GL	Symphoricarpus albus	SY AL*
Pinus contorta	PI CO	Vaccinium caespitosum	VA CA*
Populus balsamifera	PO BA	Viburnum edule	VI ED
P. tremuloides	PO BA	Unknown Browse	UN BR

* These species were included in forbs category for purposes of density/cover analysis because of decumbent growth form.

LICHENS, MOSSES AND FERNS

LICHENS

Peltigera apthosa	PE AP
Cladonia spp.	CL SP

MOSSES

Hylocomium splendens	HY SP
Pleurozium schreberi	PL SC

FERNS

Gymnocarpium dryopteris	GY DR

COMMON AND SCIENTIFIC NAMES OF MAMMALS AND BIRDS IDENTIFIED IN THE STUDY

Common Name	Scientific Name	Common Name	Scientific Name
MAMMALS			
Snowshoe Hare	Lepus americanus	Elk (Wapiti)	Cervus elaphus
Red-backed Vole	Clethrionomys gapperi	Moose	Alces alces
Heather Vole	Phenacomys intermedius	Mule Deer	Odocoileus hemionus
Meadow Vole	Microtus pennsylvanicus	White-tailed Deer	Odocoileus virginianus
Deer Mouse	Peromyscus maniculatus	Caribou	Rangifer tarandus
Coyote	Canis latrans	Cougar	Felis concolor
Red Fox	Vulpes vulpes	Black Bear	Ursus americanus
Grey Wolf	Canis lupus	Grizzly Bear	Ursus arctos
Canada Lynx	Lynx canadensis	Marten	Martes americana
Least Weasel	Mustela nivalis	Fisher	Martes pennanti
Ermine	Mustela erminea	Red Squirrel	Tamiasciurus hudsonicus
Least Chipmunk	Eutamias minimus	N. Flying Squirrel	Glaucomys sabrinus
Big Brown Bat	Eptesicus fuscus		
BIRDS			
Spruce Grouse	Dendragopus canadensis	Common Goldeneye	Bucephala clangula
Blue Grouse	Dendragopus obscurus	Bufflehead	Bucephala albeola
Ruffed Grouse	Bonasa umbellus	Hooded Merganser	Lophodytes cucullatus
Sharp-tailed Grouse	Tympanunchus phasianellus	Gray Jay	Perisoreus canadensis
American Kestrel	Falco sparverius	Black-billed Magpie	Pica pica
Merlin	Falco columbarius	Common Raven	Corvus corax
Swainson's Hawk	Buteo swainsonii	Swainson's Thrush	Hylocichla ustulata
Northern Goshawk	Accipiter gentilis	Hermit Thrush	Hylocichla guttata
Black-capped Chickadee	Parus atricapillus	American Robin	Turdus migratorius
Boreal Chickadee	Parus hudsonicus	Cedar Waxwing	Bombycilla cedorus
Red-breasted Nuthatch	Sitta canadensis	European Starling	Hurnus vulgaris
White-breasted Nuthatch	Sitta carolinensis	Warbling Vireo	Vireo gilvus
Tree Swallow	Tachycineta bicolor	Red-eyed Vireo	Vireo olivaceus
Violet-green Swallow	Tachycineta thalassina	Orange-crowned Warbler	Vermivora celata
House wren	Troglodytes aedon	Yellow-rumped Warbler	Dendroica cononata
Golden-crowned Kinglet	Rugulus satrapa	Magnolia Warbler	Dendroica magnolia
Ruby-crowned Kinglet	Regulus calendula	Black-and-White Warbler	Miniotilta varia
Mountain Bluebird	Sialia curricoides	Yellow Warbler	Dendroica petechia
Fox Sparrow	Passerella iliaca	Red Crossbill	Loxia curvirosta
Song Sparrow	Melospiza melodia	Purple Finch	Carpodacus purpureus
Lincoln's Sparrow	Melospiza lincolnii	Pine Siskin	Carduelis pinus
White-crowned Sparrow	Zonotrichia leucophrys	Northern Flicker	Colaptes auratus
White-throated Sparrow	Zonotrichia albicollis	Downy Woodpecker	Picoides pubeceus
American Tree Sparrow	Spizella arborea	Hairy Woodpecker	Picoides villosus
Chipping Sparrow	Spizella passerina	Three-toed Woodpecker	Picoides tridactulus
Vesper Sparrow	Pooecetes gramineus	Yellow-bellied Sapsucker	Sphyrapicus varius
Dark-eyed Junco	Junco hyemalis	Say's Phoebe	Sayornis saya
Common Loon	Gavia immer	Alder Flycatcher	Empidonax alnorum
Northern Saw-whet Owl	Aegolius acadicus	Willow Flycatcher	Empidonax traillii
Boreal Owl	Aegolius funereus	Yellow-bellied Flycatcher	Empidonax flaviventria
Great Gray Owl	Strix nebulosa	Western Wood-Pewee	Contopus sordidulus
Common Nighthawk	Chordeiles minor	Rufous Hummingbird	Selasphorus rufus
Killdeer	Charadrius vociferus	Belted Kingfisher	Ceryle alcyon
Solitary Sandpiper	Tringa solitaria		
Upland Sandpiper	Bartramia longicauda		
Common Snipe	Gallinago gallinago		

Appendix 3

Statistical Analyses of 1988 Forest-Wildlife Data

Comparison of values among three forest types (Mixedwood, Pine, Spruce) using combined scarified and unscarified data for the following comparisons:

1. Percent Cover (Grasses and Forbs)
2. Deciduous Browse Density
3. Tree Snag Density
4. Coniferous and Deciduous Tree Cover (Shelter and Security Cover)
5. Coniferous Density
6. Wildlife Abundance (Pellet Groups/Ha)

Table 1. Random block design analysis (SPSS - x Release for IBM/MTS) of differences in foliage cover of grasses and forbs, density of deciduous browse and snags among three forest types* (mixedwood, pine, spruce) 32 years after logging.

	MIXEDWOOD (X)	PINE (Y)	SPRUCE (Z)	STANDARD ERROR OF THE MEAN
FORBS (% cover)	18.73. a**	25.22 a	26.75 a	± 1.653
GRASSES (% cover)	16.97 a	19.53 a	19.67 a	± 2.895
BROWSE (Density/Ha)	46425 a	39050 a	45625 a	± 6111.073
PLANT SPECIES***				
	GRASS, FORB AND MAT-LIKE SHRUB COVER			
AR UV	6.33 a	0.21 b	12.47 c	± 0.779
Aster sp.	0.90 a	2.04 b	1.01 a	± 0.260
Astrag sp./HE SP/OX SP	0.84 a	0.0 a	3.11 b	± 0.152
EP AN	0.49 a	7.99 b	0.18 a	± 0.570
FR VI	2.46 a	0.54 a	0.69 a	± 0.258
JU CO + JU HO	0.0 a	0.0 a	2.62 a	± 0.560
LIBO	0.42 a	2.18 b	2.05 b	± 0.107
VI AM + LA OC	1.65 a	0.09 b	0.00 b	± 0.167
BR IN + BR SP	5.07 a	0.01 b	2.26 b	± 0.456
CA CA + CA MO	0.0 a	8.70 b	0.22 a	± 0.138
CAREX	0.48 a	0.04 a	3.37 a	± 0.915
EL IN	11.03 a	10.72 a	13.39 a	± 3.752
	DECIDUOUS TREE DENSITIES			
POPLAR	3400.00 a	2250.00 a	3950.00 a	± 425.245
ROSE	29300.00 a	23375.00 a	32575.00 a	± 9881.559
SA SP	500.00 a	975.00 a	4850.00 b	± 262.599
	SNAGS			
15-30 cm diam.	13.00 a	11.00 a	9.67 a	± 4.290
31+ diam	3.33 a	4.00 a	2.00 a	± 0.943
Total snags	16.33 a	15.00 a	11.67 a	± 3.706
Cavities	10.33 a	4.00 a	10.33 a	± 4.320
	DECIDUOUS BROWSE			
Poplar	161.50 a	173.50 a	252.50 a	±65.962
Willow	7.50 a	118.50 a	403.50 a	± 4.041
Rose	60.50 a	53.50 a	122.50 a	± 16.258
Total browse	292.50 a	1093.00 a	877.00 a	± 175.810

* Scarified and unscarified data was combined for each forest; mature data was not used.

** Xa Ya Za = not significantly different from each other.
Xa Ya Zb = X and Y are significantly different from Z.
Xa Yb Zc = X, Y, and Z are all significantly different from each other.

*** See appendix 2 for common and scientific names of these symbols.

Table 2. Random block design analysis (SPSS-x Release for IBM/MTS) of differences in coniferous, deciduous, and total tree cover; canopy closure (shelter) and security (hiding) cover* among three forest types, 32 years after logging.

	MIXEDWOOD	PINE	SPRUCE	SE OF $\overline{X}$
		CONIFEROUS COVER		
Ht. classes 1 - 7	1904.67 a	156.50 a	6585.00 a	±1229.999
Ht. classes 8	281.67 a	71.50 a	126.00 a	± 72.276
Ht. classes 9 - 10	604.33 a	607.25 a	147.50 a	± 157.476
Ht. classes 11 - 12	264.33 a	482.00 a	34.00 a	± 107.979
Ht. classes 8 - 12	1150.33 a	1160.75 a	307.50 a	± 331.604
Total Coniferous	3055.00 a	1317.25 a	6892.50 a	±1252.051
		DECIDUOUS COVER		
Ht. classes 1 - 7	48916.66 a	37375.00 a	44550.00 a	±5498.452
Ht. classes 8	300.00 b	800.00 a	525.00 ab	± 65.670
Ht. classes 9 - 10	516.67 a	750.00 a	550.00 a	± 149.16
Ht. classes 11 - 12	316.67 a	125.00 a	0.00 a	± 101.550
Ht. classes 8 - 12	1133.33 a	1675.00 a	1075.00 a	± 206.761
Total Deciduous	50050.00 a	39050.00 a	45625.00 a	±5691.527
		TOTAL TREE COVER		
Ht. classes 1 - 7	50821.33 a	37531.50 a	51135.00 a	±4622.219
Ht. classes 8	581.67 a	871.50 a	651.00 a	± 126.269
Ht. classes 9 - 10	1121.00 a	1357.25 a	697.50 a	± 201.440
Ht. classes 11 - 12	581.00 a	607.00 a	34.00 a	± 204.973
Ht. classes 8 - 12	2283.67 a	2835.75 a	1382.50 a	± 498.331
Total Cover	53105.00 a	40367.25 a	52517.50 a	±5020.853
		CANOPY CLOSURE (SHELTER)		
Ht. classes 1 - 7	2253.29 a	329.89 a	1368.23 a	± 416.863
Ht. classes 8	474.45 a	233.28 a	48.23 a	± 185.543
Ht. classes 9 - 10	982.59 a	2313.80 a	53.58 a	± 464.031
Ht. classes 11 - 12	450.28 a	1591.26 a	19.18 a	± 312.717
Ht. classes 8 - 12	1907.32 a	4138.34 a	121.00 a	± 944.385
Total Canopy Cover	4160.55 a	4468.19 a	1489.20 a	±1306.273
Total Security	277.60 a	4468.19 a	317.20 a	± 51.053
		CONIFEROUS DENSITY		
Spruce	2761.67 a	145.00 a	6892.50 a	± 1383.529
Pine	291.33 a	1168.00 b	0.0 c	± 170.662
ToTal Conifers	3053.00 a	1317.25 a	6892.50 a	±1252.002

SECURITY (Hiding) COVER

	Scarified	Unscarified	Mature
Mixed	59.25 a	125.80 b	105.53 b
Pine	128.30	131.90 a	-
Spruce	99.43 a	112.03 b	104.20 c

* Scarified and unscarified values were combined and comparisons made among forest types except for Security (hiding) cover where comparisons were also among scarified, unscarifed and mature as well as among three forest types.

Table 3. Random block design analysis (SPSS-x Release for IBM/MTS) of differences in abundance of deer, elk, moose, snowshoe hare, grouse, and coyote among three forest types, (mixedwood, pine, spruce)32 years after logging.

WILDLIFE SPECIES		MIXEDWOOD	PINE	SPRUCE	S.E OF $\bar{x}$
WILDLIFE PELLET GROUPS/Ha					
Deer	- Summer	10.00 a	31.00 a	38.00 a	± 9.534
	- Winter	14.00 a	63.00 a	164.00 b	± 23.372
	- Total	24.00 a	94.00 a	202.00 b	± 23.642
Elk	- Summer	0.0 a	0.0 a	17.00 a	± 3.381
	- Winter	1.33 a	2.00 a	22.00 b	± 2.503
	- Total	1.33 a	2.00 a	39.00 b	± 5.462
Moose	- Summer	- (0)	- (0)	- (0)	-
	- Winter	0.0 a	24.00 b	0.0 a	± 2.898
	- Total	0.0 a	24.00 b	0.0 a	± 2.898
Hares	- Total	2448.00 a	1003.00 a	34.0 a	±1279.236
Grouse	- Total	57.33 a	182.00 a	11.00 a	± 46.441
Coyote	- Total	- (0)	- (0)	- (0)	-

MTS ANOVA Analyses of 1988 Data After Pooling Plot Data Into Five, 20 Plot Blocks of Data

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Specifics of Data Input

1) Security (escape) Cover data (Vegetative Profile Board) - Data lumped into 3 height classes:
   Ht. 1 = Classes 1 and 2 = <1 m
   Ht. 2 = Classes 3 and 4 = 1-2 m
   Ht. 3 = Class 5 = 2-2.5 m

2) Snag Density - Density of dead and decadent tree snags of 2 diameters at breast height (dbh), namely: 15-30 cm dbh, >30 cm dbh.
   Also density of cavities per hectare.

3) Coniferous Canopy Closure (Thermal/Shelter cover) - Data lumped into 5 height classes:
   Ht. 1 = ≤3 m = Height classes 1- 7;
   Ht. 2 = 3-4 m = Height classes 8;
   Ht. 3 = 4-8 m = Height classes 9 and 10;
   Ht. 4 = 8-10+ m = Height classes 11 and 12;
   Ht. 5 = 3-10+ m = Height classes 8 and 12.

4) Deciduous Tree/Shrub Density - total, poplar, willow, rose, others. Data lumped into the same 5 height classes as shown above.

5) Forest Types - Forest 1 = Mixedwood, Forest 2 = Pine, Forest 3 = Spruce.

6) Scar vs Scar = Scarified Sample 1 vs Scarified Sample 2;
   Unsc vs Unsc = Unscarified Sample 1 vs Unscarified Sample 2;
   Scar vs Unscar = Scarified Ave vs Unscarified Ave.

7)

Mean 1	Mean 2	Mean 3	
a	b	a	Mean 2 is different from Means 1 and 2;
ab	a	b	Mean 1 in not different from 1 or 2, but Means 2 and 3 are different from each other;
a	b	c	All are different from each other.

Table 4 a. ANOVA of big game security (escape) cover in 32 year-old clear-cuts.

Clear-cut Types	Height✓ Classes	MIXEDWOOD Mean 1	Mean 2	Sig.** Level	PINE Mean 1	Mean 2	Sig. Level	SPRUCE Mean 1	Mean 2	Sig. Level
Scar vs Scar	Total	Only			74.68	79.46	0.540	62.26	57.06	0.599
	Ht. 1	Sample			83.00	85.98	0.408	78.32	66.34	0.137
	Ht. 2	1			70.34	75.34	0.624	55.68	51.68	0.680
	Ht. 3	Available			66.66	74.68	0.495	41.32	49.32	0.513
Unsc vs Unsc	Total	only			79.06	79.20	0.976	69.58	64.80	0.417
	Ht. 1	Sample			79.00	82.34	0.532	78.34	78.66	0.938
	Ht. 2	2			79.00	77.00	0.737	66.32	57.00	0.235
	Ht. 3	Available			79.34	77.34	0.737	58.66	52.68	0.470
Scar vs unsc	Total	35.60	73.48	0.00*	77.07	79.13	0.480	59.66	67.19	0.167
	Ht. 1	43.68	76.74	0.01*	84.49	80.67	0.230	72.33	78.50	0.411
	Ht. 2	29.32	71.34	0.01*	72.84	78.00	0.196	54.18	61.66	0.293
	Ht. 3	32.00	71.20	0.01*	70.67	78.34	0.205	45.32	55.67	0.174

Table 4 b. ANOVA of big game security cover values among three forest type clear-cuts (32 year-old).

Clear-cut Types	Height ✓ Classes	MIXEDWOOD Mean 1	PINE Mean 2	SPRUCE Mean 2	Sig. Level
Scarified	Total	35.60 a	77.07 b	59.66 c	0.0091*
	Ht. 1	43.68	84.49	72.33	0.0948
	Ht. 2	29.32 a	72.84 b	54.18 c	0.0075*
	Ht. 3	32.00 a	70.67 b	45.32 c	0.0119*
Unscarified	Total	73.48 ab	79.13 a	67.19 b	0.0088*
	Ht. 1	76.74	80.67	78.50	0.2133
	Ht. 2	71.34 ab	78.00 a	61.66 b	0.0246*
	Ht. 3	71.20 a	78.34 a	55.67 b	0.0031*

* the means are significantly different at 95% level (p<.05)

✓ Ht 1 = <1 m, Ht 2 = 1-2 m, Ht 3 = 2-2.5 m

Table 5a. ANOVA of snag densities within each forest.

Clear-cut Types	dbh[√] (cm)	MIXEDWOOD Mean 1	MIXEDWOOD Mean 2	MIXEDWOOD Sig. Level	PINE Mean 1	PINE Mean 2	PINE Sig. Level	SPRUCE Mean 1	SPRUCE Mean 2	SPRUCE Sig. Level
Scar vs Scar	Total		Only		0	30.00	0.05*	0	0	1.00
	15-30		Sample		0	24.00	0.10	0	0	1.00
	31+		1		0	6.00	0.17	0	0	1.00
	Cavities		Available		0	2.00	0.35	0	0	1.00
Unsc vs Unsc	Total	24.00	22.00	0.817	32.00	54.00	0.140	32.00	12.00	0.030*
	15-30	14.00	8.00	0.305	20.00	42.00	0.084	28.00	10.00	0.070
	31+	10.00	14.00	0.608	12.00	12.00	1.000	4.00	2.00	0.545
	Cavities	12.00	22.00	0.419	8.00	6.00	0.545	8.00	6.00	0.724
Scar vs unsc	Total	0	23.00	0.001*	15.00	43.00	0.271	0	22.00	0.159
	15-30	0	11.00	0.016*	12.00	31.00	0.364	0	19.00	0.169
	31+	0	12.00	0.037*	3.00	12.00	0.096	0	3.00	0.096
	Cavities	-	-	-	-	-	-	-	-	-

Table 5b. ANOVA of snag densities among the forests.

Clear-cut Types	dbh[√] (cm)	MIXEDWOOD Mean 1	PINE Mean 2	SPRUCE Mean 3	Sig. Level
Scarified	Total	0	15.00	0	0.3081
	15-30	0	12.00	0	0.3081
	31+	0	3.00	0	0.3081
	Cavities	0	1.00	0	0.3081
Unscarified	Total	23.00	43.00	22.00	0.2935
	15-30	11.00	31.00	19.00	0.3643
	31+	12.00 a	12.00 a	3.00 b	0.0247*
	Cavities	17.00	7.00	7.00	0.1548

* the means are significantly different
√ diameter (cm) of snag at breast height

Table 6a. ANOVA of canopy closure within each 32 year-old forest type.

Clear-cut Types	Height Classes	MIXEDWOOD Mean 1	MIXEDWOOD Mean 2	MIXEDWOOD Sig. Level	PINE Mean 1	PINE Mean 2	PINE Sig. Level	SPRUCE Mean 1	SPRUCE Mean 2	SPRUCE Sig. Level
Scar vs Scar	Total				5183.6	3889.6	0.406	1866.3	858.7	0.006*
<3 m	Ht. 1	Only			208.4	87.0	0.107	1830.2	844.3	0.021*
3-4 m	Ht. 2	Sample			282.7	142.2	0.058	10.9	5.7	0.417
4-8 m	Ht. 3	1			2447.6	2526.9	0.932	25.3	8.5	0.186
8-10 m	Ht. 4	Available			2245.0	1133.5	0.154	0	0	1.000
3-10+ m	Ht. 5				4975.2	3802.6	0.436	36.2	14.2	0.239
Unsc vs Unsc	Total	1403.6	6295.1	0.002*	3761.7	4132.4	0.394	1598.5	2285.2	0.247
<3 m	Ht. 1	984.3	2886.7	0.007*	544.8	343.9	0.339	1249.8	2082.1	0.124
3-4 m	Ht. 2	75.9	827.3	0.009*	288.6	206.5	0.310	137.3	96.8	0.470
4-8 m	Ht. 3	211.0	1669.7	0.002*	2214.3	1840.6	0.194	147.3	88.6	0.270
8-10 m	Ht. 4	132.4	911.4	0.045*	714.1	1743.4	0.022*	71.1	17.8	0.059
3-10+ m	Ht. 5	419.3	3401.8	0.008*	3216.9	3790.5	0.299	348.6	203.1	0.244
Scar vs Unsc	Total	1893.4	3849.4	0.080	4536.6	3947.1	0.473	1362.5	1941.8	0.442
<3 m	Ht. 1	1210.5	1935.5	0.273	147.7	444.4	0.127	1337.3	1665.9	0.661
3-4 m	Ht. 2	83.5	451.6	0.036*	212.5	247.6	0.708	8.3	117.0	0.034*
4-8 m	Ht. 3	233.4	940.4	0.031*	2487.2	2027.4	0.138	16.9	118.0	0.081
8-10 m	Ht. 4	56.6	521.9	0.034*	1689.2	1228.7	0.605	0	44.5	0.237
3-10+ m	Ht. 5	373.8	1910.6	0.028*	4388.9	3503.7	0.308	25.2	275.9	0.076

Table 6b. ANOVA of canopy closure of 32 year-old clear-cuts among three forest types.

Clear-cut Types	Height Classes	MIXEDWOOD Mean 1	PINE Mean 2	SPRUCE Mean 3	Sig. Level
Scarified	Total	1893.4 a	4536.6 b	1362.5 a	0.0178*
<3 m	Ht. 1	1210.5	147.7	1337.3	0.0608
3-4 m	Ht. 2	83.5 a	212.4 a	8.3 a	0.0379
4-8 m	Ht. 3	233.4 a	2487.2 b	16.9 c	0.000*
8-10 m	Ht. 4	56.6 a	1689.2 a	0 a	0.0337
3-10+ m	Ht. 5	373.8 a	4388.9 b	25.2 a	0.0028*
Unscarified	Total	3849.3	3947.0	1941.8	0.5930
<3 m	Ht. 1	1935.5	444.4	1665.9	0.3149
3-4 m	Ht. 2	451.6	247.5	117.0	0.6056
4-8 m	Ht. 3	940.4	2027.4	118.0	0.1149
8-10 m	Ht. 4	521.9	1228.7	44.5	0.2252
3-10+ m	Ht. 5	1910.5	3503.7	275.9	0.1704

* the means are significantly different

Table 7a. ANOVA of conifer density (thermal shelter) within each forest.

Clear-cut Types	Height Classes	MIXEDWOOD Mean 1	MIXEDWOOD Mean 2	MIXEDWOOD Sig. Level	PINE Mean 1	PINE Mean 2	PINE Sig. Level	SPRUCE Mean 1	SPRUCE Mean 2	SPRUCE Sig. Level
Scar vs Scar	Total				1714	752	0.040*	17000	5004	0.072
<3 m	Ht. 1	Only			74	18	0.037*	16790	4920	0.078
3-4 m	Ht. 2	Sample			98	26	0.007*	60	32	0.400
4-8 m	Ht. 3	1			816	482	0.193	150	52	0.137
8-10 m	Ht. 4	Available			4726	226	0.335	0	0	1.000
3-10+ m	Ht. 5				1640	734	0.045*	210	84	0.191
Pine					1618	710	0.061	0	0	1.000
Spruce					96	40	0.416	17000	5004	0.072
Unsc vs Unsc	Total	1706	3068	0.090	1298	1264	0.861	2020	6584	0.049*
<3 m	Ht. 1	1216	1556	0.449	220	106	0.291	1624	6052	0.045*
3-4 m	Ht. 2	88	430	0.009*	96	64	0.203	148	264	0.211
4-8 m	Ht. 3	246	852	0.000*	744	560	0.032*	172	216	0.445
8-10 m	Ht. 4	156	430	0.032*	238	534	0.037*	84	52	1.182
3-10+ m	Ht. 5	490	1712	0.002*	1078	1146	0.686	396	532	0.361
Pine		146	10	0.042*	1118	990	0.363	0	0	1.000
Spruce		1560	3258	0.037*	172	266	0.500	2020	6584	0.049*
Scar vs Unsc	Total	3120	2387	0.275	1233	1281	0.9297	11002	4302	0.4061
<3 m	Ht. 1	2620	1386	0.011*	46	163	0.2068	10855	3838	0.3834
3-4 m	Ht. 2	120	259	0.234	62	80	0.6926	46	206	0.1155
4-8 m	Ht. 3	310	549	0.222	649	652	0.9889	101	194	0.2255
8-10 m	Ht. 4	70	293	0.010*	2476	386	0.4518	0	68	0.0512*
3-10+ m	Ht. 5	500	1101	0.122	1187	1112	0.8840	147	464	0.0759
Pine		790	78	0.029*	1164	1054	0.8327	0	0	1.000
Spruce		2330	2409	0.904	68	219	0.1100	11002	4302	0.4061

Table 7b. ANOVA of conifer density among the forests.

Clear-cut Types	Height Classes	MIXEDWOOD Mean 1		PINE Mean 2		SPRUCE Mean 3		Sig. Level
Scarified	Total	3120		1233		11002		0.1409
<3 m	Ht. 1	2620		46		10855		0.1119
3-4 m	Ht. 2	120		62		46		0.6469
4-8 m	Ht. 3	310	ab	649	a	101	b	0.0308*
8-10 m	Ht. 4	70		2476		0		0.2705
3-10+ m	Ht. 5	500		1187		147		0.0687
Pine		790		1164		0		0.0517
Spruce		2330		68		11002		0.1117
Unscarified	Total	2387		1281		4302		0.4060
<3 m	Ht. 1	1386		163		3838		0.2657
3-4 m	Ht. 2	259		80		206		0.5365
4-8 m	Ht. 3	549		652		194		0.3181
8-10 m	Ht. 4	293		386		68		0.2855
3-10+ m	Ht. 5	1101		1112		464		0.4410
Pine		78	a	1054	b	0	a	0.0014*
Spruce		2409		219		4302		0.2676

Table 8a. ANOVA of deciduous density within each forest.

Clear-cut Types	Height Classes	MIXEDWOOD Mean 1	MIXEDWOOD Mean 2	MIXEDWOOD Sig.** Level	PINE Mean 1	PINE Mean 2	PINE Sig. Level	SPRUCE Mean 1	SPRUCE Mean 2	SPRUCE Sig. Level
Scar vs Scar	Total				43200	42000	0.814	79200	29500	0.035*
	Poplar	O n l y			2500	3300	0.574	5600	2600	0.113
	Willow				2400	300	0.089	6900	2500	0.125
	Rose	1			26400	21500	0.297	32900	15500	0.003*
	Other				11900	16900	0.113	33800	8900	0.134
	Ht. 1	S a m p l e			38800	39000	0.960	77300	28800	0.036*
	Ht. 2				1100	800	0.613	1100	200	0.105
	Ht. 3				1900	1800	0.920	800	500	0.402
	Ht. 4	A v a i l a b l e			1400	400	0.090	0	0	1.000
	Ht. 5				4400	3000	0.384	1900	700	0.600
Unsc vs Unsc	Total	36700	64300	0.004*	39000	38200	0.909	62600	60400	0.710
	Poplar	2400	1800	0.384*	1600	1300	0.683	4600	2700	0.177
	Willow	200	600	0.111	500	700	0.720	1400	8600	0.113
	Rose	30500	51000	0.017*	2100	24600	0.437	48100	33400	0.045*
	Other	3600	10900	0.0 *	15900	11600	0.280	8500	15700	0.113
	Ht. 1	36000	60500	0.004*	36500	36400	0.989	60700	59600	0.846
	Ht. 2	300	1100	0.111	700	600	0.760	1000	400	0.108
	Ht. 3	400	1800	0.115	1400	800	0.323	800	400	0.291
	Ht. 4	0	900	0.055*	400	400	1.00	100	0	0.347
	Ht. 5	700	3800	0.002*	2500	1800	0.248	1900	800	0.090
Scar vs unsc	Total	46900	50500	0.728	42600	38600	0.031	54350	61500	0.801
	Poplar	4300	2100	0.131	2900	1450	0.077	4100	3650	0.824
	Willow	600	400	0.380	1350	600	0.551	4700	5000	0.950
	Rose	38400	40750	0.795	23950	22800	0.742	24200	40750	0.283
	Other	3600	7250	0.086	14400	13750	0.862	21350	12100	0.549
	Ht. 1	45300	48250	0.761	38900	36450	0.002*	53050	60150	0.797
	Ht. 2	300	700	0.317	950	650	0.198	650	700	0.935
	Ht. 3	1100	1100	1.00	1850	1100	0.132	650	600	0.860
	Ht. 4	200	450	0.514	900	400	0.423	0	50	0.423
	Ht. 5	1600	2250	0.510	3700	2150	0.186	1300	1350	0.957

Table 8b. ANOVA of deciduous density among forests.

Clear-cut Types	Height Classes	MIXEDWOOD Mean 1	PINE Mean 2	SPRUCE Mean 3	Sig. Level
Scarified	Total	46900	42600	54350	0.603
	Poplar	4300	2900	4100	0.414
	Willow	600	1350	4700	0.191
	Rose	38400	23950	24200	0.975
	Other	3600	14400	21350	0.551
	Ht. 1	45300	38900	53050	0.526
	Ht. 2	300	950	650	0.495
	Ht. 3	1100 a	1850 b	650 a	0.003*
	Ht. 4	200	900	0	0.115
	Ht. 5	1600 a	3700 b	1300 a	0.050*
Unscarified	Total	50500	38600	61500	0.274
	Poplar	2100	1450	3650	0.152
	Willow	400	600	5000	0.343
	Rose	40750	22800	40750	0.282
	Other	7250	13750	12100	0.436
	Ht. 1	48250	36450	60150	0.206
	Ht. 2	700	650	700	0.990
	Ht. 3	1100	1100	600	0.700
	Ht. 4	450	400	50	0.565
	Ht. 5	2250	2150	1350	0.788

Table 9a ANOVA of pellet densities within each forest.

Clear-cut Types	Species	MIXEDWOOD Mean 1	MIXEDWOOD Mean 2	MIXEDWOOD Sig. Level	PINE Mean 1	PINE Mean 2	PINE Sig. Level	SPRUCE Mean 1	SPRUCE Mean 2	SPRUCE Sig. Level
Scar vs Scar	Deer S				50	24	0.322	60	48	0.694
	Deer W	Only			70	20	0.060	108	104	0.932
	Deer T				120	44	0.004*	168	152	0.816
	Elk S				0	0	1.00	24	24	1.00
	Elk W	1			10	4	0.593	20	32	0.576
	Elk T				10	4	0.590	44	56	0.561
	Moose S				0	0	1.00	0	0	1.00
	Moose W	Sample			40	20	0.434	0	0	1.00
	Moose T				40	20	0.434	0	0	1.00
	Hare T				5220	1100	0.001*	16	0	0.347
	Grouse T	Available			1320	16	0.129	36	8	0.429
	Coyote T				0	0	1.00	0	0	1.00
Unsc vs Unsc	Deer S	20	4	0.474	60	40	0.539	0	44	0.0*
	Deer W	180	4	0.163	80	310	0.130	216	228	0.872
	Deer T	200	8	0.124	140	350	0.184	216	272	0.482
	Elk S	0	0	1.00	0	0	1.00	0	20	0.013*
	Elk W	20	0	0.141	0	0	1.00	16	20	0.694
	Elk T	20	0	0.141	0	0	1.00	16	40	0.074
	Moose S	0	0	1.00	0	0	1.00	0	0	1.00
	Moose W	0	0	1.00	44	40	0.902	0	0	1.00
	Moose T	0	0	1.00	44	40	0.902	0	0	1.00
	Hare T	0	4696	0.002*	196	1570	0.130	116	4	0.090
	Grouse T	370	32	0.167	52	330	0.217	0	0	1.00
	Coyote T	0	0	1.00	0	0	1.00	0	0	1.00
Scar vs Unsc	Deer S	20	12	0.638	37	50	0.511	54	22	0.296
	Deer W	0	92	0.282	45	195	0.330	106	222	0.003*
	Deer T	20	104	0.178	82	245	0.282	160	244	0.102
	Elk S	0	0	1.00	0	0	1.00	24	10	0.296
	Elk W	0	10	0.317	7	0	0.145	26	18	0.333
	Elk T	0	10	0.317	7	0	0.145	50	28	0.243
	Moose S	0	0	1.00	0	0	1.00	0	0	1.00
	Moose W	0	0	1.00	30	42	0.360	0	0	1.00
	Moose T	0	0	1.00	30	42	0.360	0	0	1.00
	Hare T	0	2348	0.101	3160	883	0.404	8	50	0.455
	Grouse T	50	201	0.207	668	191	0.548	22	0	0.257
	Coyote T	0	0	1.00	0	0	1.00	0	0	1.00

S = Summer, W = winter, T = total of year-round

Table 9b. ANOVA of pellet densities among the forests.

Forest	Species	Mean 1		Mean 2		Mean 3		Sig. Level
Scarified	Deer S	20		37		54		0.242
	Deer W	0	a	45	ab	106	b	0.059*
	Deer T	20		82		160		0.091
	Elk S	0		0		24		1.00
	Elk W	0	b	7	a	26	a	0.040*
	Elk T	0	b	7	a	50	a	0.004*
	Moose S	0		0		0		1.00
	Moose W	0	a	30	b	0	a	0.035*
	Moose T	0	a	30	b	0	a	0.025*
	Hare T	0		3160		8		0.158
	Grouse T	50		668		22		0.312
	Coyote T	0		0		0		1.00
Unscarified	Deer S	12		50		22		0.307
	Deer W	92		195		222		0.574
	Deer T	104		245		244		0.482
	Elk S	0		0		10		0.465
	Elk W	10		0		18		0.244
	Elk T	10		0		28		0.232
	Moose S	0		0		0		1.00
	Moose W	0	a	42	b	0	a	0.000
	Moose T	0	a	42	b	0	a	0.000
	Hare T	2348		883		60		0.574
	Grouse T	201		191		0		0.525
	Coyote T	0		0		0		1.00

Table 10a. ANOVA of forb/grass coverage in 32 year-old clear-cuts within each forest.

SPECIES[2]	MIXEDWOOD(1)			PINE(2)			SPRUCE(3)		
	Mean 1[1]	Mean 2[1]	Sig. Level	Mean 1	Mean 2	Sig. Level	Mean 1	Mean 2	Sig. Level
				SCARIFIED FORBS					
TOTAL F	Only			25.07	25.31	0.925	28.59	20.92	0.020*
ARUV				0	0.85	0.423	13.20	10.06	0.066
ASTER				ANALYSES			FAILED		
ASHEOX		1		0	0	1.000	4.99	1.73	0.151
EPAN				6.74	7.29	0.677	0.35	0.28	0.715
FRVI				0.74	0.38	0.132	0.67	0.65	0.934
JUCHO				0	0	1.000	0.52	2.77	0.024*
LIBO	Sample			2.86	0.87	0.158	2.88	0.17	0.049*
VIAM/LAOC				0.05	0.07	0.764	0.02	0	0.432
				SCARIFIED GRASSES					
TOTAL G				14.70	17.04	0.542	24.63	17.67	0.083
BRIN				0.02	0	1.000	1.50	1.20	0.858
CACAMO	Available			7.49	9.51	0.340	0	0.58	0.068
CAREX				0.05	0.04	0.874	2.89	1.12	0.119
ELIN				7.18	7.42	0.934	20.14	14.62	0.063
				UNSCARIFIED FORBS					
TOTAL F	19.55	15.32	0.207	22.01	28.48	0.062	25.15	32.26	0.309
ARUV	8.29	3.02	0.116	0	0	1.000	9.42	17.19	0.222
ASTER	0.65	1.31	0.284	1.57	2.48	0.136	0.63	0.87	0.185
ASHEOX	1.03	0.11	0.123	0	0	1.000	3.66	1.93	0.115
EPAN	0.60	0.73	0.662	9.49	8.42	0.754	0	0.10	0.338
FRVI	2.54	3.29	0.176	0.17	0.88	0.029*	0.43	1.02	0.231
JU HO	0	0	1.000	0	0	1.000	4.51	2.67	0.609
LIBO	0.10	1.49	0.214	2.24	2.74	0.788	2.65	2.49	0.920
VIAM/LAOC	1.78	0.91	0.055	0.10	0.05	0.349	0	0	1.000
				UNSCARIFIED GRASSES					
TOTAL G	18.60	12.76	0.010*	22.65	23.66	0.744	17.61	18.79	0.396
BRIN	7.41	3.77	0.240	0.03	0	0.423	4.39	1.96	0.058
CACAMO	0	0	1.00	6.17	11.62	0.328	0	0.31	0.310
CAREX	0.18	0.04	0.258	0.04	0.02	0.553	2.18	7.27	0.095
ELIN	10.71	8.81	0.460	16.33	11.97	0.210	11.04	7.76	0.145

Table 10a continued.

SPECIES[2]	MIXEDWOOD(1)			PINE(2)			SPRUCE(3)		
	Mean 1[1]	Mean 2[1]	Sig. Level	Mean 1	Mean 2	Sig. Level	Mean 1	Mean 2	Sig. Level
				SCARIFIED vs UNSCARIFIED FORBS					
TOTAL F	20.02	17.44	0.335	25.190	25.25	0.988	24.76	28.71	0.529
ARUV	7.01	5.66	0.637	0.425	0	0.423	11.63	13.31	0.728
ASTER	0.65	0.98	0.502	2.055	2.02	0.958	1.28	0.75	0.341
ASHEOX	1.12	0.57	0.310	0	0	1.000	3.36	2.79	0.788
EPAN	0.32	0.67	0.196	7.015	8.96	0.084	0.31	0.05	0.049*
FRVI	2.01	2.92	0.099	0.560	0.52	0.938	0.66	0.72	0.846
JUCOHO	0	0	1.000	0	0	1.000	1.64	3.59	0.313
LIBO	0.05	0.80	0.241	1.865	2.49	0.604	1.52	2.57	0.522
VIAM/LAOC	1.95	1.35	0.242	0.060	0.07	0.634	0.01	0	0.423
				SCARIFIED vs UNSCARIFIED GRASSES					
TOTAL G	18.26	15.68	0.459	15.87	23.16	0.029*	21.15	18.20	0.491
BRIN	4.55	5.59	0.646	0.01	0.01	0.808	1.35	3.17	0.274
CACAMO	0	0	1.000	8.50	8.89	0.904	0.29	0.15	0.721
CAREX	0.86	0.11	0.006*	0.04	0.03	0.312	2.00	4.72	0.419
ELIN	12.31	9.76	0.343	7.30	14.15	0.088	17.38	9.40	0.130

Mean[1] = Scarified Mean 2 = Unscarified
Total F = total forbs Total G = total grass
ASHEOX = Astragalus, Hedysarum and Oxytropis nitrogen-fixing species
VIAMLAOC = Vicea and Lathyrus nitrogen-fixing species
CACAMO = Calamagrostis canadensis and C. montanensis
JUCOHO = Juniperis communis and J. horizontalis

Table 10b. ANOVA of forb/grass coverage in 32 year-old clear-cuts among forests.

	MIXEDWOOD Mean 1	PINE Mean 2	SPRUCE Mean 3	Sig. Level
		SCARIFIED FORBS		
TOTAL F	20.02	25.190	24.75	0.8984
ARUV	7.01 a	0.425 b	11.63 a	0.0035*
ASTER	0.65	2.055	1.28	0.1327
ASHEOX	1.12	0	3.36	0.0858
EPAN	0.32 a	7.015 b	0.31 a	0.0001*
FRVI	2.01	0.560	0.66	0.5456
JUCOHO	0	0	1.64	0.1712
LIBO	0.05	1.865	1.52	0.8203
VIAM/LAOC	1.95 a	0.060	0.01 c	0.0227
		SCARIFIED GRASSES		
TOTAL G	18.26	15.870	21.25	0.1763
BRIN	4.55 a	0.010 b	1.35 c	0.0016
CACAMO	0 a	8.500 b	0.29 a	0.0024
CAREX	0.86	0.045	2.00	0.0730
ELIN	12.31 ab	7.300 a	17.38 b	0.0209
		UNSCARIFIED FORBS		
TOTAL F	17.435	25.250	28.705	0.1583
ARUV	5.655	0	13.305	0.0882
ASTER	0.980	2.025	0.750	0.1352
ASHEOX	0.570	0	2.795	0.0766
EPAN	0.665 a	8.955 b	0.050 a	0.0005*
FRVI	2.915 a	0.525 b	0.725 b	0.0276*
JUCOHO	0 a	0 a	3.590 b	0.0269*
LIBO	0.795	2.490	2.570	0.1000
VIAM/LAOC	1.345 a	0.075 b	0 b	0.0538*
		UNSCARIFIED GRASSES		
TOTAL G	15.680	23.155	18.200	0.1175
BRIN	5.590	0.015	3.175	0.1136
CACAMO	0 a	8.895 b	0.155 a	0.0445*
CAREX	0.110	0.030	4.725	0.1723
ELIN	9.760	14.150	9.40	0.2284

Appendix 4

Foliage Cover of Grasses and Forbs

Table 1. Percent cover of grasses and forbs in mature forests plus scarified (SC) and unscarified (UN) clear-cuts.

Forest Type & Age	Percent Cover*					
	Grasses		Forbs		Combined	
	SC	UN	SC	UN	SC	UN
WHITE SPRUCE FOREST						
Mature	28		16		44	
1	8	24	1	4	9	28
5	54	60	42	37	97	97
26	23	22	18	27	41	49
32	21	19	25	29	46	47
LODGEPOLE PINE FOREST						
Mature	6		-		-	
1	9	13	-	-	-	-
5	64	74	46	38	110	112
26	20	28	17	12	37	40
32	16	23	25	25	41	48
MIXEDWOOD FOREST						
Mature	-		-		-	
1	7	8	-	-	-	-
5	45	56	29	19	74	75
26	27	17	15	14	42	31
32	18	16	20	17	38	33
(THREE FORESTS AVES.)						
Mature	17		16		44	
1	8	15	-	-	-	-
5	54	63	43	31	94	95
26	23	22	17	18	40	40
32	18	19	23	24	42	43

* Sample size (n) = 10 with each replication representing one value.

Table 2a. Grass cover (foliage) in mature and clear-cut blocks.

SPECIES	Mature	Year 1 Scar	Year 1 Unsc	Year 6 Scar	Year 6 Unsc	Year 26 Scar	Year 26 Unsc	Year 32 Scar	Year 32 Unsc
WHITE SPRUCE FOREST									
All Species	28.2	8.2	23.5	53.8	60.2	22.2	21.0	21.1	18.2
Hairy Wild Rye	6.4	7.0	21.0	15.7	49.1	20.7	15.4	17.4	9.4
Sedges	21.6	tr	tr	12.1	2.6	1.2	1.3	2.0	4.7
Brome	0.1	1.2	2.5	7.2	6.6	0.1	0.6	1.3	3.2
Bluejoint	0	0	tr	0.8	tr	tr	3.3	tr	0.1
LODGEPOLE PINE FOREST									
All Species	6.0	8.5	12.5	63.8	73.8	20.1	28.5	15.9	23.2
Hairy Wild Rye	5.5	7.5	11.5	51.4	71.0	12.8	21.0	7.3	14.1
Sedges	0	0	0	4.0	0.3	0.4	tr	tr	tr
Bluejoint	0.5	0.5	1.0	5.4	0.4	7.3	7.4	8.5	8.9
Brome	0	0	0	0	0.1	tr	tr	tr	tr
MIXEDWOOD FOREST									
All Species	-	6.9	8.0	45.1	55.5	25.8	17.0	18.3	15.7
Hairy Wild Rye	-	3.3	2.8	36.3	40.1	18.2	13.7	12.3	9.8
Sedges	-	0	0	1.3	0.6	0.6	0.4	0.9	0.1
Brome	-	2.6	0	6.4	14.7	5.5	2.3	4.6	5.6
Bluejoint	-	0	5.2	0.1	0	0	0	0	0

Table 2b. Forb cover (foliage) in mature and clear-cut blocks.

SPECIES	Mature	Year 1 Scar	Year 1 Unsc	Year 6 Scar	Year 6 Unsc	Year 26 Scar	Year 26 Unsc	Year 32 Scar	Year 32 Unsc
WHITE SPRUCE FOREST									
All Species	15.6	1.2	4.1	42.8	37.2	17.8	26.3	25.0	29.0
Aster	0.3	0.1	0.3	8.8	5.0	0.2	0.4	1.3	0.8
Fireweed	0	0	0.1	9.1	0.9	8.0	12.0	0.3	0.1
Strawberry						0.4	0.5	0.7	0.7
Bedstraw	3.0	0.3	1.5	2.7	3.0	1.2	0.8	1.1	0.6
Indian Potatoe	1.0	0.4	0.7	0.7	2.4	1.3	2.0	2.2	1.5
LODGEPOLE PINE FOREST									
All Species	-	-	-	46.0	38.4	15.5	11.0	25.2	25.2
Aster	-	-	-	7.2	8.9	1.0	0.8	2.1	2.0
Fireweed	-	-	-	18.9	13.5	2.8	4.5	7.0	9.0
Dewberry	-	-	-	11.3	6.8	tr	tr	1.4	1.6
Bedstraw	-	-	-	0.7	0.5	0.1	tr	0.1	tr
Mertensia	-	-	-	1.2	1.6	1.1	0.6	1.0	1.2
Strawberry	-	-	-			0.4	0.3	0.6	0.5
MIXEDWOOD FOREST									
All Species	-	-	-	29.1	18.9	15.8	13.6	20.0	17.4
Aster	-	-	-	3.9	2.5	1.0	1.1	0.6	1.2
Fireweed	-	-	-	1.6	2.4	0.3	0.3	0.3	0.7
Strawberry	-	-	-	11.1	5.0	1.5	1.9	2.0	2.9
Bedstraw	-	-	-	3.4	1.1	1.7	0.8	1.5	0.8
Solomon Seal	-	-	-	2.0	1.1	tr	tr	1.4	1.4

Table 3. Foliage cover of grasses and forbs 32 years after logging.

	WHITE SPRUCE SCARIFIED					
	SAMPLE 1		SAMPLE 2		AVERAGE	
Species	% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency
			FORBS			
AC MI	0	0	0.09	21	0.045	10.5
AG GL	0	1	0.02	2	0.01	1.5
AN CH	0.05	7	0.16	17	0.105	12
AN MU	0.01	1	0.02	2	0.015	1.5
AN PA	0.08	14	0.02	4	0.05	9
AN PU	0.20	11	0.21	13	0.205	12
AQ BR	0.05	5	0.03	4	0.04	4.5
AR UV*	13.20	65	10.06	43	11.63	54
AS CO	0.05	2	0	0	0.021	1
AS CI	1.55	77	0.71	58	1.13	67
AS SI	0.09	6	0.16	11	0.13	8.5
AS AL	0.01	1	0	0	0.005	0.5
AS FR	0.97	23	0.12	4	0.545	13.5
AS ST	0.06	4	0.41	12	0.235	8
BO BO	0.01	2	0.01	2	0.01	2
CA RO	0.08	17	0.12	29	0.10	23
CA MI	0.08	7	0.04	2	0.06	4.5
CO CA	0.01	1	0	0	0.005	0.5
CY CA	0.02	3	0.12	1	0.07	2
CY PA	0.01	1	0.01	1	0.01	1
EP AN	0.35	18	0.28	22	0.315	20
EQ AR	0.03	8	0.03	6	0.03	7
ER CA	0.01	2	0.07	6	0.04	4
ER GL	0	1	0.03	4	0.015	2.5
FR VI	0.67	40	0.65	35	0.66	37.5
GA BO	0.61	58	1.51	79	1.06	68.5
GE AM	0.02	4	0.18	24	0.10	14
GE CR	0.09	14	0	0	0.045	7
GE LI	0.34	18	0.18	7	0.26	12.5
HA HY	0.01	2	0	1	0.005	1.5
HA VI	0.02	5	0	0	0.01	2.5
HE AL	1.70	43	0.10	8	0.90	25.5
HE MA	1.93	36	0.64	35	1.285	35.5
HI UM	0.02	5	0	0	0.01	2.5
JU HO*	0	0	2.77	18	1.385	9
JU CO*	0.52	7	0	0	0.26	3.5
LA OC	0.02	1	0	0	0.01	0.5
LI PH	0.11	14	0	0	0.055	7
LI BO	2.88	42	0.17	14	1.525	28
ME PA	0.57	40	0.05	4	0.31	22
OX SP	0.30	15	0.22	8	0.26	11.5
OX MO	0.02	3	0.24	11	0.13	7
PA FI	0.01	2	0	1	0.005	1.5

PE NA	0	1	0	1	0	0.5
PE SP	0.52	22	0.07	5	0.295	13.5
PY AS	0.29	19	0.05	4	0.17	11.5
PY SE (OR SE)	0.09	11	0.08	6	0.085	8.5
PY SP	0.18	24	0.04	9	0.11	16.5
RU PU	0.01	1	0	0	0.005	.05
SE PA	0	1	0	0	0	0.5
SE PS	0.06	10	0.15	26	0.105	18
SI MO	0	0	0.04	3	0.02	1.5
SM ST	0	0	0.35	24	0.175	12
SM RA	0	0	0.03	2	0.015	1
SO DE	0.05	7	0.13	11	0.09	9
TA OF	0.09	13	0.20	26	0.145	19.5
TO GL	0	1	0	0	0	0.5
VI AM	0	1	0	0	0	0.5
VI SP	0.02	3	0.04	7	0.03	5
ZI CO	0	0	0.03	1	0	0
ZY EL	0.51	37	0.28	22	0.395	29.5
UN FO	0.01	20	0	1	0.005	1.5
TOTAL FORB COVER	28.99%		20.92%		24.74%	

GRASSES

AG TR	.008	2	0.15	3	0.115	2.5
BR IN	1.50	23	1.20	37	1.35	30
CA AU	1.27	35	0.30	19	0.785	27
CA CA	0	0	0.01	1	0.005	0.5
CA CP	0.52	13	0.55	16	0.535	14.5
CA MO	0	0	0.57	17	0.285	8.5
CA EB	1.10	32	0.27	11	0.685	21.5
EL IN	20.14	97	14.62	98	17.38	97.5
PO SP	0.01	1	0	0	0.005	0.5
UN GR	0.01	1	0	0	0.005	0.5
TOTAL GRASS COVER	24.63%		17.67%		21.15%	

LICHENS, MOSSES, FERNS

HY SP	1.20	24	7.02	64	4.11	44
TOTAL FORB AND GRASS COVER	53.22%		38.59%		45.89%	

* Shrubs buts used as forbs for cover values.

	WHITE SPRUCE UNSCARIFIED					
	SAMPLE 1		SAMPLE 2		AVERAGE	
Species	% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency
FORBS						
AC MI	0	1	0	1	0	0.5
AN CH	0	1	0.02	3	0.01	2
AN MU	0.	1	0	1	0	0.5
AN PA	0.01	4	0.19	29	0.10	16.5
AN PU	0.07	8	0.49	35	0.28	21.5
AQ BR	0.01	2	0.02	3	0.015	2.5
AR SP	0.02	3	0	0	0.01	1.5
AR UV*	9.42	45	17.19	66	13.305	55.5
AS CI	0.60	45	0.79	58	0.695	51.5
AS SI	0.03	6	0.08	6	0.055	6
AS AL	0.01	1	0	1	0.005	1
AS FR	0.83	29	0.29	15	0.56	22
AS ST	0.07	5	0.11	9	0.09	7
BO BO	0	0	0.01	2	0.005	1
CA RO	0	0	0.06	11	0.03	5.5
CA MI	0.03	4	0.11	12	0.07	8
CY CA	0.02	3	0	1	0.01	2
CY PA	0	0	0.01	1	0.005	0.5
EP AN	0	0	0.10	8	0.05	4
EQ AR	0	1	1.04	33	0.52	17
ER CA	0	0	0.03	4	0.015	2
FR VI	0.43	30	1.02	38	1.725	34
GA BO	0.45	61	0.71	55	0.58	58
GE AM	0.08	11	0.09	14	0.85	12.5
GE CR	0.03	6	0.01	2	0.02	4
GE LI	1.97	77	0.64	35	1.305	56
GO RE	0.01	1	0	0	0.005	0.5
HA HY	0	0	0.01	2	0.005	1
HA OB	0	0	0.01	3	0.005	1.5
HA VI	0	0	0.01	1	0.005	0.5
HE AL	0.90	25	0.41	17	0.655	21
HE FL	0	0	0.01	1	0.005	0.5
HE MA	1.78	35	1.20	44	1.49	39.5
JU HO*	0.78	10	1.33	6	1.055	8
JU CO*	3.73	12	1.34	9	2.535	10.5
LI PH	0.06	10	0.01	4	0.035	7
LI BO	2.65	58	2.49	40	2.57	49
LU PA	0	0	0.02	2	0.01	1
MA CA	0	0	0.01	2	0.005	1
ME PA	0.30	20	0.27	24	0.285	22
OX SP	0.05	2	0.05	5	0.05	3.5
OX MO	0.01	1	0.02	3	0.015	2
PA FI	0	0	0.01	3	0.005	1.5
PE NA	0	0	0.01	2	0.005	1
PE SP	0.04	4	0.55	35	0.295	19.5

PY AS	0.19	22	0.25	16	0.22	19
PY SE (OR SE)	0.10	21	0.04	6	0.07	13.5
PY SP	0.15	25	0.14	19	0.145	22
RA AC	0	0	0.02	1	0.01	0.5
RU PU	0.02	2	0.08	8	0.05	4.5
SE PS	0.02	7	0.06	14	0.04	10.5
SM ST	0.03	5	0.17	10	0.10	7.5
SM RA	0	0	0.01	1	0.005	0.5
SO DE	0.01	1	0.22	10	0.115	5.5
SO AR	0	0	0.01	1	0.005	0.5
SO GI	0.01	1	0.08	3	0.045	2
TA OF	0.01	2	0.10	17	0.055	9.5
TO GL	0	0	0.14	4	0.07	2
TR PR	0	0	0.04	3	0.02	1.5
VI SP	0	0	0.02	5	0.01	2.5
ZI CO	0	0	0.02	1	0.01	0.5
ZY EL	0.22	21	0.18	17	0.20	19
UN FO	0	0	0	1	0	0.5
TOTAL FORB COVER	25.15%		32.35%		28.75%	

GRASSES

AG SC	0	0	0.13	6	0.065	3
BR IN	4.39	68	1.96	52	3.175	60
CA AU	0.57	28	0.78	20	0.675	24
CA CA	0	0	0.16	4	0.08	2
CA CP	0.81	16	3.09	49	1.95	32.5
CA MO	0	0	0.15	5	0.075	2.5
CA SP	0	0	0	0	1.145	7
CA EB	0.80	26	1.11	38	0.955	32
EL IN	11.04	98	7.76	78	9.40	88
JU BA	0	0	1.33	15	0.665	7.5
JU SP	0	0	0.01	1	0.005	0.5
PO PR	0	0	0.01	2	0.005	1
UN GR	0	1	0.01	1	0.005	1
TOTAL GRASS COVER	17.61%		18.79%		18.20%	

LICHENS, MOSSES, FERNS

HY SP	5.95	56	6.21	49	6.08	52.5
TOTAL FORB AND GRASS COVER =	42.76%		51.14%		46.95%	

Species	LODGEPOLE PINE SCARIFIED SAMPLE 1 % Cover	% Frequency	SAMPLE 2 % Cover	% Frequency	AVERAGE % Cover	% Frequency
FORBS						
AC MI	0.01	2	0	0	0.005	1
AC RU	0	0	0.50	12	0.25	6
AR NU	0	0	0.24	6	0.12	3
ARSP	0.54	43	1.00	57	0.77	50
AR UV	0	0	0.85	1	0.425	0.5
AS CO	0.45	14	1.69	45	1.07	29.5
AS CI	1.39	65	0.58	33	0.985	49
BO BO	0.01	2	0	0	0.005	1
CA MI	0.08	6	0.10	4	0.09	5
CO CA	4.27	89	2.94	70	3.605	79.5
DE GL	0.04	2	0.16	9	0.10	5.5
EP AN	6.74	94	7.29	80	7.015	87
EQ AR	0.18	31	0.48	28	0.33	29.5
FR VI	0.74	44	0.38	29	0.56	36.5
GA BO	0.12	19	0.04	6	0.08	12.5
GA TR	0.02	3	0.06	8	0.04	5.5
GE BI	0	0	0.19	4	0.095	2
GE CR	0	1	0.06	7	0.03	4
GE RI	0	0	0.09	2	0.045	1
HA VI	0	0	0	1	0	0.5
HE LN	0.25	5	2.43	26	1.34	15.5
HE FL	0.16	32	0.12	13	0.14	22.5
LA OC	0.02	3	0.15	17	0.085	10
LE GR	0.22	1	0	0	0.11	1
LI BO	2.86	64	0.87	30	1.865	47
MA CA	0.61	39	0.60	50	0.605	44.5
ME PA	1.26	49	0.80	43	1.03	46
PA FI	0	1	0	0	0	0.5
PE SP	1.48	56	0.34	23	0.91	39.5
PY AS	0.31	28	0.29	30	0.30	29
PY SP	0.25	37	0.06	11	0.155	24
RU PU	1.46	70	1.24	59	1.35	64.5
SM ST	0	0	0.03	1	0.015	0.5
SO SP	0.01	1	0	0	0.005	0.5
SP LU	0.05	7	0.35	24	0.20	15.5
ST AM	0.04	5	0.15	6	0.095	10.5
TA OF	0.05	7	0.17	7	0.11	7
TH VE	0.01	1	0.52	10	0.265	5.5
TR PR	0	0	0	1	0	0.5
VA CA	1.20	21	0.21	7	0.705	14
VA VI	0.15	4	0	0	0.075	2
VI AM	0.03	3	0.01	1	0.02	2
VI SP	0.06	9	0.32	12	0.19	10.5
TOTAL FORB COVER	25.07%		25.31%		25.19%	

GRASSES

AG TR	0	0	0.03	2	0.015	1
BR IN	0.02	2	0	0	0.01	1
CA AU	0.05	3	0	0	0.025	1.5
CA CA	7.49	91	9.51	90	8.5	90.5
CA SP	0	0	0.04	2	0.02	1
EL IN	7.18	79	7.42	57	7.30	68
FE RU	0	0	0.01	1	0.005	0.5
PO PA	0	0	0.01	1	0.005	0.5
PO PR	0	0	0.02	1	0.01	0.5
TOTAL GRASS COVER	14.75%		17.04%		15.89%	

LICHENS, MOSSES, FERNS

CL SP	0.01	1	0.02	2	0.015	1.5
GY DR	0.01	2	0.01	1	0.01	1.5
HY SP	15.76	64	7.75	45	11.755	54.5
LY SP	0	0	0.01	1	0.005	0.5
PE AP	0.14	6	0	0	0.07	3
TOTAL FORB AND GRASS COVER	39.81%		42.35%		41.08%	

Species	LODGEPOLE PINE UNSCARIFIED SAMPLE 1 % Cover	% Frequency	SAMPLE 2 % Cover	% Frequency	AVERAGE % Cover	% Frequency
			FORBS			
AC MI	0	1	0.04	6	0.02	3.5
AC RU	0	0	0.04	3	0.02	1.5
AR NU	0	0	0	1	0	0.5
ARSP	0.67	51	0.85	42	0.76	46.6
AS CO	1.02	27	1.48	25	1.25	26
AS CI	0.55	32	1.00	41	0.775	36.5
CA MI	0.08	2	0.23	8	0.155	7
CO CA	3.09	88	3.15	82	3.12	85
DE GL	0.08	6	0.08	5	0.08	3.5
EP AN	9.49	100	8.42	97	8.955	98.5
EQ AR	0.08	11	0.56	36	0.32	23.5
FR VI	0.17	14	0.88	44	0.525	29
GA BO	0.01	2	0.03	4	0.02	3
GA TR	0.01	1	0.04	5	0.025	3
GE CR	0.03	6	0.01	2	0.02	4
GE RI	0	0	0.04	2	0.02	1
HA VI	0.01	1	0	1	0.005	1
HE LN	0.24	6	1.37	13	0.805	9.5
HE FL	0.08	17	0.04	7	0.06	12
LE GR	0.22	1	0.08	4	0.15	2.5
LI BO	2.24	63	2.74	57	2.49	60
LU PA	0	0	0.01	1	0.005	0.5
MA CA	0.19	26	0.30	24	0.245	25
ME PA	0.86	44	1.54	55	1.20	49.5
PE SP	0.41	29	0.90	29	0.655	29
PY AS	0.47	45	0.49	35	0.48	40
PY SP	0.04	7	0.05	5	0.045	6
RU PU	1.04	59	2.08	73	1.56	66
SM ST	0	0	0	1	0	0.5
SP LU	0.18	15	0.20	12	0.19	13.5
ST AM	0.19	3	0.09	6	0.14	4.5
TA OF	0.03	3	0.05	6	0.04	4.5
VA CA	0.43	4	1.57	11	1.00	7.5
VI AM	0.10	6	0.05	5	0.075	6
VI SP	0	0	0.01	1	0.005	0.5
TOTAL FORB COVER	22.01%		28.48%		25.245%	

GRASSES

BR IN	0.03	1	0	0	0.015	0.5
CA AU	0.03	4	0.02	2	0.025	3
CA CA	6.17	62	11.62	85	8.895	73.5
CA SP	0.01	1	0	1	0.005	1
EL IN	16.33	85	11.97	82	14.15	83.5
FE SP	0.08	1	0	0	0.08	1
PH PR	0	0	0.01	1	0.005	0.5
PO PR	0	0	0.04	4	0.02	2
TOTAL GRASS COVER	22.65%		23.66%		23.155%	

LICHENS, MOSSES, FERNS

CL SP	0.04	5	0.09	8	0.065	6.5
GY DR	0.01	2	0	0	0.005	1
HY SP	5.06	41	10.06	47	7.56	44
PE AP	0.16	7	0.08	5	0.12	6
PLSC	0	0	0.07	2	0.035	1
TOTAL FORB AND GRASS COVER	44.66%		52.14%		48.40%	

M I X E D W O O D	S C A R I F I E D		
	SAMPLE 1		NO SAMPLE 2
Species	% Cover	% Frequency	
		FORBS	
AC MI	0.56	75	
AG GL	0.07	5	
AN MU	0.03	8	
AQ BR	0	1	
AR UV	7.01	42	
ARSP	0	0	
AS CO	0.18	10	
AS CI	0.47	22	
AS AL	0.13	10	
AS FR	0.21	10	
BO BO	0	1	
CA RO	0.03	3	
EP AN	0.32	17	
EQ AR	0	0	
ER CA	0.10	6	
ER GL	0.10	7	
FR VI	2.01	80	
GA BO	1.50	96	
GE CR	0.05	5	
HE MA	0.24	12	
LA OC	1.52	84	
LI PH	0.02	3	
LI BO	0.05	4	
ME PA	0.33	25	
OX SP	0.54	14	
PY AS	0	1	
PY SE (OR SE)	0.01	1	
SE PA	0.01	1	
SE PS	0.02	5	
SI MO	0	1	
SM ST	1.40	59	
ST LO	0	1	
SY AL	2.30	63	
TA OF	0.14	14	
TR PR	0.12	5	
TR RE	0.02	2	
VI AM	0.43	39	
VI SP	0.09	16	
UN FO	0.01	2	
TOTAL FORB COVER	20.02%		

GRASSES

AG SP	0.01	2
AG TR	0.03	2
BR IN	4.55	91
CA AU	0.86	26
EL IN	12.31	100
PH PR	0.07	4
PH PR	0	0
PO PA	0.25	14
PO SP	0.10	7
PO PR	0.07	4
UN GR	0.01	2

TOTAL GRASS
COVER 18.26%

LICHENS, MOSSES, FERNS

HY SP	24.19	63
PE AP	1.14	34

TOTAL FORB AND
GRASS COVER 38.28%

Species	MIXEDWOOD UNSCARIFIED SAMPLE 1 % Cover	% Frequency	SAMPLE 2 % Cover	% Frequency	AVERAGE % Cover	% Frequency
			FORBS			
AC MI	0.32	54	0.17	36	0.245	45
AG GL	0.02	3	0	0	0.01	1.5
AN MU	0.01	3	0.01	2	0.01	2.5
AR UV	8.29	46	3.02	26	5.655	36
AR SP	0	0	0.03	3	0.015	1.5
AS CO	0.36	9	0.04	2	0.20	5.5
AS CI	0.65	41	1.27	65	0.96	53
AS AL	0.23	16	0	1	0.115	8.5
AS FR	0.24	10	0.01	1	0.125	5.5
CA MI	0	0	0	1	0	0.5
CA RO	0.03	4	0	0	0.015	2
EP AN	0.60	27	0.73	41	0.665	34
EQ AR	0	0	0	1	0	0
ER CA	0.04	4	0.01	2	0.025	3
ER GL	0.08	5	0.01	1	0.045	3
FR VI	2.54	83	3.29	84	2.915	83.5
GA BO	1.14	87	0.51	74	0.825	80.5
GA TR	0	0	0.01	2		
GE CR	0.01	2	0	1	0.005	1.5
GE LI	0.08	6	0.03	3	0.06	4.5
HE MA	0.19	150.07	3	0.13	9	
LA OC	1.22	78	0.70	69	0.96	73.5
LI PH	0.01	1	0.03	3	0.02	1.5
LI BO	0.10	6	1.49	54	0.795	30
OX SP	0.37	7	0.03	2	0.20	4.5
PL MA					9	0.5
SE PA	0	1	0	0	0	0.5
SI MO	0	1	0.01	2	0.005	1.5
SM RA	0	0	0.17	12	0.085	6
SM ST	1.63	59	1.07	53	1.35	56
SO DE	0.01	1	0	1	0.005	1
ST LO	0.01	2	0	0	0.005	1
SY AL	0.49	37	2.16	62	1.325	49.5
TA OF	0.06	7	0.02	3	0.04	5
TR PR	0.04	2	0.02	1	0.03	1.5
TR RE	0.06	4	0.02	2	0.04	3
VI AM	0.56	42	0.21	32	0.385	37
VI SP	0.12	13	0.18	21	0.15	17
ZI CO	0.02	3	0	0	0.01	1.5
UN FO	0.02	4	0	0	0.01	2
TOTAL FORB COVER	19.95%		15.32%		17.44%	

GRASSES

AG TR	0	0	0.04	2	0.02	1
BR IN	7.14	93	3.77	70	5.59	81.5
CA AU	0.16	14	0.03	3	0.095	8.5
CA SP	0.02	2	0.01	1	0.015	1.5
EL IN	10.71	95	8.81	95	9.76	95
FE SP	0	0	0.03	1	0.015	0.5
PO PA	0.17	6	0.06	4	0.115	5
PO SP	0.02	1	0.01	1	0.015	1
PO PR	0.07	3	0	0	0.035	1.5
UN GR	0.04	4	0	0	0.02	2
TOTAL GRASS COVER	18.60%		12.76%		15.68%	

LICHENS, MOSSES, FERNS

CL SP	0	0	0.02	3	0.01	1.5
HY SP	66.19	99	52.23	91	59.21	95
PE AP	1.25	42	1.36	34	1.305	38
PL SC	0	0	0.02	1	0.01	0.5
TOTAL FORB AND GRASS COVER	38.15%		28.09%		33.12%	

Appendix 5

Changes in Density of Woody Plants Following Logging

Table 1. Regeneration parameters for Year 26, scarified and unscarified treatments of spruce, pine and mixedwood forests.

REGENERATION PARAMETERS	FOREST TYPE					
	Spruce		**Pine**		**Mixedwood**	
	SC	UN	SC	UN	SC	UN
Stocking rate[a]	24	27	15	12	8	25
Density	9.3	2.3	2.3	1.3	1.5	1.7
Multiple trees	70	38	28	19	12	27
Mean height (m)[b]	0.78	1.97	6.17	4.63	1.44	2.85
Mean height (m)[f]	0.72	1.46	-	-	1.44	1.89
Growth rate [bc]	0.05[d]	0.09[d]	0.24[e]	0.18[e]	0.09[d]	0.12[d]
N (trees)	200	200	182	182	148	148

[a] Values in table are for spruce in the Spruce and Mixedwood forests and pine in the Pine forest. Percent of 0.89 m^2 plots occupied by conifers.
b Based on systematically selected trees.
c Mean height divided by years since stand establishment.
d Growth rates based on Years 10 - 26 = 16 years.
e Growth rates based on Years 1 - 26 = 26 years.
f Excluding residuals.

Table 2. Density per hectare of coniferous (C) and deciduous (D) trees taller than 0.5 m in mature and 32year-pld clear-cut blocks within three forest types, 1988.

BLOCK AND TREE TYPE*		HEIGHT CLASSES 4-5 ** 0.6-1m	6 1-2 m	7 2-3 m	8 3-4 m	9 4-6 m	10 6-8 m	11 8-12 m	12 >10
				MIXEDWOOD FOREST					
SC:	C	390	980	390	120	150	160	70	0
	D	800	500	100	300	400	600	100	100
	T	1190	1480	490	420	550	760	170	100
UN-1:	C	126	208	138	88	178	68	80	7
	D	400	700	200	300	100	100	0	0
	T	526	908	338	388	278	168	80	76
UN-2:	C	198	562	550	454	536	384	292	138
	D	200	300	200	300	200	100	400	100
	T	398	862	750	754	736	484	692	238
Ave. UN	C	162	385	344	271	357	226	186	107
	D	300	500	200	300	150	100	200	50
	T	462	885	544	571	507	326	386	157
Mature	C	268	536	300	288	160	144	76	224
	D	-	-	-	-	-	-	-	-
	T	-	-	-	-	-	-	-	-
				LODGEPOLE PINE					
SC-1:	C	4	10	48	100	220	656	876	30
	D	900	1600	800	1100	700	300	100	0
	T	904	1610	848	1200	920	956	976	30
SC-2:	C	0	4	10	26	110	372	214	12
	D	800	1400	300	800	800	400	100	200
	T	800	1404	310	826	910	772	314	212
Ave. SC:	C	2	7	29	63	165	514	545	21
	D	850	1500	600	950	750	350	100	100
	T	852	1507	629	1013	915	864	645	121
UN-1:	C	22	20	66	96	90	452	214	48
	D	400	800	800	700	300	0	0	100
	T	422	820	866	796	390	452	214	148
UN-2:	C	10	10	44	64	178	382	442	92
	D	1300	600	800	600	200	300	0	0
	T	1310	610	844	664	378	682	442	92
Ave. UN:	C	16	15	55	80	134	417	328	70
	D	850	700	800	650	250	150	0	50
	T	866	715	855	730	384	567	328	120
				WHITE SPRUCE FOREST					
SC-1:	C	2950	1320	200	60	90	60	0	0
	D	1500	3600	1900	1100	500	200	0	0
	T	4450	4920	2100	1160	590	260	0	0
SC-2:	C	1104	620	124	32	36	16	0	0
	D	500	1000	700	100	200	300	0	0
	T	1604	1620	824	132	236	316	0	0
Ave. SN:	C	2027	970	162	46	63	38	0	0
	D	1000	2300	1300	600	350	250	0	0
	T	3027	3270	1462	646	413	288	0	0
UN-1:	C	280	400	144	148	84	88	64	20
	D	1200	2200	1200	700	600	0	0	0
	T	1480	2600	1344	848	684	88	64	20
UN-2:	C	864	1080	440	264	136	80	36	16
	D	800	1600	300	200	100	300	0	0
	T	1664	2680	740	464	236	380	36	16
Ave. UN	C	572	740	292	206	110	84	50	18
	D	1000	1900	750	450	350	150	0	0
	T	1572	2640	1042	656	460	234	50	18
Mature:	C	184	252	144	144	112	132	224	548
	D	-	-	-	-	-	-	-	-
	T	-	-	-	-	-	-	-	-

* C = coniferous, D = deciduous, T = total

** for deciduous trees, only height class 5 (70-100 cm) was taken; not class 4.

Table 3. Tree and shrub densities (per ha) in mature and logged (Years 6, 26 and 32) forests.

SPECIES	YEAR	WHITE SPRUCE SC	WHITE SPRUCE UN	LODGEPOLE PINE SC	LODGEPOLE PINE UN	MIXEDWOOD SC	MIXEDWOOD UN
Alnus crispa	M	0		17		0	
(Green Alder)	6	0	0	176	232	0	0
	26	0	0	2614	1868	0	0
	32	0	0	2300	1400	0	0
Betula spp.	M	17		0		0	
(Birch)	6	67	133	0	0	0	0
	26	209	51	0	0	0	0
	32	200	250	0	0	0	0
Lonicera spp.	M	494		0		247	
(Honeysuckle)	6	148	465	17	17	462	1043
	26	585	1119	0	52	1013	1707
	32	350	1100	500	450	600	1700
Picea glauca	M	279		166*		282	
(White	6	363	1043	32	49	68	55
spruce)	26	22355	6858	160	387	1333	4641
	32	9479	4306	69	221	2340	2501
Pinus contorta	M	0		67		36	
(Lodgepole	6	0	0	3048	570	50	18
pine)	26	0	0	3734	2187	426	266
	32	0	0	1285	1051	790	72
Populus spp.	M	709		0		582	
(Poplar)	6	3684	5125	1308	620	2277	1350
	26	5079	4002	3565	702	3734	2560
	32	4300	3600	3050	1450	4600	2200
Potentilla	M	67		0		0	
fruticosa	6	-	-	0	0	0	0
(Shrubby	26	639	1225	0	0	0	0
cinquefoil)	32	800	1350	0	0	0	0
Rosa spp.	M	13672		6062		8067	
(Rose)	6	16431	20326	7840	8860	10368	11175
	26	33023	39158	24914	25768	31316	29182
	32	24350	40800	23950	22800	40800	40750
Salix Spp.	M	2422		100		67	
(Willow)	6	2880	4481	703	100	485	388
	26	3947	3414	1333	533	426	426
	32	4700	5000	1350	600	600	400
Shepaherdia	M	198		0		1218	
canadensis	6	230	198	0	0	282	657
(Buffaloberry)	26	852	852	0	0	373	533
	32	1100	800	0	0	200	450
Virburnum	M	267		346		0	
edule	6	0	331	796	1821	0	0
(Low-bush	26	746	318	4215	6085	0	0
cranberry)	32	500	500	5700	7500	0	0
Others	M	139					
AMAL RIOX	6						
RUST SOSC	26						
SARA VACA	32	100	1450	4200	2850	200	350
Totals	M	18264		6640		9001	
	6	24484	31632	13956	12279	15574	17387
	26	67018	57595	40646	34565	41020	43048
	32	45879	59156	42404	38322	50130	48423

* Also includes subalpine fir.

Table 4a. Densities of coniferous and deciduous trees in mature and 32-year-old clear-cut forests, 1988.

TREATMENT	TREES/HA IN MIXEDWOOD FOREST							
	Pine	Spruce	Poplar	Rose	Willow	Others	Deciduous Total	Total
SC - 1	790	2340	4600	40800	600	1000	47000	50130
UN - 1	144	1558	2600	30500	200	1100	34400	36102
UN - 2	12	3444	1800	51000	600	3900	57300	60756
Ave. UN	72	2501	2200	40750	400	2500	45850	48429
Mature	36	2500	No data collected					

TREATMENT	TREES/HA IN LODGEPOLE PINE FOREST							
	Pine	Spruce	Poplar	Rose	Willow	Others	Deciduous Total	Total
SC - 1	1859	98	2800	26400	2400	9200	40800	42757
SC - 2[1]	710	40	3300	21500	300	16200	41300	42050
Ave. SC	1285	69	3050	23950	1350	12700	41050	42404
UN - 1[2]	1116	172	1600	21000	500	13900	37000	38288
UN - 2[3]	986	270	1300	24600	700	10500	37100	38356
Ave. UN	1051	221	1450	22800	600	12200	37050	38322
Mature			No		data		collected	

1 ABLA = 2 trees/ha 2 ABLA = 8 trees/ha 3 ABLA = 8 trees/ha

TREATMENT	TREES/HA IN WHITE SPRUCE FOREST							
	Pine	Spruce	Poplar	Rose	Willow	Others	Deciduous Total	Total
SC - 1	-	14030	5600	33200	6900	3800	49500	63530
SC - 2	-	4928	3000	15500	2500	2300	23300	28228
Ave. SC	-	9479	4300	24350	4700	3050	36400	45879
UN - 1	-	2028	4500	48100	1400	5500	59500	61528
UN - 2	-	6584	2700	33500	8600	5400	50200	56784
Ave. UN	-	4306	3600	40800	5000	5450	54850	59156
Mature	-	2780	No data collected					

Table 4b. Plant density of deciduous and coniferous woody species 26 years after logging in three forest types.

SPECIES*	#/Ha and % Comp	WHITE SPRUCE SC	WHITE SPRUCE UN	LODGEPOLE PINE SC	LODGEPOLE PINE UN	MIXEDWOOD SC	MIXEDWOOD UN
ALCR	#/Ha	0	0	2614	1868	0	0
	% Comp	0	0	5.9	4.6	0	0
AMAL	#/Ha	51	1225	0	106	266	266
	% Comp	0.1	2.0	0	0.3	0.7	0.7
BEGL+	#/Ha	209	51	0	0	0	0
BEPA	% Comp	0.3	0.1	0	0	0	0
LODI+	#/Ha	585	1119	0	424	1013	1707
LOME	% Comp	0.8	1.8	0	1.0	2.6	4.3
PICO	#/Ha	0	0	3736	2186	425	266
	% Comp	0	0	8.4	5.4	1.1	0.7
PIGL	#/Ha	24558	7259	158	373	1334	4642
	% Comp	34.9	11.9	0.4	0.9	3.4	11.6
POBA	#/Ha	5070	4002	3256	639	425	479
	% Comp	7.2	6.6	7.3	1.6	1.1	1.2
POTR	#/Ha	0	0	533	51	3736	2562
	% Comp	0	0	1.2	0.1	9.5	6.4
POFR	#/Ha	639	1225	0	0	0	0
	% Comp	0.9	2.0	0	0	0	0
RIOX	#/Ha	0	0	1386	906	0	51
	% Comp	0	0	3.1	2.2	0	0.1
ROAC	#/Ha	33046	39187	24932	25786	31339	29204
	% Comp	47.0	64.5	55.9	63.5	79.5	72.7
RUST	#/Ha	0	0	1386	1279	0	0
	% Comp	0	0	3.1	3.1	0	0
SASP	#/Ha	3948	3414	1334	533	425	425
	% Comp	5.6	5.6	3.0	1.3	1.1	1.1
SHCA	#/Ha	852	852	0	0	373	533
	% Comp	1.2	1.4	0	0	1.0	1.3
VIED	#/Ha	746	318	4215	6085	51	0
	% Comp	1.1	0.5	9.5	15.0	0.1	0
OTHERS	#/Ha	664	2104	1028	394	15	13
	% Comp	0.9	3.6	2.3	1.0	<0.1	<0.1
TOTALS	#/Ha	70368	60756	44578	40630	39402	40148
	% Comp	100.0	100.0	100.0	100.0	100.0	100.0

* See Appendix 2 for scientific and common names of symbols

Table 5. Densities (per ha) of deciduous woody plants in mature forests and various age classes of clear-cuts of scarified (SC) and unscarified (UN) clear-cuts.

Forest	Poplar		Rose		Willow		Others		Deciduous Total	
Age	SC	UN	SC	UN	SC	UN	SC	UN	SC	UN
WHITE SPRUCE FOREST										
Mature	717		13832		2450		30		17029	
1	1268	68	8165	8600	583	433	314	951	10330	10052
6	3684	5125	16341	20326	2880	4481	1126	657	24121	30589
9	10097	3472	-	-	8532	2389	-	-	-	-
17	4748	3841	37771	47054	5121	5655	2079	3837	49719	60387
26	5079	4002	33023	39158	3947	3414	2614	4163	44663	50737
32	4300	2600	24350	40800	4700	5000	3050	5450	36400	54850
LODGEPOLE PINE FOREST										
Mature	0		6082		100		391		6573	
1	0	0	5833	13550	0	432	848	952	6681	15350
6	1308	620	7840	8860	703	100	1025	2080	10876	11660
9	1062	1440	-	-	1865	2297	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
26	3565	702	24914	25768	1333	533	6940	4988	36752	31991
32	3050	1450	23950	22800	1350	600	12700	12200	41050	37050
MIXEDWOOD FOREST										
Mature	582		8067		67		-		8716	
1	20	1333	4020	16682	18	2600	394	7467	4455	28082
6	2277	1350	10368	11175	485	388	2326	4401	15456	17314
9	1531	4385	-	-	488	1807	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
26	3734	2560	31316	29182	426	426	3785	5973	39261	38141
32	4600	2200	40800	40750	600	400	1000	2500	47000	45850

Table 6. Trends in poplar and willow densities (per ha) following logging.

FOREST	POPLAR			WILLOW		
AGE	SC[2]	UN[2]	% Diff[1]	SC	UN	% Diff
WHITE SPRUCE FOREST						
Mature	**717**			**2450**		
1	1268	68	-95	583	433	-26
6	3684	5125	+39	2880	4481	+56
9	10097	3472	-66	8532	2389	-72
17	4748	3841	-19	5121	5655	+10
26	5079	4002	-21	3947	3414	-14
32	4300	3600	-16	4700	5000	+ 6
$\bar{x}$	**4863**	**3351**	**-31**	**4294**	**3562**	**-17**
LODGEPOLE PINE FOREST						
Mature	**0**			**100**		
1	0	0	0	0	432	+432
6	1308	620	-53	703	100	- 86
9	1062	1440	+36	1865	2297	+ 23
26	3565	702	-80	1333	533	- 60
32	3050	1450	-52	1350	600	- 56
$\bar{x}$	**1797**	**847**	**-53**	**1050**	**792**	**- 25**
MIXEDWOOD FOREST						
Mature	**582**			**67**		
1	20	1333	+6565	18	2600	+14344
6	2277	1350	-41	485	388	-20
9	1531	4385	+186	488	1807	+270
26	3734	2560	-31	426	426	0
32	4600	2200	-52	600	400	-33
$\bar{x}$	**2432**	**2366**	**- 3**	**403**	**1124**	**+179**
All Forests x	**3031**	**2188**	**-28**	**1916**	**1826**	**-5**

[1] $\frac{\text{Difference x 100}}{\text{Scarified}}$

[2] SC = Scarified
UN = Unscarified

Table 7. Density (*/ha) of coniferous and deciduous trees >.5 m tall and those tall enough to provide inimalwinter thermal cover (>2 m) in 32 year-old clear-cuts and mature forests.

BLOCK	TREE TYPE[1]	HEIGHT CLASSES (m) 0.6-1.0	1-2	<----COVER TREES----> 2-3	3-4	4-6	6-8	8-10	>10	COVER TREE TOTALS (>2m)
				MIXEDWOOD FOREST						
32 -	C	390	980	390	120	150	160	70	0	890
Year	D	800	500	100	300	400	600	100	100	1600
Scarified	T	1190	1480	490	420	550	760	170	100	2490
32 -	C	162	385	344	271	357	226	186	107	1491
Year	D	300	500	200	300	150	100	200	50	1000
Unscarified	T	462	885	544	571	507	326	386	157	2491
	C	268	536	300	288	160	144	76	224	1192
Mature	D	-	-	-	-	-	-	-	-	-
	T	-	-	-	-	-	-	-	-	-
				LODGEPOLE PINE FOREST						
32 -	C	2	7	29	63	165	514	545	21	1337
Year	D	850	1500	600	950	750	350	100	100	2850
Scarified	T	852	1507	629	1013	915	864	645	121	4187
32 -	C	16	15	55	80	134	417	328	70	1084
Year	D	850	700	800	650	250	150	0	50	1900
Unscarified	T	866	715	855	730	384	567	328	120	2984
Mature	C	-	-	-	-	-	-	-	-	-
				WHITE SPRUCE FOREST						
32 -	C	2027	970	162	46	63	38	0	0	309
Year	D	1000	2300	1300	600	350	250	0	0	2500
Scarified	T	3027	3270	1462	646	413	288	0	0	2809
32 -	C	572	740	292	206	110	84	50	18	760
Year	D	1000	1900	750	450	350	150	0	0	1700
Unscarified	T	1572	2640	1042	656	460	234	50	18	2460
Mature	C	184	252	144	144	112	132	224	548	1304

[1] C = coniferous, D = deciduous, T = total coniferous + deciduous.

Appendix 6

Deciduous and Coniferous Heights in 32 Year-old Clear-cuts Within Three Forest Types

Table 1. Mean heights (m) of deciduous and coniferous trees* and shrubs* in 32 year-old clear-cuts within three forest types, 1988.

TREATMENT	POPLAR	ROSE	WILLOW	CONIFERS
		MIXEDWOOD FOREST		
SC - 1	2.48	0.18	0.53	0.42
UN - 1	1.41	0.17	2.5●	0.28
- 2	4.12	0.17	1.77	0.33
AVE. UN	2.77	0.17	2.13	0.31
		LODGEPOLE PINE FOREST		
SC - 1	2.86	0.21	1.45	0.59
- 2	3.44	0.19	2.57*	0.61
AVE. SC	3.15	0.20	2.01	0.60
UN - 1	2.37	0.20	2.32	0.45
- 2	2.32	0.26	3.31	0.51
AVE UN	2.35	0.23	2.82	0.48
		MIXEDWOOD FOREST		
SC - 1	2.22	0.23	0.95	0.60
- 2	1.69	0.13	1.11	0.46
AVE. SC	1.96	0.18	1.03	0.53
UN - 1	2.02	0.22	1.33	0.43
- 2	1.90	0.19	0.46	0.35
AVE UN	1.96	0.21	0.90	0.39

* Deciduous height classes and means used in 1988 were:

Height Classes	Range (m)	Mean (m)
1	0- .1	.05
2	.1- .2	.15
3	.2- .4	.30
4	.4- .7	.55
5	.7-1.0	.85
6	1-2	1.5
7	2-3	2.5
8	3-4	3.5
9	4-6	5.0
10	6-8	7.0
11	8-10	9.0
12	10.1+	11.0

● Only 2 samples
* Only 3 samples

Table 2. Coniferous heights (m) in three forest types, 32 years after logging.

FOREST TYPE		SCARIFIED	UNSCARIFIED
Mixedwood Sample	1	1.88	2.50
	2	-	3.97
	Ave.	1.88	3.24
Pine Sample	1	7.38	5.72
	2	7.11	7.13
	Ave.	7.25	6.34
Spruce Sample	1	0.64	1.86
	2	0.71	1.08
	Ave.	0.68	1.47

Table 3. Mean height (m) of coniferous and deciduous woody plants in mature forests and in various age-classes of scarified (SC) or unscarified (UN) clear-cuts.

Age	Coniferous[1]		<---- D e c i d u o u s ----> Poplar		Rose		Willow		Total	
	SC	UN	SC	UN	SC	UN	SC	UN	SC	UN
WHITE SPRUCE FOREST										
Mature	10 m		2.47		.41		.68		.81	
1										
6			.54	1.17	.44	.49	.67	.95	.54	1.34
9										
17	.18	.53	1.66	2.19	.23	.27	.88	.79	1.11	2.21
26	.48	.91	1.27	1.76	.25	.32	1.08	1.03	1.15	1.57
32	.68	1.47	1.96	1.96	.18	.21	1.03	.90		
LODGEPOLE PINE FOREST										
Mature	10 m									
1										
6			.35	.46	.34	.34	.43	.61		
9			1.03	.82			1.02	.96		
17										
26	3.62	3.22	2.45	2.38	.20	.23	2.30	1.99	1.78	1.38
32	7.25	6.43	3.15	2.35	.20	.23	2.01	2.82		
MIXEDWOOD FOREST										
Mature	10 m		.82				.30			
1			.10	.40	.10	.10	.10	.30		
6			.58	.94	.34	.34				
9			.67	1.23			.56	.78		
17										
26	1.13	1.42	1.98	1.86	.21	.21	1.08	1.54	.99	1.64
32	1.88	3.24	2.48	2.77	.18	.17	1.53	2.13		

[1] Spruce in spruce and mixedwood forest; pine in pine forest. (All trees included, not just dominants).

Appendix 7

Coniferous Canopy Cover and Cervid Visibility in 32 Year-old Clear-cuts

Table 1. Coniferous canopy closure values for mature forests and 32-year old clear cuts.

	CONIFEROUS CANOPY COVER (m^2/Hectare)							
	<------H e i g h t C l a s s e s----->							
	1-5	6	7	8	9	10	11-12	
Height range	≤1 m	1-2 m	2-3 m	3-4 m	4-6 m	6-8 m	>8 M	Total
MIXEDWOOD FOREST								
Winter Cover Quality	<-Nil ->	<-----Poor ----->		<----Fair ----->		Good - Very Good		
SC	713.9	555.2	221.0	68.0	85.0	90.7	39.	1773.3
% [1]	7.1	5.5	2.2	0.7	0.8	0.1	0.40	17.7
UN -1	656.4	157.3	104.4	66.5	134.6	51.4	118.0	1288.6
%	6.5	1.5	1.0	0.6	1.3	0.5	1.2	12.9
UN -2	1048.4	1091.1	1067.8	881.4	1040.6	745.5	834.8	6709.3
%	10.5	11.0	10.7	8.8	10.4	7.5	8.3	67.1
Ave. UN	852.4	624.2	586.0	473.9	587.6	398.4	476.4	3999.0
%	8.5	6.2.	5.8	4.7	5.9	4.0	4.7	40.0
Mature	1117.0	741.0	414.7	398.1	221.2	199.1	414.7	3505.8
%	11.2	7.4	4.1	4.0	2.2	2.0	4.1	35.0
LODGEPOLE PINE FOREST								
SC -1	47.5	29.7	142.6	297.	653.84	1949.6	2692.6	5813.4
%	0.5	0.3	1.4	2.9	6.5	19.5	26.9	58.1
SC- 2	21.7	21.7	54.2	141.0	596.6	2017.7	1225.8	4078.8
%	0.2	0.2	0.5	1.4	6.0	20.2	12.2	40.8
Ave. SC	33	25.71	98.45	219.1	625.2	1983.6	1959.2	4946.1
%	0.3	0.	0.98	2.2	6.2	19.4	19.6	49.4
UN - 1	400.5	59.8	197.2	286.9	866.7	1350.9	711.3	3873.3
%	4.0	0.6	2.0	2.9	8.7	13.5	7.1	38.7
UN 2	169.0	32.5	143.0	208.0	578.4	1241.3	1735.3	4107.5
%	1.7	0.3	1.4	2.1	5.8	12.4	17.3	41.1
Ave. UN	284.7	46.1	170.1	247.4	722.6	1296.1	1223.3	3990.4
&	2.8	0.	1.70	2.5	7.2	12.9	12.2	39.9
WHITE SPRUCE FOREST								
SC 1	1654.1	177.5	26.9	8.1	12.1	8.1	0	1886.7
%	16.5	1.8	0.3	0.1	0.1	0.1	0	18.9
SC -2	710.7	107.5	21.5	5.5	6.2	2.8	0	854.2
%	7.1	1.1	0.2	0.0	0.1	0.0	0	8.5
Ave. SC	1182.4	142.5	24.2	6.8	9.2	5.4	0	1370.5
%	11.8	1.4	0.2	0.1	0.1	0.1	0	13.7
UN 1	815.5	302.0	108.7	111.7	63.4	66.4	63.4	1531.3
%	8.2	3.0	1.1	1.1	0.6	0.6	0.6	15.3
UN 2	1159.5	276.3	112.6	67.5	34.8	20.5	13.3	1684.5
%	11.6	2.7	1.1	0.7	0.3	0.2	0.1	16.8
Ave. UN	987.5	289.2	110.6	89.6	49.1	43.4	38.4	1607.9
%	9.9	2.9	1.1	0.9	0.5	0.4	0.4	16.1
Mature	1959.2	403.4	230.5	230.5	179.3	211.3	1235.7	4449.7
%	19.6	4.0	2.3	2.3	1.8	2.1	12.4	44.5

[1] % means % of canopy closure

Table 2. Visibility values at five heights above ground in mature and 32 year-old clear-cut blocks.

FOREST BLOCK	HEIGHT CLASSES 1 (<.5 m)	2 (.5-1.0 m)	3 (1.0-1.5 m)	4 (1.5-2. m)	5 (2.0-2.5 m)	Aves. (0-2.5 m)
MIXEDWOOD FOREST						
SC[1]	49.4	63.4	72.0	69.4	68.0	64.4
UN-2[2]	16.6	26.0	26.0	27.4	26.6	24.5
Mature	16.0	36.0	45.4	45.4	40.6	36.7
LODGEPOLE PINE FOREST						
SC-1	10.6	23.5	29.4	30.0	33.4	
SC-2	10.6	17.4	23.4	26.6	25.4	
Ave. SC	10.6	20.4	26.4	28.3	29.4	23.0
UN-1	16.6	25.4	22.6	19.4	20.6	
UN-2	13.4	22.0	22.6	23.4	22.6	
Ave. UN	15.0	23.7	22.6	21.4	21.6	20.9
WHITE SPRUCE FOREST						
SC-1	13.4	30.0	38.0	48.6	58.6	
SC-2	28.0	39.4	45.4	51.4	50.6	
Ave. SC	20.7	34.7	41.7	50.0	54.6	40.3
UN-1	16.6	26.6	30.6	36.6	41.4	
UN-2	14.6	28.0	38.0	48.0	47.4	
Ave. UN	15.6	27.3	34.3	42.3	44.4	32.8
Mature	18.6	31.4	41.4	44.6	51.4	37.5
AVES. OF ALL THREE FORESTS						
SC	22.4	34.7	41.6	45.2	47.2	38.2
UN	15.6	25.6	28.0	31.0	31.7	26.4
Mature	17.3	33.7	43.4	45.0	46.0	37.1

[1] SC = Scarified clear-cut

[2] UN = Unscarified clear-cut, UN-2 is unscarified Sample 2 as Sample 1 is being lost to gravel pit operations.

Appendix 8

Wildlife Abundance (Winter vs Summer)

Following Logging

Big Game

YEAR	FOREST	BLOCK	DENSITY/Km^2		PELLET GROUPS/Ha	
			Summer	Winter	Scarified	Unscarified
Mature	Spruce	Mature	1.5		17	
1	"	Scar.	0.8	0	35	17
5	"	"	3.5	0	35	50
9	"	"	-	-	75	15
17	"	"	10.0	0.2	162	1025
26	"	"	-	-	405	400
32	"	"	-	-	210	446

During Years 1-5, in summer, most use in spruce clear-cuts was by deer plus light use by moose in the unscarified block. By Year 9, 40% of use was winter use by deer and elk with most use still in the unscarified block.

Winter use declined compared with summer use in Year 17, apparently because residual mature spruce blocks, which formerly covered one-third of the area, were removed in Years 12 and 13.

Theoretically, browse forage in the 17 year-old scarified block could support 32 moose or 94 elk or 336 deer/km^2 annually. In fact, summer densities were 10 big game/km^2 (6 deer, 1 moose, 3 elk). Winter densities were only 0.2/km^2 for big game.

Big game use of the unscarified block averaged 2.7 times greater than that in the scarified block, during Years 1-17.

During Year 32, big game abundance, based on pellet-group counts, was 112, -6 and 470% greater in unscarified spruce, pine and mixedwood clear-cuts than in respective scarified blocks (Table 2). Big game use was greatest in spruce, then in pine and least in mixedwood clear-cuts with most use by deer in both summer and winter.

In the 285 ha lodgepole pine clear-cut, big game use during Years 1-6 was 2.4 times greater in unscarified than scarified clear-cuts. Most use was confined to a 25% perimeter area adjacent to the uncut forest. Only summer use occurred in Year 6 with elk and deer tracks common in both clear-cuts. In Year 9, use was 2.4 times greater than Year 6 and this use was by moose. There was 1.7 times more use in unscarified than in scarified blocks and 87% of the use was during winter. One herd of 4-6 white-tailed deer summered within the area where a mature grove of balsam poplar remained in the scarified block. One herd of four elk (2 cows + 2 bulls) plus another of four (3 cows, 1 calf) used the upper half of the unscarified block. The big game density was estimated at 4/km^2 for the summer season. In Year 25, most summer use was of deer and one herd of 5-10 elk was flushed from thick pine and alder growth of the scarified block. Pellet groups indicated that winter use by moose exceeded summer use. In November there was one herd of 4-5 mule deer and no white-tailed deer near the above grove of balsam poplar. No elk or moose were using clear-cuts during that month. In summer of Year 26, no pellet groups were found on the plots but three fresh moose beds were found in the upper half of the unscarified block. Some deer use occurred in the vicinity of the grove of balsam poplar. No sign of elk was observed. In January 1983 (Year 27), the following densities of big game tracks/ha were observed: 7 deer, 3 moose in scarified; 3 deer, 5 moose in unscarified and 0 deer, 0 moose in mature blocks. A helicopter survey in March 1983 revealed 2 adult moose in the scarified block.

Within the mixedwood forest, most big game use during Years 1-6 was summer use by deer. By Year 7 big game use was 7.4 and 12.6 times greater than in the spruce and pine clear-cuts, respectively. Most use was by deer and elk plus a small amount of winter use by moose. The mature, residual seed blocks (100 x100 m) provided important security and winter shelter cover for all three species. In Year 9, 57% of big game use within mature seed blocks was by elk whereas elk use comprised 72 and 78% of big game use in scarified and unscarified blocks, respectively. Deer comprised 16% of big game use in the seed blocks compared with 8 and17% in scarified and unscarified blocks. Moose comprised 27% of big game use in the seed blocks compared with 20 and 6% scarified and unscarified blocks, respectively. Deer comprised 16% of big game use in the seed blocks compared with 8 and17% in scarified and unscarified blocks. Thus elk use, in decreasing order, was: unscarified, scarified and seed blocks. Deer use was unscarified, seed blocks and scarified while moose use was seed blocks, scarified and unscarified. In the scarified block, big game use was greatest within 6 m of seed blocks whereas use was more extensive in the unscarified block. In the summer of Year 25, a small herd of elk and 5 or 6 deer used the unscarified and to a lesser extent the scarified blocks. Gravel pit and other human activities kept big game populations far below the range carrying capacity of the clear-cuts. Winter use was negligible but deer and elk attempted to use the clear-cuts in spring to use the new grass and forb growth. In the summer of Year 26, one herd of 4+ elk were seen in the unscarified block and light deer use also existed. No big game pellet groups occurred on the plots indicating light big game use. Within a week of the opening of the September hunting season, the elk had moved north across the Athabasca River and deer had vacated the clear-cuts. In January and March of Year 27, no big game were using the clear-cuts.

Grouse

In spruce clear-cuts, spruce grouse disappeared following logging but small numbers of nesting blue grouse used the scarified block during Years 3-25 in summer. A light population of ruffed grouse used both clear-cut blocks but did not become common until Year 26. By Year 32, they were common in the scarified block.

In pine clear-cuts, all grouse disappeared following logging and were non-existent during Years 1-26. In Year 32, spruce grouse were common in both clear-cuts, especially the scarified block while ruffed grouse occurred only around the perimeter of the young pine forest.

In mixedwood clear-cuts, ruffed grouse remained and spruce grouse disappeared from the unscarified block following logging. Both disappeared from the scarified block. By Year 26, ruffed grouse were present in both clear-cuts during winter but were only one-third as abundant as grouse in the adjacent mature block.

Furbearing Mammals

Their numbers were depleted following logging, except weasels, coyotes and lynx which responded to an increased density of mice and hares. Furbearers remained scarce to Year 17. By Year 26, red squirrels were common in all unscarified blocks but not in scarified blocks. For the three forests, the abundance of red squirrels was 31 and 4 times greater in the mature than in scarified and unscarified blocks, respectively. Considering five furbearers (coyote, wolf, lynx, weasel, squirrel), their abundance was 17 and 3 times greater in mature than in scarified and unscarified blocks. They were 8.6 and 7.0 times greater in the mixedwood than in spruce and pine forest blocks at Year 27.

Snowshoe Hares

Their numbers remained low during Years 1-10 but were more abundant in unscarified than scarified blocks in spruce and mixedwood forests. In Year 25 (1981), their numbers were high in all three forests but especially in mixedwood and pine forest blocks. Browsing of coniferous and deciduous woody species indicated high abundance during the previous 2 or 3 years. In January 1983 (Year 27), highest densities were in mixedwood blocks where abundance values (track counts) were 2.4

and 1.1 times greater than in spruce and pine blocks. Highest densities were in unscarified blocks except for the spruce forest where the density was highest in the mature block.

Hares girdled 66.5 and 48.0% of pine in scarified and unscarified blocks of the pine forest in Year 26. Girdling of conifers was not noticeable within the spruce and mixedwood clear-cuts.

Table 1. Winter abundance of wildlife within mature and 26 year-old scarified and unscarified clear-cut blocks in three forest types, January 1983.

BLOCKS	DENSITIES* of SETS of TRACKS/HA										
	BIG GAME		CARNIVORES				RODENTS			BIRDS	
	Deer	Moose	Coyote	Wolf	Lynx	Weasel	S.S. Hare	Red Squirrel	Mice	Ruffed Grouse	TOTALS
CAMP 1 (WHITE SPRUCE)											
Mature	0	0	33	0	0	0	923	31	25	0	1012
Unscarified	27	0	29	0	15	10	471	56	537	0	1145
Scarified	10	0	8	0	0	4	218	0	142	31	413
CAMP 5 (LODGEPOLE PINE)											
Mature	0	0	15	0	4	0	687	152	0	0	858
Unscarified	2	4	23	2	0	0	1396	21	0	0	1448
Scarified	8	2	12	0	0	0	1341	0	0	0	1363
CAMP 9 (MIXEDWOOD)											
Mature	0	0	58	0	0	0	1481	1179	4	25	2747
Unscarified	0	0	67	0	0	2	2191	246	10	8	2524
Scarified	10	0	15	0	0	2	181	44	2	6	250

*The sample size was two belt-transects (4 m x 300 m) = 2400 m^2 or 0.24 ha. 2 samples = 0.48 ha. Values/ha = total for Samples 1 + 2 x 2.083.

Table 2. Winter versus summer big game abundance following logging in three forest types.

YEAR	FOREST TYPE	PELLET GROUPS PER HECTARE							
		DEER		ELK		MOOSE		TOTALS	
		SC*	UN*	SC	UN	SC	UN	SC	UN
1	Mixedwood	0/0	0/17√	0/0	0/0	0/0	0/0	0/0	0/17
	Pine	0/0	0/0	0/0	0/17	0/17	0/32	0/17	0/50
	Spruce	0/17	0/0	0/17	0/0	0/0	0/17	0/35	0/17
6	Mixedwood	50/17	17/50	250/50	132/17	0/0	17/0	300/67	167/67
	Pine	0/0	0/0	0/17	0/32	0/0	0/0	0/17	0/32
	Spruce	0/17	0/32	0/0	0/17	17/0	0/0	17/17	0/50
9	Mixedwood	15/15	45/0	242/32	182/32	75/0	15/0	332/45	242/30
	Pine	0/0	0/0	0/0	0/0	45/0	60/15	45/0	60/15
	Spruce	30/0	0/0	15/0	0/15	30/0	0/0	75/0	0/15
17	Mixedwood	-	-	-	-	-	-	-	-
	Pine	-	-	-	-	-	-	-	-
	Spruce	55/55	325/270	0/55	300/107	0	0	55/110	625/377
26	Mixedwood	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Pine	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
	Spruce	162/0	265/0	135/0	135/0	107/0	0/0	404/0	400/0
32	Mixedwood	0/20	92/12	0/0	10/0	0/0	0/0	0/20	102/12
	Pine	60/65	102/38	5/5	0/0	25/20	24/6	90/90	126/44
	Spruce	106/54	294/112	26/24	25/15	0/0	0/0	132/78	319/127

* SC = Scarified, UN = Unscarified

√ 0 = Winter, 17 = Summer

Table 3. Big game sign occurrence for each species using Wilcoxan signed- rank tests in scarified (SC) and unscarified (UN) clear-cuts during Years 1-27.

Species	ΣSC	ΣUN	ΣSC ranks	ΣUN ranks	ΣProb.[1]	N[2]
			WHITE SPRUCE FOREST			
Deer	48	100	30	64	.005	24
Elk	6	35	6	29	.005	13
Moose	4	10	4	10	.010	9
			LODGEPOLE PINE FOREST			
Deer	4	21	3	13	.047	6
Elk	1	8	1	6	.016	6
Moose	12	12	4	12	.010	10
			MIXEDWOOD FOREST			
Deer	1	11	1	7	.016	6
Elk	17	24	12	19	.027	11
Moose	0	1	0	1	*	1

* Sample size insufficient for testing.
SC Sum of signed differences (scarified).
UN Sum of signed differences (unscarified).
SC rank Sum of signed-rank differences (scarified).
UN rank Sum of signed-rank differences (unscarified).

[1]Probability values <.05 are significant.
[2]Number of surveys where sign was present.

Table 4. Total big game sign occurrence using Wilcoxan signed-rank tests in scarified (SC) and unscarified clear-cuts for three time periods (Years 1-9, 17, 26-27).

Years After	ΣSC	ΣUN	ΣSC ranks	ΣUN ranks	ΣProb.	N[1]
			WHITE SPRUCE FOREST			
1-9	13	50	13	44	.004	14
17	0	38	0	6	.060	3
26-27	18	18	10	12	>.01 nsd	7
			LODGEPOLE PINE FOREST			
1-9	0	5	0	5	.060	3
17	-	-	-	-	-	-
26-27	11	30	7	22	.055	8
			MIXEDWOOD FOREST			
1-9	12	9	5	4	>.10 nsd	4
17	-	-	-	-	-	-
26-27	3	26	2	16	.016	7

\- No sampling conducted.
1 Number of surveys where sign was present.
nsd no significant difference.

Appendix 9

Browse Forage Production in 32 Year-old Clear-cuts, 1988

Table 1. Browse forage production (gms/20 m2)* in 32 year-old clear-cuts, 1988.

BLOCK SAMPLE	GREEN or DRY	WILLOW L**	WILLOW S**	POPLAR L	POPLAR S	ROSE L	ROSE S	HONEY-SUCKLE L	HONEY-SUCKLE S	BIRCH L	BIRCH S	LOW-BUSH CRANBERRY L	LOW-BUSH CRANBERRY S	OTHERS L	OTHERS S	TOTALS
WHITE SPRUCE FOREST																
														AMAL		
SC-1	GR	695	589	599	597	508	360			180	140	54	49	0	0	
	DR	313	377	258	400	234	252			81	91	23	32	0	0	
SC-2	GR	795	866	583	486	99	50			0	0	2	2	0	0	
	DR	358	554	251	326	46	35			0	0	1	1	0	0	
SC-Ave	GR	745	727	591	541	303	205			90	70	28	25	0	0	(3325)
	DR	335	465	254	363	140	143			40	45	12	16	0	0	(1813)
UN-Ave	GR	436	371	365	359	217	193	5	8	35	40	69	91	330	373	
	DR	196	237	157	241	100	135	2	5	16	26	30	60	142	246	
UN-2	GR	1038	1085	410	325	152	123	4	6	15	20	13	13	0	0	
	DR	467	694	176	218	70	86	2	4	7	13	6	9	0	0	
UN-Ave	GR	737	728	387	342	184	158	4	7	25	30	41	52	165	186	(3046)
	DR	331	465	166	229	85	110	2	4	12	19	18	34	71	123	(1669)
LODGEPOLE PINE FOREST																
								ABLA		**RUST**				**ALCR**		
SC-1	GR	368	302	476	403	100	97	2	2	0	0	119	157	415	410	
	DR	166	193	205	270	46	68	1	1	0	0	51	104	207	287	
SC-2	GR	165	95	335	320	67	74	30	25	2	3	281	324	920	1016	
	DR	74	61	144	214	31	52	13	16	1	2	121	214	460	711	
SC-Ave	GR	266	198	405	361	83	85	16	13	1	1	200	240	667	713	(3249)
	DR	120	127	174	242	38	60	7	8	1	1	86	159	333	499	(1855)
										RIOX						
UN-1	GR	48	73	270	225	82	90	0	0	62	62	258	268	734	746	
	DR	22	47	116	151	38	63	0	0	29	43	111	177	367	522	
								RUST								
UN-2	GR	320	355	253	271	101	103	15	15	50	45	167	193	1732	1922	
	DR	144	227	109	182	46	72	7	10	23	31	72	127	866	1345	
UN-Ave	GR	184	214	261	248	91	96	7	7	56	53	212	230	1233	1334	(4226)
	DR	83	137	112	166	42	67	3	5	26	37	91	152	616	933	(2470)
MIXEDWOOD FOREST																
								LODI								
SC-1	GR	22	32	603	561	85	85	49	41							(1478)
	DR	10	20	259	376	39	60	22	27							(813)
UN-2	GR	0	0	6	7	153	100	23	27							(316)
	DR	0	0	3	5	70	70	10	18							(176)
										RIOX		**ALCR**				
%H_2O	GR	55	36	57	33	54	30	55	35	54	30	57	34	50	30	
								SOSC		**AMAL**		**ALGA**		**RUST**		
								55	36	57	34	54	28	54	30	
								BEOC								
								55	35							

* Results are grams from 20,1 m^2 plots = 20 m^2 sample. To convert to kg/ha multiply by .5.
** L = Leaves S = stems ≤.75 cm diameter.

Table 2. Woody forage (browse) production and consumption in spruce clear-cuts 5, 17 and 26 years after logging.

Species	Mature		YEARS AFTER LOGGING 5		17		26	
			SC	UN	SC	UN	SC	UN
% Use of Stems [1]								
	*	**						
Poplar	37.1	0	0	.7	4.8	5.0	.7	3.0
Rose	.8	.8	1.1	1.8	12.8	25.2	24.9	27.8
Willow	16.8	0	1.5	2.4	6.0	12.3	11.0	9.3
Others	12.2	6.0	.4	1.5	4.1	3.2	16.6	16.4
x̄ Total	14.5	1.0	1.3	2.5	12.4	20.5	20.2	22.6
Rank	4	8	7	6	5	2	3	1
Biomass Production (kg/ha)[1] Green Weight								
Poplar	23.5		509.6	291.2	1419.0	1536.6	829.0	493.0
Rose	161.3		302.4	267.7	196.0	236.3	247.0	393.0
Willow	362.8		72.8	383.0	222.9	464.8	969.0	926.0
Others	44.8		78.4	54.9	68.3	28.0	30.0	26.0
x̄ Total	592.4		963.2	996.8	1906.2	2265.7	2074.0	1838.0
Rank	7		6	5	3	1	2	4
Total Biomass Used (kg/ha)[1] in Summer								
	*	**						
Poplar	8.6	0	0	2.0	68.1	76.8	5.8	14.8
Rose	1.3	1.3	3.4	4.8	25.1	59.6	61.5	109.3
Willow	60.8	0	1.1	9.2	13.3	57.2	106.6	85.7
Others	5.5	2.7	.3	.8	2.8	.9	4.9	4.3
x̄ Total	76.2	4.0	4.8	16.8	109.3	194.5	178.9	214.1
Rank	5	8	7	6	4	2	3	1

* Field surveys conducted five years after nearby clear-cuts had been logged.
** Field surveys conducted 26 years after nearby clear-cuts had been logged.
[1] Current year's woody plant growth.

Table 3. Woody forage (browse) production and consumption in spruce, pine and mixedwood clear-cuts 26 years after logging.

Species	Spruce SC	Spruce UN	Pine SC	Pine UN	Mixedwood SC	Mixedwood UN
Biomass Production[1] (kg/ha)						
Poplar	829 (377)	493 (258)	389 (182)	46 (22)	749 (358)	202 (97)
Rose	247 (110)	393 (163)	162 (64)	242 (117)	171 (89)	104 (72)
Willow	969 (435)	962 (436)	191 (87)	271 (125)	316 (139)	6 (3)
Others	30 (12)	26 (9)	1316 (686)	1844 (916)	65 (24)	50 (18)
Total	2074 (934)	1838 (866)	2058 (1019)	2403 (1195)	1301 (610)	398 (190)
Rank	3	4	2	1	5	6
Total Biomass Used[2] (kg/ha)						
Poplar	6 (0)	15 (0)	172 (4)	30 (0)	159 (0)	72 (0)
Rose	61 (0)	109 (3)	132 (5)	154 (8)	25 (6)	49 (6)
Willow	107 (0)	86 (0)	99 (0)	99 (3)	75 (39)	4 (4)
Others	5 (0)	4 (3)	917 (2)	1025 (0)	20 (5)	18 (1)
Total	170 (0)	214 (5)	1320 (11)	1308 (11)	279 (50)	143 (11)
Rank	5 (6)	4 (5)	1 (3)	2 (4)	3 (1)	6 (2)
Percent Biomass Used in Summer Plus Winter, and in Summer ( ) Only						
Poplar	0.7 (0)	3.0 (0)	44.3 (0.9)	38.0 (0)	21.3 (0)	35.8 (0)
Rose	24.9 (0)	27.8 (0.7)	81.6 (3.1)	63.6 (3.2)	14.9 (3.4)	35.3 (4.0)
Willow	11.0 (0)	9.3 (0)	51.7 (0)	36.4 (1.0)	23.9 (18.4)	70.0 (2.9)
Others	16.6 (0)	16.4 (9.3)	48.6 (0.2)	43.2 (0)	31.3 (6.8)	40.1 (2.5)
Total	20.2 (0)	22.6 (0.6)	69.7 (0.5)	55.6 (0.4)	20.0 (3.7)	36.1 (2.8)

1 Current years growth of leaves and twigs combined; green and dry ( ) weights up to 2.4 m (8.0 ft.) above ground.

2 Biomass used is summer plus winter use from visual use of all plots and summer only ( ) use derived from clip plot data.

Appendix 10

Avifauna Sightings in Clear-cuts and Mature Forests

Table 1. Grouse observed in 32 year-old clear-cuts, June-August, 1988.

MONTH	GROUSE SPECIES	MIXEDWOOD SCAR.	MIXEDWOOD UNSC.	PINE SCAR.	PINE UNSC.	SPRUCE SCAR.	SPRUCE UNSC.
JUNE	Ruffed					2 females with broods	
	Spruce			1			
JULY	Ruffed	1	1				
	Spruce				female with 7 chicks		
AUGUST	Ruffed					female with 6 juv.	
	Spruce			2,4			
OCTOBER	Ruffed		1				
	Spruce	1 also in mature	1				
Totals	Ruffed	1	2	0	0	3 broods	none
	Spruce	0	1	7	8	0	0

Table 2. Abundance of birds in mature and 32 year old cleat-cuts of three forest types, summer 1988.

GROUP & SPECIES	WHITE SPRUCE Unsc.	Scar.	Mature	Total	LODGEPOLE PINE Unsc.	Scar.	Mature	Total	MIXEDWOOD Unsc.	Scar.	Mature	Total
Flycatchers												
Traill's	0	6	0	6	0	2	-	2	0	1	0	1
Others	2	0	0	2	0	3	-	3	0	2	0	2
Chickadees												
Black-capped	4	0	0	4	6	2	-	8	8	1	0	9
Boreal	0	0	0	0	6	0	-	6	0	0	0	0
Thrushes												
Robin	12	32	0	44	1	0	-	1	9	8	1	18
Hermit	2	0	0	2	14	13	-	27	14	16	0	30
Others	2	2	0	4	15	5	-	20	2	5	0	7
Warblers												
Yellow-rumped	11	0	0	11	4	3	-	7	19	1	2	22
Orange-crowned	0	3	0	3	6	2	-	8	1	0	0	1
Others	1	1	1	3	10	4	-	14	0	1	1	2
Vireos												
Warbling	0	1	0	1	4	6	-	10	0	0	0	0
Waxwings												
Cedar	0	12	0	12	0	0	-	0	0	0	0	0
Ravens												
Common	1	0	0	1	3	1	-	4	6	1	1	8
Sparrows												
All	7	9	0	16	4	1	-	5	43	9	2	54
Siskins												
Pine	0	5	0	5	4	0	-	4	24	4	1	29
Juncos												
Dark-eyed	7	6	1	14	6	5	-	11	16	5	1	22
Nuthatches												
White & Red-breasted	2	1	2	5	4	1	-	5	5	1	5	11
Kinglets												
Golden&Ruby-crowned	1	1	0	2	8	3	-	11	2	0	0	2
Finches												
Purple	0	0	0	0	0	0	-	0	1	0	0	1
Crossbills												
Red	0	0	0	0	0	0	-	0	2	1	1	4
Jays												
Gray	5	2	6	13	20	2	-	22	1	0	0	1
Woodpecker												
Flicker	3	1	0	4	6	0	-	6	14	6	3	23

Ruffed	0	8	0	8	0	7	-	7	7	0	0	7
Spruce	0	0	0	0	23	2	-	25	1	0	1	2
Hawks												
Kestrel	0	0	0	0	1	0	-	1	0	0	0	0
Merlin	0	0	0	0	0	0	-	0	0	0	1	1
Goshawk	0	0	0	0	1	0	-	1	0	0	0	0
Others	0	0	0	0	0	0	-	0	0	1	0	1
Bluebird												
Mountain	2	0	0	2	0	0	-	0	0	0	0	0
Swallows												
Tree	0	0	0	0	0	0	-	0	0	1	0	1
Starling												
European	0	0	0	0	0	0	-	0	3	0	0	3
Other birds												
All	22	4	0	26	10	1	-	11	4	1	0	5
Total Birds	83	94	10	187	156	63	-	219	183	65	20	268
Observation Hrs.	30.5	28.5	10.5	69.5	40.0	39.0	-	79	32.5	27.5	13.7	73.7
# Per Hour	2.7	3.3	1.0	2.7	3.9	1.6	-	2.8	5.6	2.4	1.5	3.6
# Species	12	18	4	25	25	17	-	26	22	19	12	30

Table 3 Abundance of avifauna during two successional stages following logging in three forest types.

Species	WHITE SPRUCE Scarified 1-15*	WHITE SPRUCE Scarified 16-27*	WHITE SPRUCE Unscarified 1-15	WHITE SPRUCE Unscarified 16-27	LODGEPOLE PINE Scarified 1-15	LODGEPOLE PINE Scarified 16-27	LODGEPOLE PINE Unscarified 1-15	LODGEPOLE PINE Unscarified 16-27	MIXEDWOOD Scarified 1-15	MIXEDWOOD Scarified 16-27	MIXEDWOOD Unscarified 1-15	MIXEDWOOD Unscarified 16-27
Hawks and Falcons (Accipitridae)												
Sharp-shinned	-	0	-	0	-	0	-	0	-	0	-	1
Northern Goshawk	-	0	-	0	-	0	-	0	-	0	-	3
Swainson's	-	1	-	0	-	0	-	0	-	0	-	0
American kestrel	-	0	-	0	-	0	-	0	-	6	-	4
Merlin	-	0	-	0	-	0	-	0	-	0	-	6
Totals	-	1	-	0	-	0	-	0	-	6	-	14
Grouse (Phasianidae)												
Spruce	0	1	0	1	0	0	0	1	0	0	0	4
Blue	7	3	0	0	0	0	0	0	0	0	0	0
Ruffed	0	9	0	2	0	2	0	0	0	20	8	10
Sharp-tailed	0	0	0	0	3	0	0	0	0	0	0	1
Totals	7	13	0	3	3	2	0	1	0	20	8	14
Woodpeckers (Picidae)												
Northern Flicker	**	1	-	0	-	0	-	2	-	0	-	9
Hairy+Y.b. sapsucker	-	0	-	0	-	0	-	0	-	0	-	7
Totals	-	1	-	0	-	0	-	2	-	6	-	16
Chickadees (Paridae)												
Bl. capped & Boreal	-	2	-	0	-	2	-	2	-	2	-	22
Thrushes (Muscicapidae) and Warblers (Emberizidae)												
Hermit thrush	0	1	0	0	0	0	0	1	0	0	0	0
American Robin	-	1	-	1	-	1	-	2	-	0	-	5
Warblers	-	1	-	1	-	7	-	1	-	0	-	7
Totals	-	3	-	2	-	8	-	4	-	0	-	16
Juncos, Sparrows, Siskins (Emberizidae)												
Song Sparrow	-	3	-	0	-	0	-	0	-	0	-	0
Wh.-crowned sparrow	-	2	-	0	-	0	-	0	-	0	-	0
Dark-eyed junco	-	6	-	8	-	6	-	16	-	5	-	4
Unknown sparrows	-	0	-	0	-	0	-	0	-	8	-	0
Pine Siskin	-	0	-	0	-	2	-	0	-	0	-	2
Totals	-	11	-	8	-	8	-	16	-	13	-	6
Others												
Gray jay	-	0	-	2	-	4	-	2	-	0	-	4
Common nighthawk	0	2	0	0	0	0	0	0	0	3	1	1
Hummingbird	1	0	0	0	0	0	0	0	0	0	0	0
Cedar waxwing	0	0	0	4	0	0	0	0	0	0	0	2
Red-breasted nuthatch	0	1	0	0	0	0	0	1	0	0	0	0
Vireos	-	0	-	0	-	3	-	0	-	0	-	0
Common snipe	0	0	0	1	0	0	0	1	0	0	0	0
Upland sandpiper	0	0	0	2	0	0	0	0	0	0	0	0
Starling	0	0	0	0	0	0	0	0	0	0	0	1
Totals	1	3	0	9	0	7	0	4	0	3	1	8
Grand totals	8	34	0	22	3	27	0	27	0	44	9	92

* Years 1-15 (Grass-forb and Shrub-seedling stage) and Years 16-27 (Pole-sapling) stage.

** No data. These were species not recorded during Years 1-15.

Appendix 11

Density of Tree Snags and Use by Wildlife

Year 32 (1988)

Table 1a. Density of snags with cavities.

FOREST BLOCK	TYPE OF TREE SNAGS, THEIR DENSITIES AND CAVITIES									
	Spruce		Pine		Balsam Poplar		Aspen		**Totals**	
	Snags Per Ha	Cavities Per Ha	Snags Per Ha	Cavities Per Ha	Snags Per Ha	Cavities Per Ha	Snags Per Ha	Cavities Per Ha	Snags Per Ha	Cavities Per Ha
MIXEDWOOD FOREST										
SC[1]	0	-	0	-	0	-	0	-	0	-
UN - 1	0	-	14	2	0	-	10	10	24	12
- 2	4	4	4	6	2	4	12	8	22	22
AVE.UN[1]	2	2	9	4	1	2	11	9	23	17
MATURE[1]	24	4	18	10	0	0	34	0	76	14
LODGEPOLE PINE FOREST										
SC - 1	0	-	0	-	0	-	0	-	0	-
- 2	0	-	6	2	24	0	0	-	30	2
AVE.SC	0	-	3	1	12	0	0	-	15	1
- 1	0	-	32	8	0	-	0	-	32	8
- 2	0	-	54	6	0	-	0	-	54	6
AVE.UN	0	-	43	7	0	-	0	-	43	7
WHITE SPRUCE FOREST										
SC - 1	0	-	0	-	0	-	0	-	0	-
- 2	0	-	0	-	0	-	0	-	0	-
AVE.SC	0	-	0	-	0	-	0	-	0	-
UN - 1	30	8	0	-	2	0	0	-	32	8
- 2	10	6	0	-	2	0	0	-	12	6
AVE.UN	20	7	0	-	2	0	0	-	22	7
MATURE	42	24	0	-	6	0	0	-	48	24

[1] SC = Scarified. UN = Scarified clear-cuts. Mature = Unlogged forest.

Table 1b. Density of tree snags of various diameters.

	TOTAL # SNAGS	SNAG DIAMETER (CM) 15-30	31-35	36-50	51+
MIXEDWOOD FOREST					
SC[1]	0	0	0	0	0
UN - 1	24	14	2	8	0
- 2	22	8	6	8	0
AVE. UN[1]	24	12	4	8	0
MATURE [1]	76	68	8	0	0
LODGEPOLE PINE FOREST					
SC - 1	0	0	0	0	0
- 2	30	24	4	2	0
AVE. SC	16	12	2	2	0
UN - 1	32	20	8	4	0
- 2	54	42	8	4	0
AVE. UN	44	32	8	4	0
WHITE SPRUCE FOREST					
SC - 1	0	0	0	0	0
- 2	0	0	0	0	0
AVE. SC	0	0	0	0	0
UN - 1	32	28	2	0	0
- 2	12	10	2	0	0
AVE. UN	24	20	2	0	1
MATURE	48	38	8	0	0

[1] SC = Scarified, UN = Scarified clear-cuts, Mature = Unlogged forest.

Appendix 12

Glossary of Terms

Abundance - Relative abundance of one wildlife species over time or of one species to another. Abundance based on one or more of the following direct and indirect census indices: faecal pellet group density, sets of tracks per unit area, beds, nests, cavities, cursury observations, aerial/ground counts. Does not refer to actual animal numbers per unit area (see Density).

Big Game - Moose, elk (wapiti), mule and white-tailed deer. See Cervids.

Biomass (browse) - The weight (green or dry) of woody plant forage up to 2.4 (8 ft) above ground.

Browse - That part of leaf and twig growth of shrubs, woody vines and trees available for animal consumption and known to be used as food by the animal discussed.

Canopy Cover - The vertical projection downward of the aerial portion of shrubs and trees, expressed as percent of ground occupied.

Carrying Capacity (Range Carrying Capacity) - The maximum stocking rate possible without inducing damage to vegetation or related resources.

Cervids - Big game of the deer family. For this study they are moose, elk, white-tailed and mule deer.

Cover - Shelter and security for birds and mammals. Shelter cover refers to thermal cover (protection against wind chill in winter or excessive heat in summer). Security cover refers to escape or hiding cover and is inversely related to visibility.

Degree of Use - The proportion of current year's forage production that is consumed and/or destroyed by grazing animals.

Density - The number of individuals per unit area.

Diet - A function of coverage and degree of utilization. For grasses (graminoids) and forbs in this study, it refers to average use within plots times coverage. Obtained by multiplying % coverage x use and then dividing by the total use value of all forbs or grasses.

Exposure - Direction of slope with respect to points of a compass.

Fauna - The animal life of the region.

Flora - The plant species of an area.

Forb - Any herbaceous plant other than graminoids (grass, sedge, rush). Those herbaceous plants commonly referred to as wild flowers.

Grass - Refers to members of the true grassses (Gramineae) plus grasslike (Cyperaceae and Juncaceae) plants.

Habitat - The natural abode of an animal, including all biotic, climatic, and edalphic factors affecting life. In this study habitat was assessed on the basis of vegetation and its ability to provide suitable cover.

Herbaceous - Combined forb and grass cover or biomass.

Native Species - A species which is part of the original fauna or flora of the area in question.

Numbers - Values based on quantative numbers observed. If values are counts per unit area then numbers are synonymous with density.

Palatability - The relish with which a plant species is consumed by an animal.

Plant Succession - See Succession.

Preference (Grazing Preference) - Selection of certain plants over others by grazing animals.

Preferred Species - Species preferred by animals and grazed by first choice.

Range Carrying Capacity - See Carrying Capacity.

Species Composition - The proportions of various plant species in relation to the total of a given area; expressed as cover, density, weight etc.

Stocking Rate (Stocking Density) - The relationship between number of animals and area of land at any instant of time.

Succession - The process of vegetational development whereby an area becomes successively occupied by different plant communites of higher ecological order.

Use - See Degree of Use.

Utilization - See Degree of Use.

N.L.C. - B.N.C.
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