Longterm (1956–1996) effects of clearcut logging and scarification on forest structure and biota in spruce, mixedwood, and pine communities of west-central Alberta.

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keywords: clearcut logging, scarification, silviculture, biodiversity, forest structure, succession, forest habitat, browse, ungulates

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ABSTRACT

Multiple forest types (**SPRUCE**, **MIXEDWOOD**, and **PINE**) treated with clear-cutting logging in the mid to late 1950's in west-central Alberta experienced significant changes in plant community structure during the following four decades. Successional patterns in post-logging trajectories occurred for cover and species richness of graminoid, forb, shrub, and nonvascular taxa, and these patterns were influenced greatly by regeneration (both density and height) of hardwood and softwood tree species. In general, ground cover of herbaceous vegetation increased rapidly during Yrs 1-6, declined during Yrs 6-26, then increased during Yrs 26-39. Snags and down wood densities also underwent significant changes following logging. The post-logging successional patterns in aggregate forest structure (live trees, snags, down wood, understory structure, and forage availability) were related to changes in abundance of several wildlife groups.

A major aspect of this research focused on possible differences in forest structure, tree growth, and wildlife response to clearcuts that were either scarified or left unscarified following logging. In general, unscarified cutblocks maintained higher levels of forest structure than did scarified cutblocks. Major elements of increased structural complexity found in unscarified cutblocks included multiple age cohorts of regenerating trees, higher densities of residual trees, higher rates of conifer recruitment into taller height classes, and higher density and more varied rot classes of snags.

Composition and abundance of wildlife taxa were correlated with numerous aspects of forest structure, including tree age class diversity, ratio of hardwood/softwood species, understory visibility, and abundance and rot classes of snags and down wood. Combined use by cervids was higher on unscarified than scarified cutblocks for **SPRUCE** and **PINE** forests, and higher on scarified **MIXEDWOOD** cutblocks than on unscarified cutblocks. Combined use by cavity-dependent birds was higher on unscarified than scarified cutblocks for **SPRUCE** and **MIXEDWOOD** forests, and higher on scarified **PINE** cutblocks than on unscarified cutblocks.

The use of regenerating cutblocks by several wildlife taxal groups (particularly cervids) appeared related to the proximity of unharvested forest strips between the experimental cutblocks. The removal of these residual strips at Yrs 12-15 was associated with significant reductions in cervid densities on the original cutblocks. This outcome suggests the critical importance of appropriate spatial distribution of young and old forests to certain wildlife species.

The major rationale for site scarification and subsequent planting is to improve establishment and growth performance of commercial tree species. The findings of this study over four decades do not ascribe any fiber growth advantage to scarification and subsequent plantings (or aerially seeding) in comparison to strategies where non-merchantable trees are retained, and natural regeneration occurs. Rather, for white spruce trees in both the canopy and the subcanopy strata of **SPRUCE** and **MIXEDWOOD** cutblocks, densities were significantly higher in unscarified than scarified cutblocks at the conclusion of this study.

Given the major changes in forest structure caused by scarification (generally leading to a more simple community structure), the reduced abundance of several wildlife taxa associated with this site preparation technique, and the absence of improved commercial tree growth on scarified sites, this report questions the economic and ecological wisdom of this commonly employed forest regeneration technique. This study suggests the need for additional studies that contrast the ecological, social, and economic differences of various harvest and regeneration strategies. It is imperative that these studies include experimental harvest and regeneration treatments that approximate those natural disturbance regimes that perturb forest communities.

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INTRODUCTION

Societal expectations of public forests extend beyond fiber production, requiring forest managers to devise harvest and regeneration strategies that concurrently sustain fiber production, ecosystem processes, and biota (Hunter 1990, Hansen et al. 1991). Achieving these goals has proven challenging and has lead to a critical examination of many industrial forestry practices in Canada (Dancik *et al*. 1990, Alberta Forest Conservation Strategy 1997) and in the United States (Franklin 1990, Maser 1990). Forest harvest and regeneration systems based on removal of all merchantable trees (e.g., clearcutting) and the physical preparation of the cutblock soil surface (site scarification) for purposes of conifer establishment have dominated Alberta's and Canada's commercial logging history (Natural Resources Canada 1994). This prevalent harvest and regeneration strategy has been encouraged or required by government regulations defining acceptable wood utilization and regeneration standards (for example, Alberta Provincial Operating and Ground Rules 1999). Although the practice of clearcutting and scarification have been widely adopted by silviculturalists as an appropriate strategy for managing even-aged stands of white spruce, lodgepole pine, and jack pine forests, clearcutting practices in general have been criticized for altering above and below-ground forest structure (Berg et al. 1994, Ryden et al. 1997), for impairing natural regeneration of trees (De Grace 1950 Day 1963, Maser 1990, Hansen et al. 1991, Timoney and Robinson 1996), and for altering wildlife habitat and microclimate (Raphael and White 1984, Harmon et al. 1986). In reviewing the scientific foundation for various forestry practices, Timoney (1999) concluded that the ecological and scientific basis for clearcutting and physical site preparation in boreal forests is decidedly weak, and that it's pre-eminence as a harvest and regeneration strategy is based largely on economic considerations.

Based on extensive research of forest ecosystem dynamics in the Pacific Northwest and elsewhere, new harvest and regeneration methods (i.e., "new forestry") have been proposed that allow for the removal of timber volumes while protecting seed trees, providing forest structure, and maintaining shelter for seedling protection (Robertson and Salwasser 199, B.C Ministry of Environment 1995, Weetman 1995, Sauder 1992). In the boreal and Rocky Mountain forests of western Canada, numerous studies (De Grace 1950, Lees 1963, Waldron 1964, Jarvis et al. 1966., Coates and Burton 1997) have proposed various forms of partial cutting as ecologically preferable to clearcutting. Several forestry companies have tested these methods; however, they are sparingly implemented on the commercial landscape, while clearcut harvesting has remained the dominant cutting method in most jurisdictions. There are several reasons why most companies prefer clearcut harvesting. It is the most economical and safe method to harvest trees on a commercial scale. Clearcuts are easy to design on harvesting maps and it is relatively easy to determine pre-harvest tree volumes. However, there is a large body of information compiled that demonstrates that clearcut logging may lead to degradation of naturally functioning ecosystems. These include disruptions to soil flora, altered rates of nutrient cycling, damage to soil structure, and long-term loss of soil organic content. Temporal changes may include altered rates of forest succession and altered successional trajectories. Species diversity of trees can be simplified by clearcut harvesting through planting of one or few tree species. Understory diversity changes can occur by the spread of seeds on harvesting equipment and in the manure of animals that use clearcuts, and by wind dispersal from nearby areas. Off-site effects may include changes to wildlife use of the landscape, alterations to soil hydrology, and changes in regional nutrient budgets.

Long-term studies of ecosystem change are required to understand the processes of forest dynamics over the length of a typical forest cycle (~100 years). Much of our current understanding of long-term forest changes is based on predictions from forest theory (such as forest succession), studies on forests from other geographic locations (e.g. Eastern United States or Europe), or from forest chronosequence studies which link together observations from several different forest stands varying in age (Lee et al. 1995, Stelfox et al. 1995; Lee et al. 1999, Dix and Swan 1971, Holm and Torbjorn 1999). Theories of forest dynamics are critical to understanding general processes but have current limitations because of a lack of empirical evidence and because theories are only useful for the average forest in an area and cannot be used to predict changes on a specific forest site. Similarly, although we can gain substantial insight from studies from other geographic locations, several differences in forest dynamics can be expected to occur at each forest location due to regional or local differences in climate, soils, terrain factors and tree species. A major concern with chronosequence studies is that it is difficult to separate the changes in forest composition and structure that relate to aging or developmental changes from those which are due to site factors or stochastic processes.

To address concerns about the paucity of longterm data on forest and wildlife response to forest practices, a study was initiated in 1956 in the foothills of west-central Alberta to assess forest dynamics following clearcut logging and post-harvest site scarification. Three forest types (spruce, spruce/aspen/pine mixedwood, and pine) were selected. In addition to examining the effects of regeneration among forest types, the regeneration treatment (site scarification) was also compared in each forest type to a non-scarified regeneration strategy, and each regenerating forest was compared to conditions that existed in an uncut control forest. Long-term changes were examined on the following aspects of forest dynamics: tree regeneration (tree density and species composition), forest community structure, forest cover and browse availability, and abundance of selected wildlife populations.

The primary questions addressed during this study were:

(6) How does forest community structure change following clearcut logging in each of spruce, mixedwood and pine forests?

(7) How similar is each regenerating forest to the conditions in the unharvested controls?

(8) How does site preparation (scarification) following clearcut logging affect tree regeneration and forest community structure in each forest type?

(9) How do selected wildlife species respond to forest harvest, to site preparation, and to post-harvest forests as the forests develop towards a mature state?

This report summarizes patterns in forest community structure and selected flora and fauna observed during the first 40 years following harvest treatment in spruce, mixedwood and pine forests. Previous reports of this study include Stelfox 1962, 1963, 1981, 1983, 1988; Stelfox, Telfer and Lynch 1973; Stelfox, Lynch and McGillis 1974, 1976; and Stelfox and Cormack 1962.

STUDY AREA

This study examined **SPRUCE**, **MIXEDWOOD**, and **PINE** forests in the foothills of west-central Alberta (53°25’N, 117°35’W; Figure 1). This area is composed of primarily coniferous forests in a moderate to high (1100–1400 m a.s.l.) elevation area east of Jasper National Park in the central Canadian Rocky Mountains. All data were collected within the Forest Management Agreement (FMA) currently licensed to Weldwood of Canada Ltd. This company manages the forest land base for commercial harvest to supply a kraft pulp mill and modern sawmill operation. The **SPRUCE** and **MIXEDWOOD** forest sites are located on the broad valley bottom of the Athabasca River whereas the **PINE** forest is located on an upland site approximately 200 m above the valley floor.

Based on the natural regions classification system of Alberta Environmental (1995), the **SPRUCE** forests occur in the montane subregion, the **MIXEDWOOD** forests occur in the lower foothills subregion, and the **PINE** forests occur in the upper foothills subregion. A physical summary of the experimental forests is provided in Table 1.

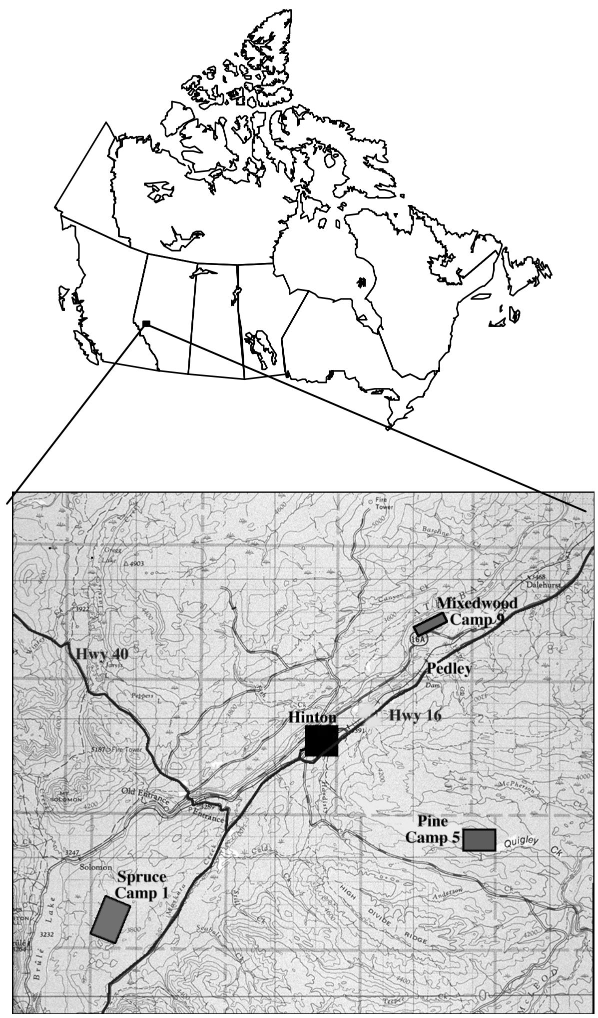


Figure 1. Location of research sites.

Table 1. General biophysical description of research sites.

Forest Type	Natural Subregion	Latitude	Longitude	Elevation (m a.s.l.)	Cutblock Area (ha)	Age at Harvest	Descriptive Location
SPRUCE (Camp 1)	Montane	53°17’N	117°54’W	1,150	400	125–140 yrs	west of Wildhorse Lake; 16 km west of Hinton
MIXEDWOOD (Camp 9)	Lower Foothills	53°29’N	117°26’W	1,100	205	80–100 yrs	north of Pedley; south of Athabasca River on river terrace
PINE (Camp 5)	Upper Foothills	53°21’N	117°24’W	1,350	283	60–70 yrs	13 km south of Hinton; north of Quigley Creek; east of Hinton-Robb road

Management History

This region has been managed since 1954 as a commercial pulp and lumber forest, initially by Northwest Pulp and Power Ltd. (1957–1977), subsequently by St. Regis (1978–1984) and Champion Forest Products (1985–1987), and currently by Weldwood of Canada (Hinton Division; 1988–1996). Forest management is dominated by two pass clearcut harvesting in blocks of 50–500 ha clustered within compartments of ~10,000 ha.

Climate

The climate of the study area is described by Powell and McIver (1976), Powell (1977), and Hillman *et al.* (1978) as continental subhumid, with long, cold winters modified by short periods of chinook conditions (föhn wind), and short, cool summers. The valley floor of the Athabasca River, in which the **SPRUCE** and **MIXEDWOOD** forests are positioned, frequently receive winter chinook conditions that include strong winds and wind-blown loess deposits. Frost puddling of this topographically depressed region is not uncommon.

Average annual precipitation is 330–390 mm for the **SPRUCE** and **MIXEDWOOD** forests (elevation 1100–1150 m) and 450 mm for the **PINE** forest (elevation 1350 m). Rainfall accounts for approximately 70% of precipitation. Mean yearly temperature is 3.9°C at 1000 m and 0 °C at the higher **PINE** forest site. The study areas are generally snow-covered from early November until mid/late April.

Daily mean, maximum and minimum temperatures, and daily total precipitation data were obtained for the period 1956-1996 for the Hinton area (Environment Canada 1999). Climate records for the Hinton area are sporadic and the data had to be combined from four different area weather stations in order to obtain a near-complete chronological record for the study period. These were the Hinton Main, Hinton Forest Technology School, Jasper Hinton Airport and the Jasper National Park East-Gate stations. All stations are within 30 km of the town of Hinton. When more than one station had data for a particular period, the data from the chronologically overlapping stations were averaged together to obtain a single value for that particular period.

Total daily precipitation (mm) was summed for each month, year, and station. When data existed for more than one station they were averaged together as noted above. Precipitation was then summed for each year when there was a complete monthly record. Precipitation was also separately summed for the months May to September, a period which represents the growing season. These results were plotted to examine the long-term trend in precipitation among years. A polynomial curve (3rd order) was fitted to the data to aid in the interpretation of results.

Temperature data was averaged within each month of each year for each station. These mean monthly values were then averaged among stations to obtain a near-complete temperature record. Finally, these means were averaged for each year in which all 12 months had recorded data. If data did not exist for all 12 months the yearly mean temperature could not be determined. As with precipitation, the growing season (May – Sept) temperature was also separately determined. These were plotted to examine long-term trends. A fitted polynomial curve (3rd order) was fitted to the data to aid in the interpretation of results.

Annual precipitation varied from approximately 230 mm in 1958 to 900 mm in 1989 (Figure 2). The long-term trend was an increase in precipitation from 1958 – 1996. From 1958 – 1975, 400 – 500 mm of precipitation occurred on average. From 1976 – 1996 the long-term average was between 500 and 600 mm.

Average annual mean temperature varied from a low of 1.5 °C in 1972 to a high of 5.5 °C in 1987 (Figure 3). The long-term trends in average annual temperature were a decrease in temperature over the years 1958 – 1969, followed by an increase to a peak in the early 1990s. In addition, the variability among years increased throughout the entire study period. Between the years 1958 and 1975 temperature varied from 1.5 to 3.5 °C. Between 1976 and 1995 temperature varied from 1.7 to 5.5 °C.

In the growing season (May – September) the annual mean of the mean daily temperature was approximately 12°C from 1958 – 1996. The mean temperature varied from 10.7 °C in 1968 to 13 °C in 1988. There was only a slight increase in growing season temperature during the study period. During these months the precipitation varied from 140 mm in 1967 to 570 mm in 1989. The long-term trend was a decrease from the 1960s to the 1970s, followed by an increase in the 1980s and early 1990s, with a subsequent decrease in the mid-1990s.

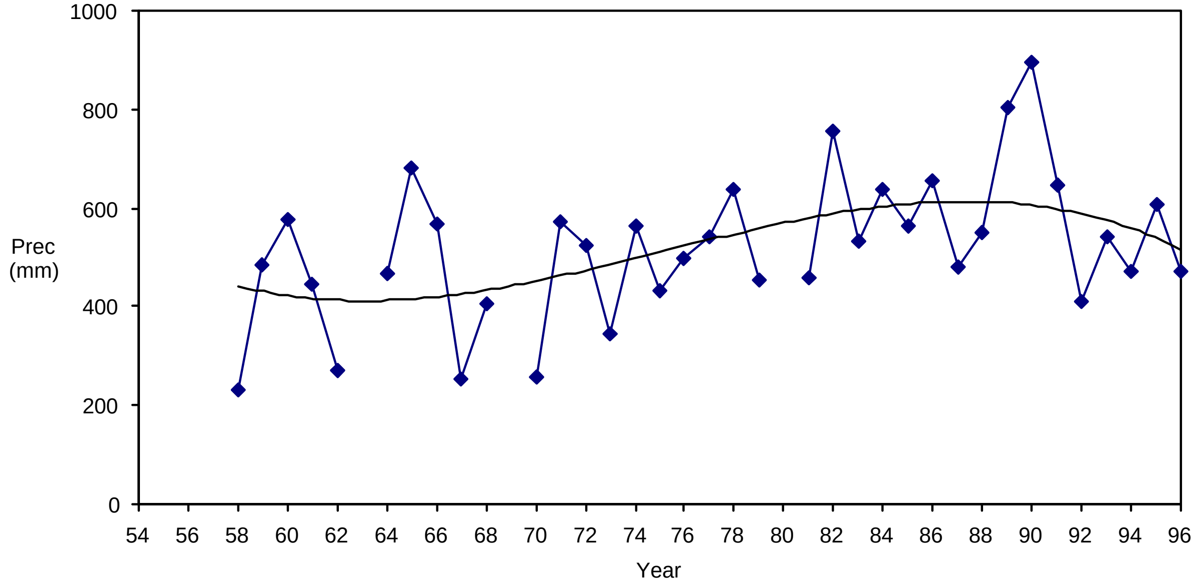


Figure 2. Mean annual precipitation in the Hinton, Alberta region, 1958 - 1996.

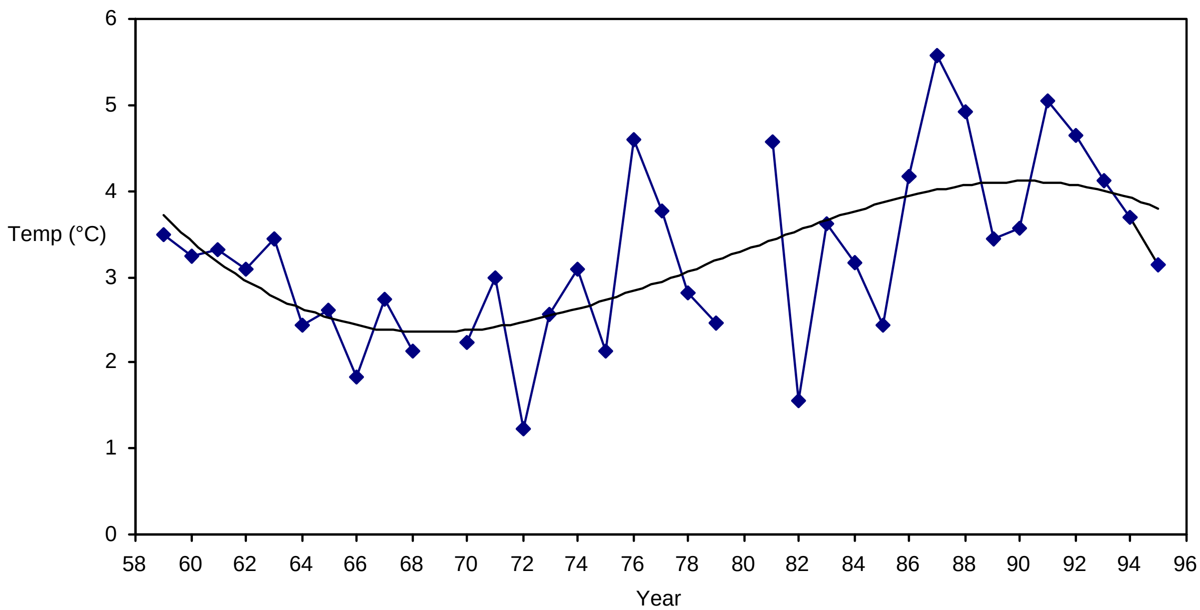


Figure 3. Mean annual temperature in the Hinton, Alberta region, 1958 - 1996.

Soils

Soils of the study area are described by Dumanski *et al.* (1972) and Corns and Annas (1983). Using the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1987), soils associated with the **SPRUCE** forests are well-drained, and are dominated by Cumulic Regosols with Orthic Brunisols and Degraded Brunisols. All horizons are weakly structured silt loams and have formed on highly calcareous aeolian materials from the Athabasca River Valley. **MIXEDWOOD** forest soils are 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. The **PINE** forest soils are well-drained and dominated by Orthic Gray Luvisols with Brunisolic Gray Luvisols.

General Forest and Wildlife Descriptions

Nomenclature of biota referred to in this study are described in Appendix 4.

Spruce Forest

At the time of experimental logging (1955–1956), the **SPRUCE** forest consisted of a dense white spruce overstory 30–40 m tall, 35–70 cm in diameter (breast height), with a scattered distribution of mature balsam poplar and black spruce in areas of impeded drainage (Plate 1). A sparse deciduous tree and shrub strata included willow, red-osier dogwood, bracted and twining honeysuckle, low-bush cranberry, buffalo-berry, shrubby cinquefoil, birch, prickly rose, ground and creeping juniper, and saskatoon. The herb strata was characterized by twin-flower, bunchberry, horsetail, coltsfoot, northern bedstraw, hedysarum, tall mertensia, wintergreen, miterwort, Solomon’s seal, baneberry and club-moss (*Lycopodium* and *Selaginella* spp.). There was generally a floor carpet of mosses (*Sphagnum*, *Dicranum, Pleurozium and Hylocomium* spp.). The only graminoids (grasses, rushes, sedges) of high cover were hairy wild rye and sedges.

Mixedwood Forest

The **MIXEDWOOD** forest canopy was dominated by white spruce, though trembling aspen and lodgepole pine were common (Plate 2). Characteristic lesser tree and shrub species were balsam poplar, twining honeysuckle, buffalo-berry, prickly rose, snowberry, common bearberry, willow, and saskatoon. The herb layer was characterized by wild strawberry, northern bedstraw, Solomon’s-seal, American vetch, milk vetches, showy loco-weed, groundsels, tall mertensia, and fireweed. Graminoids were mainly hairy wild rye and brome grasses.

Pine Forest

The **PINE** forest was a dense stand of young to mature lodgepole pine interspersed with a few clones of balsam poplar and trembling aspen (Plate 3). Dominant shrubs included green alder, prickly rose, low-bush cranberry, willow, mountain ash, wild red raspberry, blueberry and bilberry, wild gooseberry, bracted and twining honeysuckle, and red elderberry. The herb stratum consisted mainly of bunchberry, bedstraws, horsetail, twin-flower, and palmate-leaved coltsfoot. Dominant grasses were hairy wild rye and bluejoint. Less common graminoids were bluegrasses, sedges, timothy, wood rush, northern bent grass, and slender wood grass.

General Wildlife Occurrence in the Study Area

The foothills forest region of west-central Alberta contains ~284 terrestrial vertebrate species, including 218 birds, 59 mammals, 2 reptiles, and 5 amphibians (McCallum and Ebel 1987). High vertebrate species richness is presumably related to high landscape heterogeneity of this transitional region between the Rocky Mountain and the boreal forest ecosystems. Important socio-economic species include moose, elk, mule deer, white-tailed deer, grizzly bear, black bear, wolf, caribou, wolverine, fisher, marten, red squirrel, lynx, cougar, coyote, barred owl, great horned owl, ruffed grouse, spruce grouse, and long-toed salamander.

LOGGING AND SILVICULTURAL TREATMENTS

Logging and scarification treatments of **SPRUCE** and **MIXEDWOOD** forest types occurred during 1955–1956 and involved two-pass clearcut logging (Clark 1960; Plate 3). A single-pass harvest system was used for the **PINE** forest in 1956**.** The experimental **SPRUCE** (20 ha) and **PINE** (283 ha) cutblocks did not remain as isolates within an unharvested forest mosaic, but became embedded within large regional logging compartments of ~10,000 ha. During the period of this study, no other mixedwood forests were harvested adjacent to the experimental **MIXEDWOOD** cutblock (205 ha), except for a few hectares removed as part of a gravel mining operation.

Trees were felled with chain-saws (Plate 4), skidded to haul roads with horses (Plate 5), cut to length manually (Plate 6), and transported on trucks as shortwood (Plate 7). **SPRUCE** and **MIXEDWOOD** cutblocks designated for scarification were treated using Caterpillar D7–D9 tractors equipped with blade rippers or rakers (referred to as the "Crossley Plough"; Plate 8). Scarification involved the mechanical leveling of trees and shrubs and the mixing of the herbaceous layer with the upper 25–50 cm of soil. Scarification of **PINE** cutblocks involved the use of a D7–D9 caterpillar to push over pine snags and to compact slash (**Error! Reference source not found.**). Unscarified cutblocks retained standing snags and unmerchantable trees and experienced minimal soil disturbance. Both scarified **SPRUCE** and scarified **MIXEDWOOD** cutblocks were drag scarified with chains to spread slash and cones throughout the blocks.

Approximately one-third of the mature spruce forest, originally retained as residual blocks (100x800 m) between cutblocks, was removed in the second pass harvest 13 years after the original harvest. In the **MIXEDWOOD** forests, residual blocks of 100x100 m were retained for 10–15 years to serve as conifer seed source and were thereafter harvested. Approximately two-thirds of the original **MIXEDWOOD** cutblocks were left unscarified. Harvest treatment of the **PINE** forest occurred on a single 283 ha cutblock, of which the eastern half was scarified and the western half remained unscarified.

Logging of the study areas occurred in both summer and winter seasons. Whereas winter logging allowed the protection of some level of advanced understory regeneration, summer logging generally caused complete mortality of regenerating conifers. Cutblocks that were designated as unscarified were generally those with some level of advanced regeneration in their understory and were therefore likely harvested in the winter season.

Regeneration Strategy

SPRUCE FOREST

The scarified cutblock was aerially seeded in 1962 (Yr 6) with a white spruce seed mix. No planting or aerial seeding of white spruce or lodgepole pine occurred on the unscarified study cutblocks. Regeneration surveys (Weldwood Silviculture Records Management System) indicated that 82% of the scarified cutblock and 80% of the unscarified cutblock were stocked with white spruce in 1968.

MIXEDWOOD FOREST

Within scarified study cutblocks, container spruce seedlings were repeatedly planted at densities of approximately 1000/ha (Steve Ferdinand, personal communication). Although unquantified, some low density of pine seedlings may have been planted on the scarified cutblocks. Survivorship of spruce seedlings was minimal, resulting in replanting of seedlings 2-3 times during a 5 year period following logging. Poor survivorship was attributed to local frost pocketing that characterized these cutblocks following logging. No planting of pine or spruce occurred on unscarified study cutblocks. A 1961 regeneration survey of the unscarified cutblock indicated that 80% of the plots were adequately stocked with white spruce.

PINE FOREST

The scarified **PINE** cutblock was hand seeded with white spruce in 1962 and fill-planted in 1965 with white spruce and lodgepole pine seedlings in areas where stocking was considered inadequate. Regeneration surveys in 1969, 1974, and 1975 indicated stocking rates of 42, 36, and 84%, respectively. The unscarified cutblock was hand-planted with lodgepole pine seedlings in 1965 after a regeneration survey indicated that 46% of plots were stocked. A 1974 regeneration survey indicated that 98% of the cutblock was stocked with lodgepole pine.

Plate 1. Mature **SPRUCE** forest (view from edge of stand). Photo provided by J.G. Stelfox.

Plate 2. Mature **MIXEDWOOD** forest (left) and mature **PINE** forest (right). Photos provided by Weldwood of Canada, Hinton Division.

Plate 3. Typical 2-pass clearcut pattern. Photo provided by J.G. Stelfox.

Plate 4. Manual felling of white spruce using chainsaws. Photo provided by Weldwood of Canada; Hinton Division Archives.

Plate 5. Horse skidding of spruce logs to landings. Photo provided by Weldwood of Canada; Hinton Division Archives.

Plate 6. Cutting logs to length with chainsaws in preparation for truck transport. Photo provided by Weldwood of Canada; Hinton Division Archives.

Plate 7. Loaded truck hauling shortwood to pulp mill. Photo provided by Weldwood of Canada; Hinton Division Archives.

Plate 8. Photo of ripper plow. Photo provided by Weldwood of Canada; Hinton Division Archives.

EXPERIMENTAL DESIGN

Within each forest type, one scarified cutblock and one unscarified cutblock were selected for study. For each of the **SPRUCE**, **MIXEDWOOD**, and **PINE** cutblocks, selection of scarified and unscarified cutblocks occurred after consultation with the Northwest Pulp and Power company forester to ensure that the treatment cutblocks were considered comparable with respect to site, slope, aspect, and relief.

Unharvested control forests were selected for **SPRUCE** and **MIXEDWOOD** forests, but for the **PINE** forest the unharvested control was harvested after preliminary data were collected at Yr 1 and was unavailable for subsequent data collection. The unharvested control forests were the same age as the treatment stands and were similar in physiographic position and tree species composition.

Two samples (55x320 m) were established in each treatment cutblock and in the control forest. Each sample was randomly positioned a minimum distance of 30 m from the treatment boundary or forest margin to reduce edge effect. Sampling design and terminology are described in Figure 4 and definitions of units used in this report are described in Appendix 3. Each sample contained five contiguous replicates, each with six transects from which three were randomly selected for sampling. Each transect contained seven 1 m^2 plots spaced 10 m apart. A total of 100 random plots were measured in each sample.

Not all samples in each forest type survived the 40 years during which this study was conducted. For the **MIXEDWOOD** forest, scarified sample 2 was destroyed by gravel pit activities prior to 1981, and unscarified sample 1 was destroyed by a gravel pit operation following the 1988 data collection period. To reduce the chance of any future losses, applications for Protective Notation of all remaining study locations have been filed with Alberta Environmental Protection, Alberta Forest Service, in Hinton, Alberta.

Table 2 identifies plant and wildlife community variables or techniques used in this study and documents forest types, treatment types, and years that data were collected.

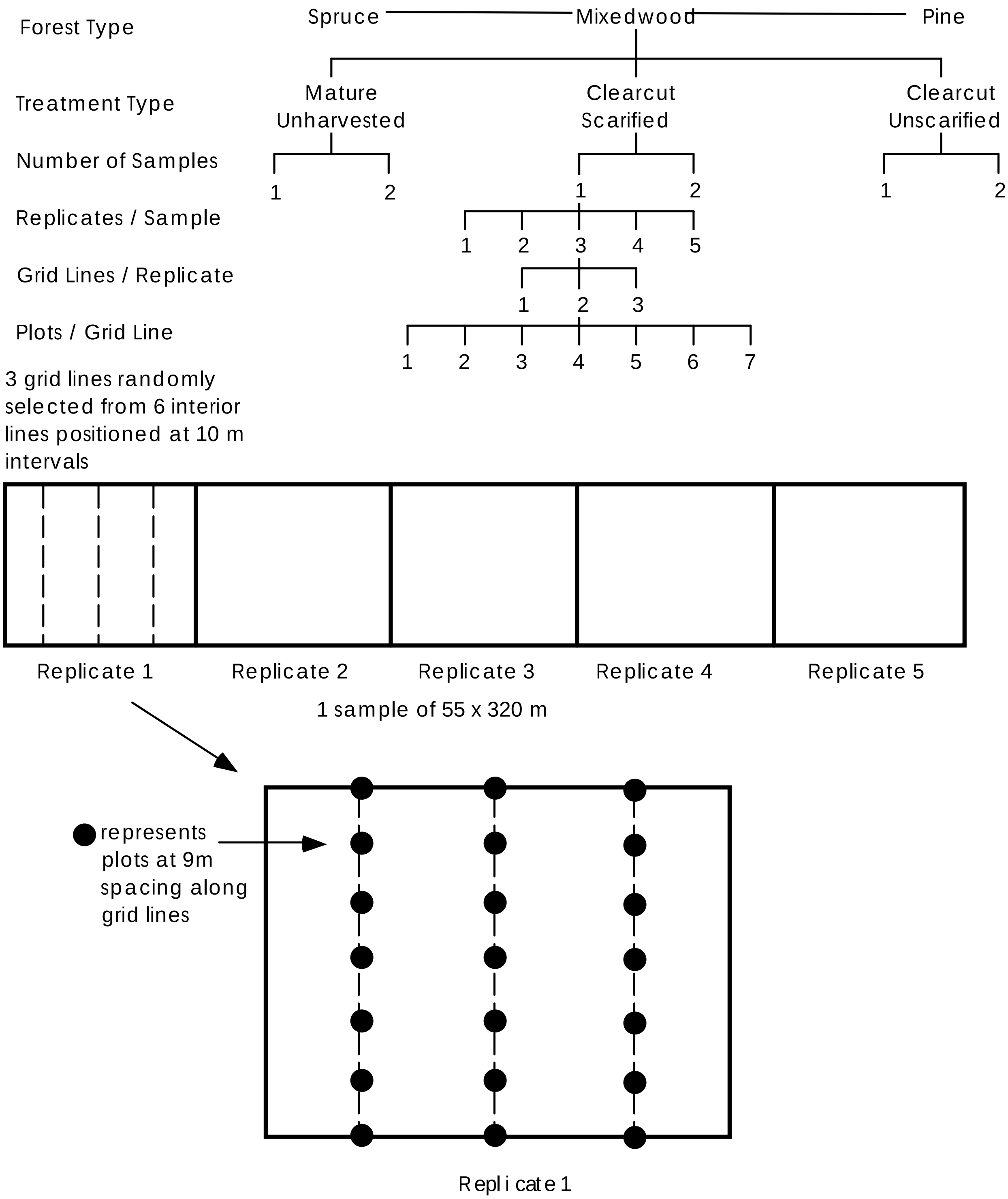


Figure 4. General experimental design and layout of plots on grid lines, grid lines within replicates, and replicates within samples.

Table 2. Attributes measured in each forest type and treatment during study. M=mature, S=scarified, U=unscarified.

SPRUCE Forests

Years post-logging	erb./Shrub Cover	Dec. Tree/ Shrub Den.	Conifer Canopy	Snags	Down Wood	Conifer Regener.	Understory Visibility	Scat	Browse Production
1	M,S,U	M,S,U				M,S,U		M,S,U	M,S,U
5	S,U	S,U							
6	S,U	S,U						S,U	
9						S,U		S,U	S,U
17		M,S,U				S,U		S,U	S,U
26	S,U	S,U	S,U	S,U		S,U		S,U	S,U
32	S,U	M,S,U	M,S,U	M,S,U		S,U	S,U	S,U	S,U
39/40	S,U	M,S,U	M,S,U	M,S,U	M,S,U	M,S,U	M,S,U	S,U	M,S,U

MIXEDWOOD Forests

Years post-logging	erb./Shrub Cover	Dec. Tree/ Shrub Den.	Conifer Canopy	Snags	Down Wood	Conifer Regener.	Understory Visibility	Scat	Browse Production
1	M,S,U	M,S,U				M,S,U		M,S,U	M,S,U
5									
6	S,U	S,U				S,U		S,U	
9								S,U	S,U
17									
26	S,U	S,U	S,U	S,U		S,U		S,U	S,U
32	S,U	M,S,U	M,S,U	M,S,U		S,U	S,U	S,U	S,U
39	M,S,U	M,S,U	M,S,U	M,S,U	M,S,U	M,S,U	M,S,U	S,U	M,S,U

PINE Forests

Years post-logging	erb./Shrub Cover	Dec. Tree/ Shrub Den.	Conifer Canopy	Snags	Down Wood	Conifer Regener.	Understory Visibility	Scat	Browse Production
1	M,S,U	M,S,U				M,S,U		M,S,U	M,S,U
5									
6	S,U	S,U				S,U		S,U	
9								S,U	S,U
17									
26	S,U	S,U	S,U	S,U		S,U		S,U	S,U
32	S,U	S,U	S,U	S,U		S,U	S,U	S,U	S,U
39	S,U	S,U	S,U	S,U	S,U	S,U	S,U	S,U	S,U

METHODS

The data forms used to record plant and wildlife attributes are presented in Appendix 2.

Plant Community Structure

Understory Vegetation

Understory vegetation was sampled in 1 m^2 plots subdivided into 10x10 cm grids. The number of plots measured in each sample was 105 in Yrs 1, 3, 4, 5, 9, and 17, and 100 in Yrs 26, 27, 32, and 39. As the botanical emphasis of this study was vascular plant species, only common mosses and lichen species were identified and recorded. Some taxa of vascular plants, such as some willows, sedges and horsetails, proved difficult to distinguish separate species. Undifferentiated species were recorded by the genus name followed by "spp." to denote unknown species.

The following attributes were measured in each 1 m^2 plot:

(1) foliage cover for graminoid (grasses, rushes, sedges), forb, dwarf shrub, and moss/lichen species to the nearest 1%;

(2) densities of deciduous and coniferous trees and shrubs in height classes: 0-0.2 m, 0.2–0.4 m, 0.4–0.6 m, 0.6-0.8m, 0.8-1.0m, 1-2 m, 2-3m, 3-4m, 4-6m,6-8m, 8-10m, and >10m;

(3) species composition for graminoids, forbs, dwarf shrubs, shrubs, and trees;

(4) heights of browse plants were recorded to the nearest 1.25 cm until plants reached 2.5 m, after which the height was estimated to the nearest 0.15 m. Deciduous and coniferous tree and shrub heights were recorded in Yrs 26, 32 and 39;

(5) herbivore use of plant species was recorded as either summer or winter use. Use classes were: 0% = none; 1–25% = light; 26–50% = moderate; 51–75% = heavy; and 76–100% = very heavy. Percent use of total current year's biomass was determined using the ocular-estimate-by-plot method (Pechanec and Pickford 1937). For browse species this technique considers leaves and green stems <0.75 cm in thickness;

(10) biomass and composition of browse was measured using twenty 1 m^2 clip-plots per sample. Browse refers to all deciduous or coniferous tree and shrub species observed to be eaten by wild ungulates. All live browse under 2.5 m in height was clipped, placed in paper bags and green weights recorded of both leaves and stems. Forage was then air-dried to a constant weight and browse forage production calculated.

Conifer Regeneration and Growth

Conifer density by height classes (see above) were measured in 100 plots (10 m^2) per sample for each forest and treatment type.

Conifer Canopy Cover

Crown widths were used to calculate crown areas assuming a circular crown base using the following equation: $\sum\Pi(\text{width})^2/4$. Percent tree cover of each conifer height class was subsequently calculated as cover (%) = 1/10000[$\sum$(density x crown area)] x 100%. The value 10,000 is used to convert data collected per square metre to a per hectare basis.

Snags

Within 100 plots (50 m^2 circular)/sample, all dead or decadent trees with DBH ≥15 cm were measured for DBH, height, density, condition, and presence and size of cavities. Six decay condition classes were used to describe the snags:

1 recently dead tree; bark still moist or green underneath

2 snag hard and dry; fine branches and bark mostly present

3 snag hard and dry; stem sound, bark variable, fine branches absent, large branches present

4 snag hard and dry but becoming soft in places; only main bole present, bark scattered or absent

5 snag moderately soft often with dry rot in bole; bark mostly absent

6 snag very soft with decomposing bole

Down Wood

Down wood was quantified in each of the forest treatments and mature controls using the line intersect technique (McRae et al. 1979). The sampling unit was the grid line for each treatment. A 50 m chain was pulled along each line to ensure a standard sample length was measured. Fifteen gridlines (750 m) were measured per sample. Each piece of down wood (> 7.5 cm) which crossed the line was measured to obtain diameter and recorded as sound (solid) or rotten (soft). Species were not recorded. Each sample was analysed to determine mean diameter, diameter distribution by decomposition class, and percent cover. The sum of all diameters divided by the length of the survey lines was multiplied by 100 to obtain percent cover. Standard error was calculated for each sample.

Wildlife Habitat Cover

Measures of thermal and security cover of mature forests and cutblocks were obtained by collecting the following:

- conifer canopy cover as defined earlier;
- visibility was estimated using a vertical 0.3x2.5 m vegetation profile board divided horizontally into five equal 0.5 m strata. The profile board was placed 20 m northwest of the plot stake and the percent of each segment that was visible was recorded. Measurements of percent visibility were made at 30 locations in each sample. Five visibility classes were used: 1 = 0–20%, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, and 5 = 81–100%.

Wildlife Abundance

Wildlife Pellet Surveys

All observed pellet groups for ungulates, grouse and hares were recorded in 100 circular plots/sample. Of these, pellets of ungulates and hare were sufficient to provide estimates of relative abundance. Scats of other species were used as indirect observations (e.g., presence/absence) and not used to estimate relative abundance. Plot sizes varied during the study and were as follows: 9.3 m^2 (Yrs 3–4), 0.9 m^2 (Yrs 9, 17 and 26) and 25 m^2 (Yrs 32 and 39). At Yrs 1 and 6, ten rectangular plots (2.0 x 30.2 m) per sample were used.

Direct Observations
During the collection of plant community and wildlife pellet data, the senior author recorded all observations of selected wildlife species with which he was familiar with appearance, vocalizations, or scat. Each data type (visual sighting, vocalization, scat group) was given equal weighting of one point. Although these data were not collected using systematic survey procedures, they are considered general indicators of relative abundance since a) the amount of time spent in each forest was similar among forest type, treatment, and year, and b) all data were collected by a single observer thus subject to same level of bias.

Permanent Photo Points
Photo points were established in 1957 to monitor gross floral and structural changes in scarified and unscarified cutblocks and in unharvested control forests. Black and white photographs were taken with a 35 mm camera mounted 1.5 m above ground. Photos were centered on a conspicuous and permanent landscape feature. The locations of photopoints are described in Appendix 1.

RESULTS

Plant species observed in each forest type are listed in Appendix Table 4.1. Their relative abundance (% cover) is presented in Appendix Table 5.1–5.4. This list is undoubtedly incomplete as numerous vernal species would be missed during the July and August survey period.

Plant Community Structure

Successional and Treatment Response of Herbaceous Plants

Summaries of temporal patterns in forest floor cover and treatment effects are described. Average cover of each cover type for each year and each forest type are presented in Appendix Table 5.1 – 5.4.

Graminoid Cover

Following logging treatment in each forest type, graminoid (grasses, rushes, sedges) cover increased rapidly, attaining its highest values by Yr 6, then declined considerably in each forest type and thereafter stabilized (Figure 5). During the early post-logging years (Yrs 1–6), grass cover was higher on unscarified than scarified cutblocks. Although this pattern continued throughout the study for **PINE** forests, scarified cutblocks in **SPRUCE** and **MIXEDWOOD** forests had greater grass cover than unscarified cutblocks during Yrs 26–39.

Forb Cover

Relative to pre-treatment levels in **SPRUCE** forests, forb cover dropped immediately following logging treatment (Yrs 1–4), then rose rapidly by Yr 6 (Figure 6). A similar pattern is presumed for **MIXEDWOOD** and **PINE** forests immediately following logging. Forb cover in each forest type declined between Yrs 6–26, and thereafter increased to highest values at Yr 39. Forb cover did not differ significantly between scarified and unscarified cutblocks for **SPRUCE** and **PINE** cutblocks, but was consistently higher on scarified than unscarified **MIXEDWOOD** cutblocks. Forb cover was higher in **PINE** forest cutblocks than in either **MIXEDWOOD** or **SPRUCE** cutblocks. At the conclusion of the study (Yr 39), forb cover had not declined to pre-treatment levels in either scarified or unscarified **SPRUCE** forest cutblocks.

Dwarf Shrub Cover

In **SPRUCE** cutblocks, dwarf shrub cover declined from the initial low values occurring prior to logging (Figure 7). Thereafter, cover increased slowly in all forest types between Yrs 6–26, then more quickly between Yrs 26–39. Dwarf shrub cover levels were highest in **SPRUCE** cutblocks, followed by **MIXEDWOOD**, and lowest in **PINE** cutblocks (Figure 7). There was no clear evidence of differences between scarified and unscarified **SPRUCE** or **PINE** cutblocks; however, scarified **MIXEDWOOD** cutblocks had higher dwarf shrub cover than unscarified cutblocks by Yr 39.

Moss Cover

Moss cover was low or absent in each forest type following logging treatment until Yr 26, after which it rose rapidly (Figure 8). Moss cover was higher in **MIXEDWOOD** forest cutblocks than in **SPRUCE** or **PINE** cutblocks. Moss cover was higher on unscarified than scarified **MIXEDWOOD** cutblocks but no differences were evident for **PINE** or **SPRUCE** cutblocks.

Total Understory Cover

Similar patterns in total plant understory cover were recorded for all forest types (Figure 9). Following a decline in plant ground cover immediately following logging in the **SPRUCE** cutblocks, levels rose quickly during Yrs 1–6, then dropped gradually between Yrs 6–26, at which point they increased from Yrs 26–39. There were no differences in total understory cover between scarified and unscarified cutblocks.

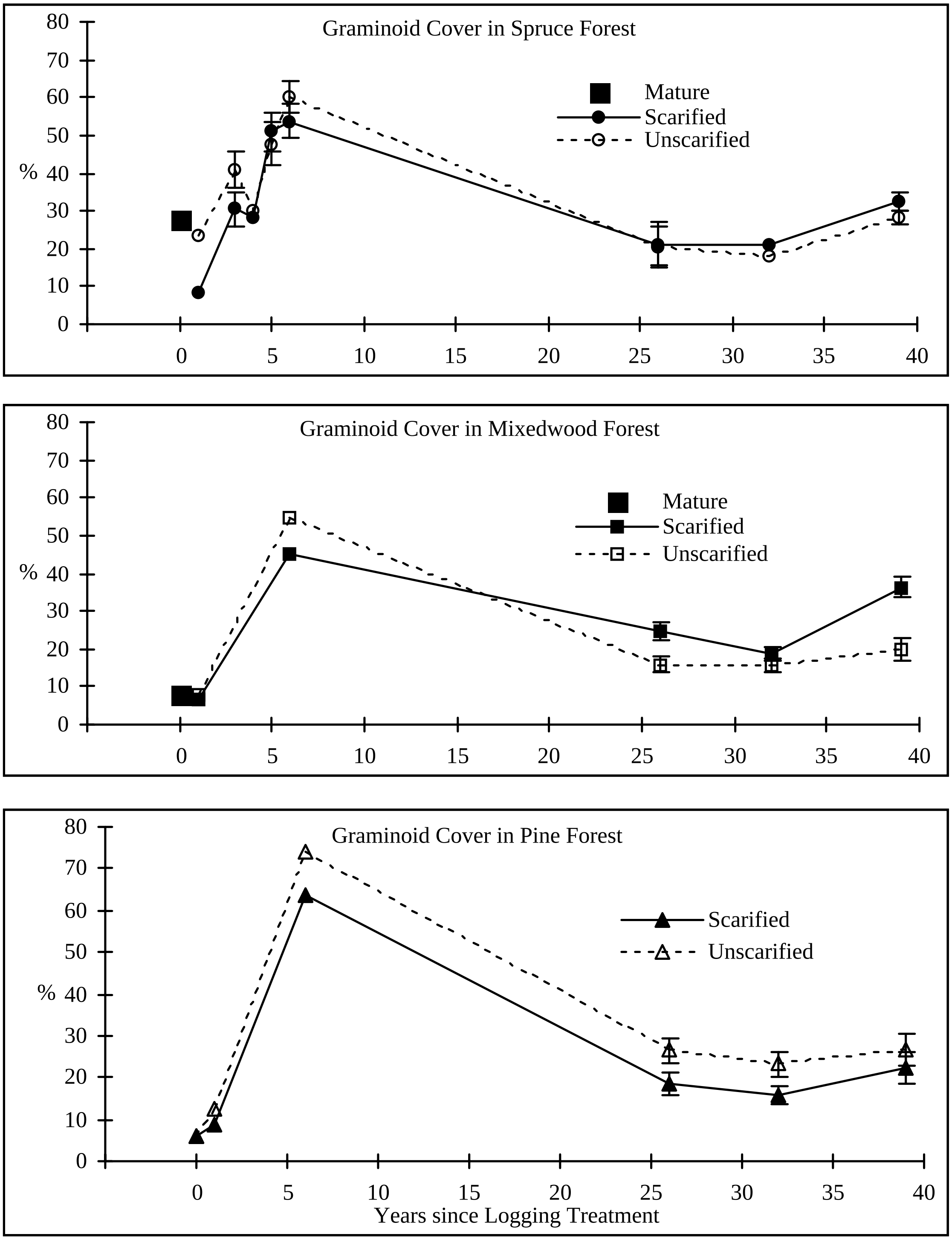


Figure 5. Changes in graminoid cover during Yrs 1–39 (1957–1995) following logging. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

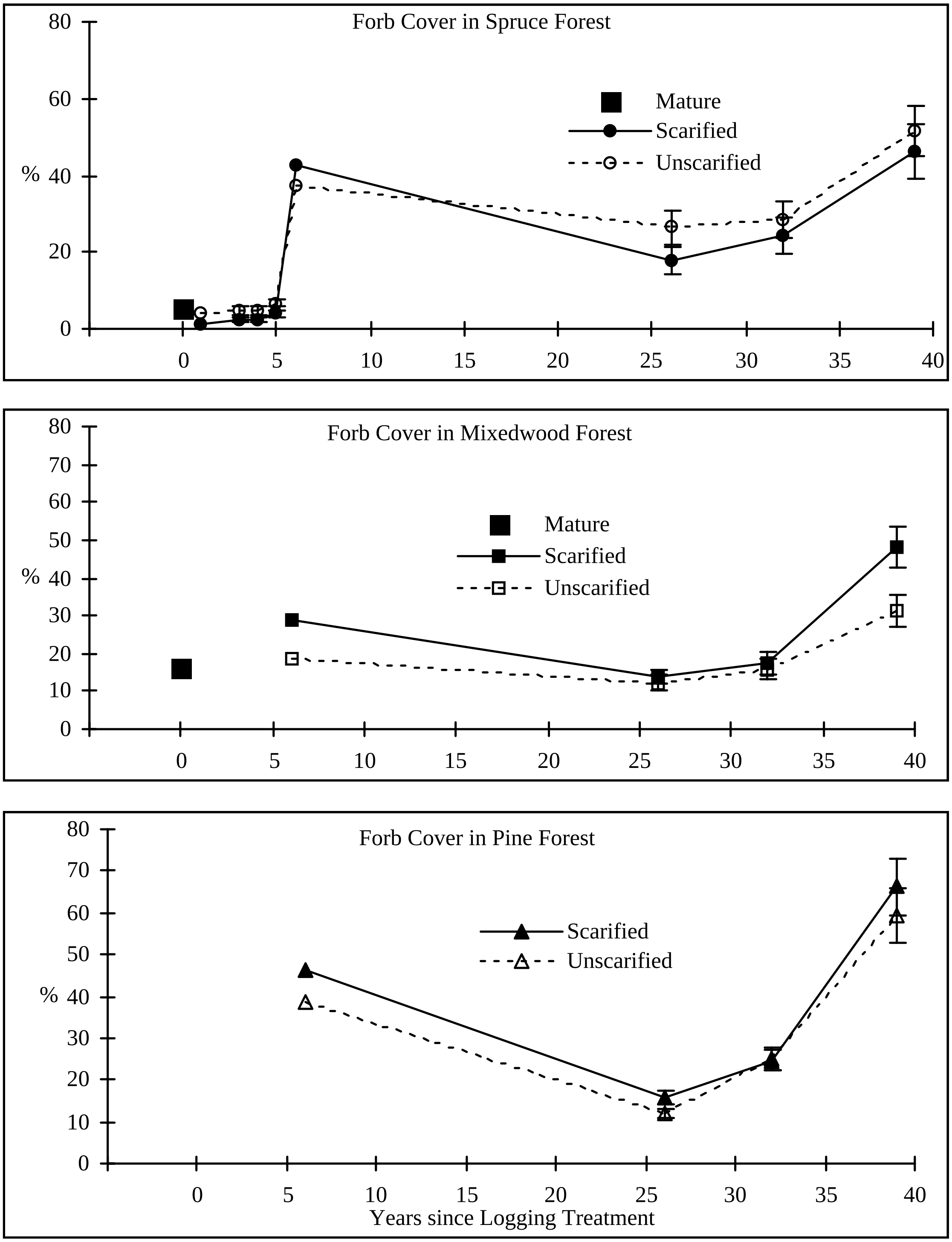


Figure 6. Changes in forb cover during Yrs 1–39 (1957–1995) following logging. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

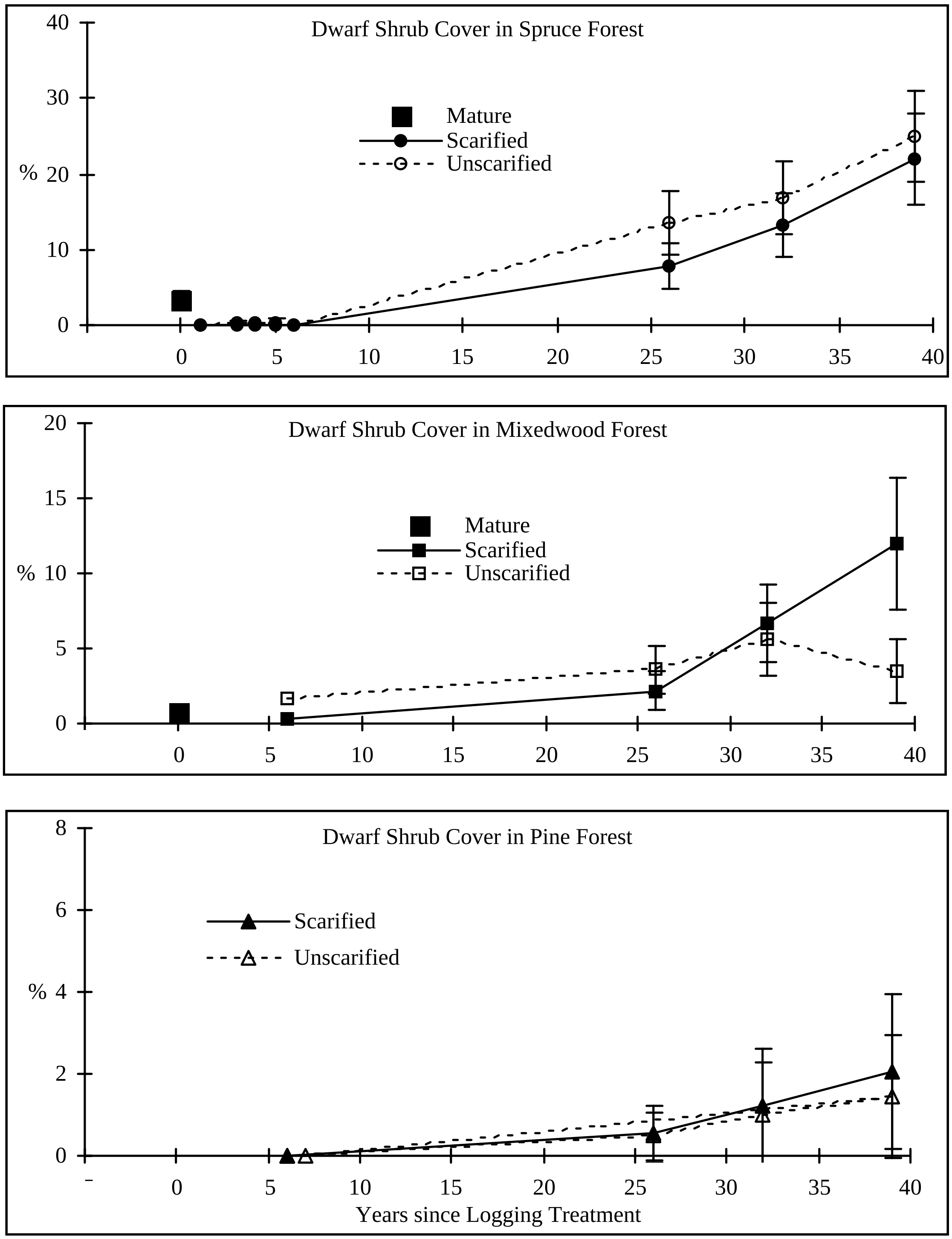


Figure 7. Changes in dwarf shrub cover during Yrs 1–39 (1957–1995) following logging. Means ± 2 S.E. presented. No measure of variation available prior to Yr 26.

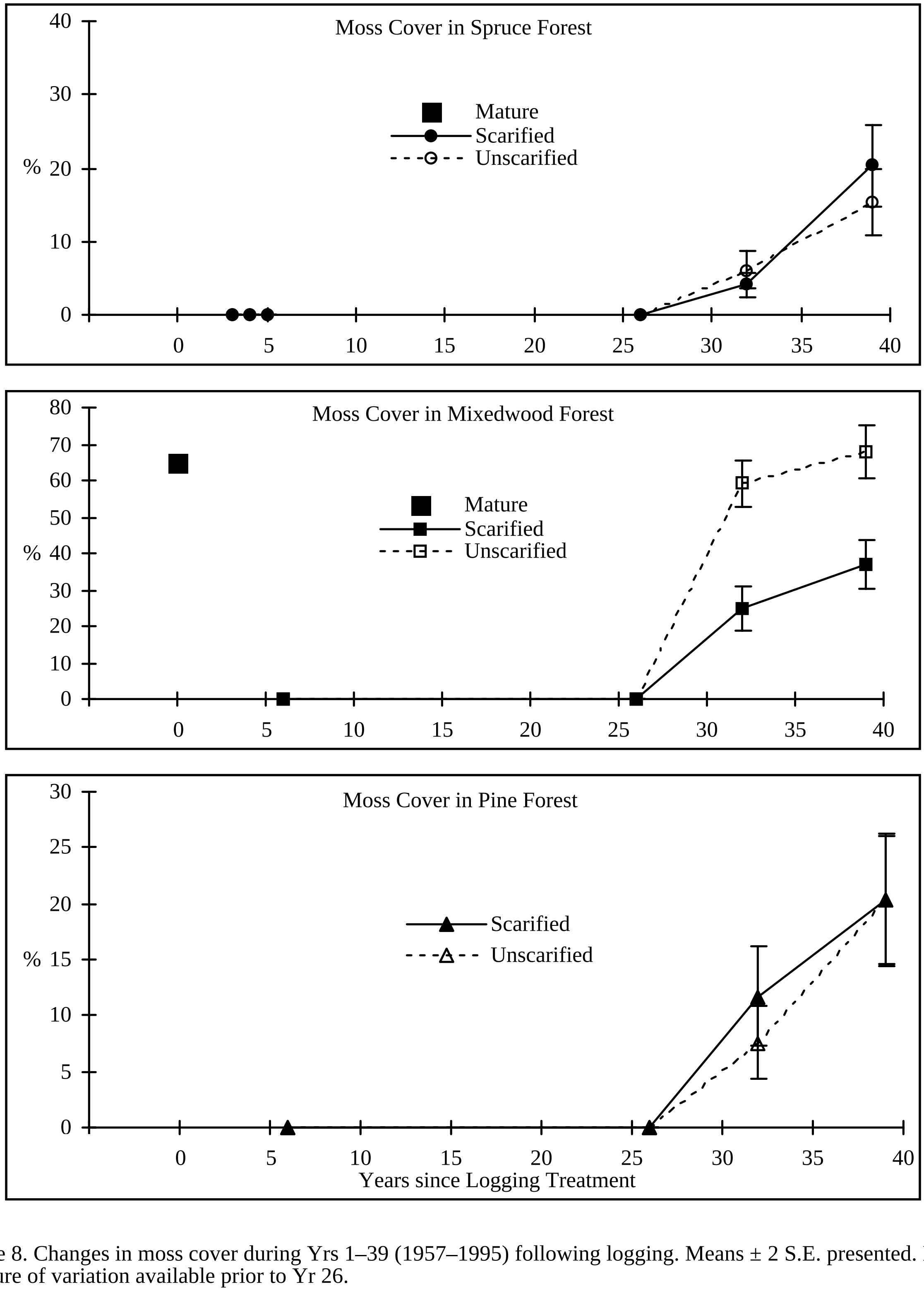


Figure 8. Changes in moss cover during Yrs 1–39 (1957–1995) following logging. Means ± 2 S.E. presented. No measure of variation available prior to Yr 26.

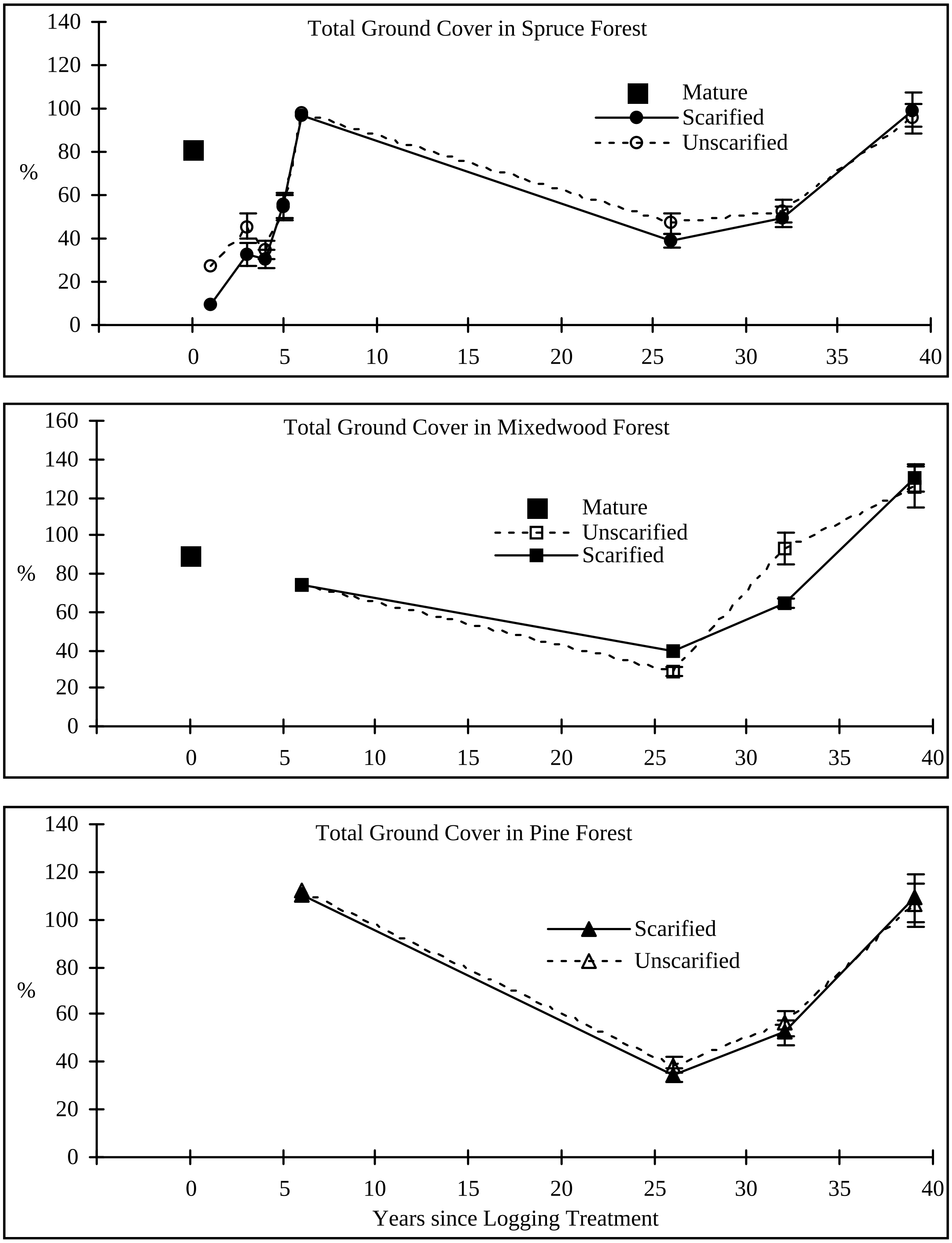


Figure 9. Changes in total ground cover (graminoid, forb, moss, dwarf shrub) cover during Yrs 1–39 (1957–1995) following logging. Means ± 2. S.E. presented. No measure of variation available prior to Yr 26.

Species Composition

SPRUCE

Hairy wild rye dominated the herbaceous community in both scarified and unscarified cutblocks, although in decreasing cover throughout the study (Figure 10). Only during Yr 39 in the unscarified cutblocks was hairy wild rye not the single most abundant plant taxa and then it was second to bearberry. Striking differences in composition of dominant herbaceous taxa were not observed between scarified and unscarified cutblocks throughout the study, although contributions of less abundant taxa did vary. In general, hairy wild rye, bearberry, sedges, and hedysarum were conspicuous taxa in each seral stage. Bluejoint and reed grasses occurred on unscarified cutblocks during Yr 26, but not on scarified cutblocks.

MIXEDWOOD

Elymus spp. dominated the herbaceous community in Yr 26 for both scarified and unscarified cutblocks and decreased by Yr 39 (Figure 11). Hairy wild rye was more abundant on unscarified than scarified cutblocks. Other dominant taxa in both scarified and unscarified cutblocks were bluejoint, fireweed, and bunchberry. There were no striking differences in composition of other major taxa on scarified and unscarified cutblocks during Yrs 26 and 39. The contribution of grass species declined between Yrs 26 and 39. Bluejoint and reed grasses were present at moderate levels during both Yrs 26 and 39 and on both scarified and unscarified cutblocks.

PINE

Hairy wild rye was the dominant taxa in both Yrs 26 and 39 and in both scarified and unscarified cutblocks. Hairy wild rye, and grasses in general, declined in cover on older cutblocks (Figure 12). Cover of leguminous species (pea vine, vetch) increased from Yr 26 to Yr 39.

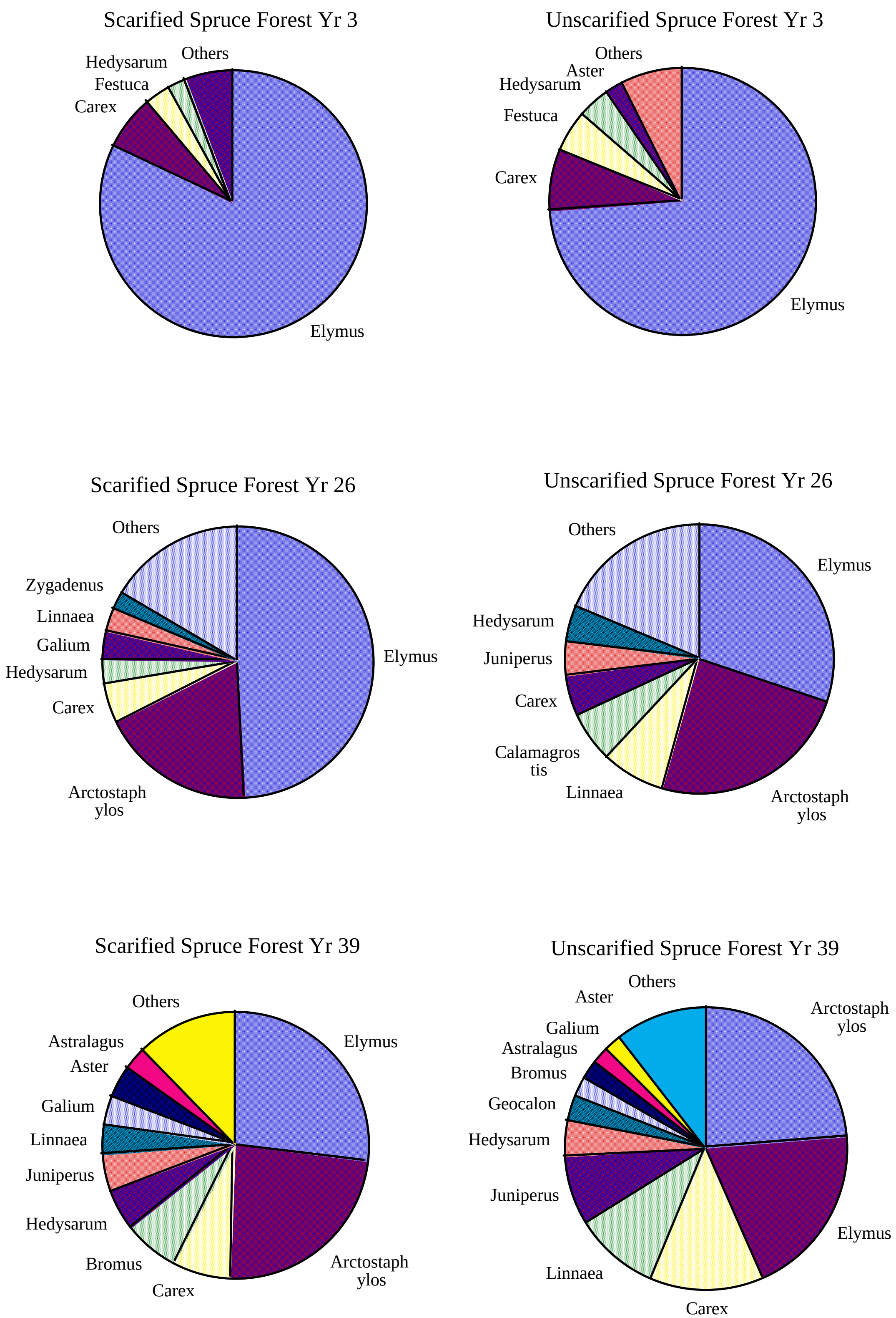


Figure 10. Successional changes in herbaceous plant species on scarified and unscarified **SPRUCE** forests.

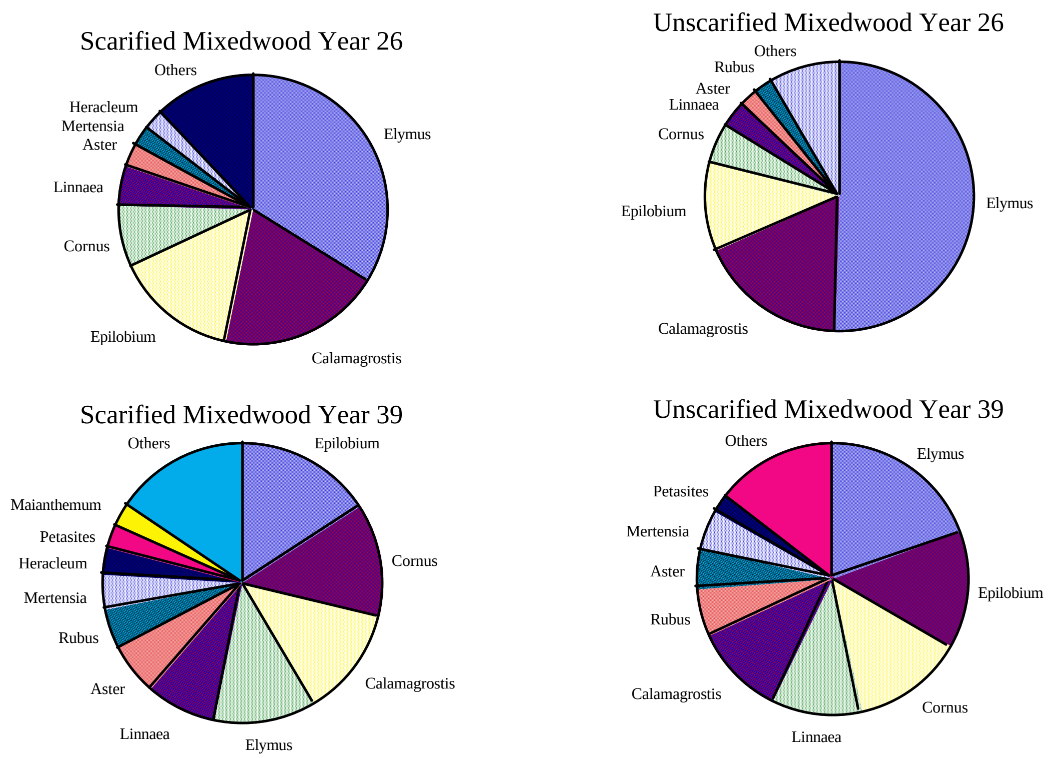


Figure 11. Successional changes in herbaceous plant species on scarified and unscarified **MIXEDWOOD** forests.

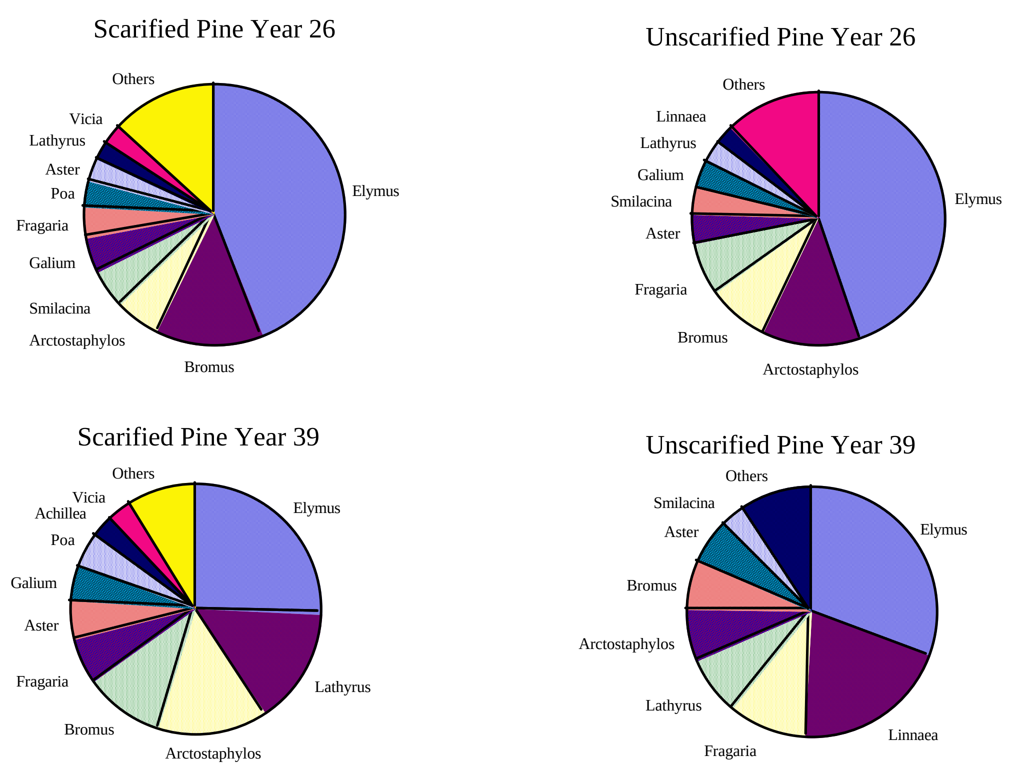


Figure 12. Successional changes in herbaceous plant species on scarified and unscarified **PINE** forests.

Composition of Herbaceous Plant Community at Conclusion of Study

SPRUCE Forests

At Yr 39, bearberry, hairy wild rye, and mosses were the dominant flora on the forest floor of both scarified and unscarified cutblocks (Figure 10). The relative contribution of the more common species was similar between scarified and unscarified cutblocks (Appendix Table 5.1, Appendix Table 5.2).

MIXEDWOOD Forests

At Yr 39, the most common plants in the understory were moss spp., hairy wild rye, bunchberry, bluejoint, and twin flower in both scarified and unscarified cutblocks (Figure 11). The relative contribution of the more common species was similar between scarified and unscarified cutblocks (Appendix Table 5.3).

PINE Forests

At Yr 39, hairy wild rye was still the most common species in both cutblock treatments although less common than at Yr 26. For other species there was considerable disparity in abundance between the two clearcut treatments. Twin-flower, strawberry and Solomon's-seal were more prevalent on unscarified cutblocks while wild pea, bearberry and bromegrass were more common on scarified cutblocks (Figure 12, Appendix Table 5.4).

Successional and Treatment Response of Shrubs

SPRUCE Forests

Total shrub density increased following logging (Yrs 1–17) and thereafter stabilized (Figure 13). Shrub densities were consistently higher on unscarified cutblocks. Shrub height increased rapidly following logging (Yrs 1-4), and then declined by ~0.25 m, primarily after Yr 26. Shrub heights were consistently taller on scarified cutblocks during Yrs 17–39.

Rose increased in density following logging during Yrs 1–17, and thereafter remained near 3-5 stems /m^2 (Figure 14). Densities were consistently higher on unscarified cutblocks. Rose height increased quickly following logging Yrs 1–3) and thereafter declined. Rose height was consistently higher on unscarified cutblocks.

Willow density and height increased immediately following logging (Figure 15). In general, no differences in density or height occurred between scarified and unscarified cutblocks.

Buffalo-berry density increased throughout the study in a similar pattern for both scarified and unscarified cutblocks (Figure 17), Height of buffalo-berry was similar on scarified and unscarified cutblocks, except during Yr 17 when it was taller on scarified cutblocks.

Honeysuckle densities increased during Yrs 1–39, with densities higher on unscarified than scarified cutblocks (Figure 18). Honeysuckle height were generally higher on unscarified cutblocks.

MIXEDWOOD Forests

Total shrub density increased continuously following logging (Figure 13) and did not differ between cutblock treatments. Mean shrub height did not change during the study (remained at ~0.5 m) and did not differ between scarified and unscarified cutblocks.

Rose increased in density continuously following logging (Figure 14) and did not differ between cutblock treatments. Rose height increased minimally following logging (Yrs 1–26) and thereafter declined minimally (Yrs 26–39). Rose height did not differ between scarified and unscarified cutblocks.

Immediately following logging, willow density was high on unscarified cutblocks and absent on scarified cutblocks (Figure 15). Willow densities on cutblock treatments quickly converged, then remained near 0.4 stems/m^2 during Yrs 6–39. Willow height was 1–2 m taller on unscarified cutblocks during Yrs 26–39 (Figure 15). Willow height was 1–2 m taller on unscarified than scarified cutblocks during Yrs 26–39.

Buffalo-berry density did not change appreciably during the study but remained more dense on unscarified than scarified cutblocks (Figure 17). Height of buffalo-berry was similar on scarified and unscarified cutblocks.

Honeysuckle densities remained low on both cutblock treatments during Yrs 1–32, then increased moderately on unscarified cutblocks. Honeysuckle height did not differ between scarified and unscarified cutblocks (Figure 18) and declined moderately between Yrs 32–39.

Ribes spp. occurred on unscarified cutblocks between Yrs 26–32 and thereafter was absent. Ribes spp. did not occur on scarified cutblocks (Figure 19).

<u>PINE</u> <u>Forests</u>

Total shrub density increased continuously following logging (Figure 13) and did not differ between cutblock treatments. Mean shrub height increased from 0.3 m at Yr 1 to ~1.0 m at Yr 27 and did not differ between scarified and unscarified cutblocks.

Rose increased in density continuously following logging (Figure 14) and did not differ between cutblock treatments. Rose height increased minimally following logging (Yrs 6–26) and thereafter declined minimally (Yrs 26–39) Rose height did not differ between scarified and unscarified cutblocks.

Willow density increased continuously following logging (Figure 15) and was more dense on scarified than unscarified cutblocks. Willow height increased during Yrs 6–26, stabilized during Yrs 26–39, and did not differ between cutblock treatments.

Green alder increased continuously on cutblocks following logging during Yrs 6-26, then stabilized during Yrs 26–39 (Figure 16). Densities were consistently higher on scarified cutblocks, whereas alder heights were consistently higher on unscarified cutblocks.

Honeysuckle densities remained low on both cutblock treatments during Yrs 1–32, then increased moderately on scarified cutblocks. Honeysuckle height was consistently higher on scarified than on unscarified cutblocks (Figure 18).

Ribes spp. first appeared on cutblocks in Yr 26, thereafter increased in density in both cutblock treatments, and was of higher density on scarified cutblocks (Figure 19). *Ribes* spp. height did not differ between cutblock treatments and declined during Yrs 26–39.

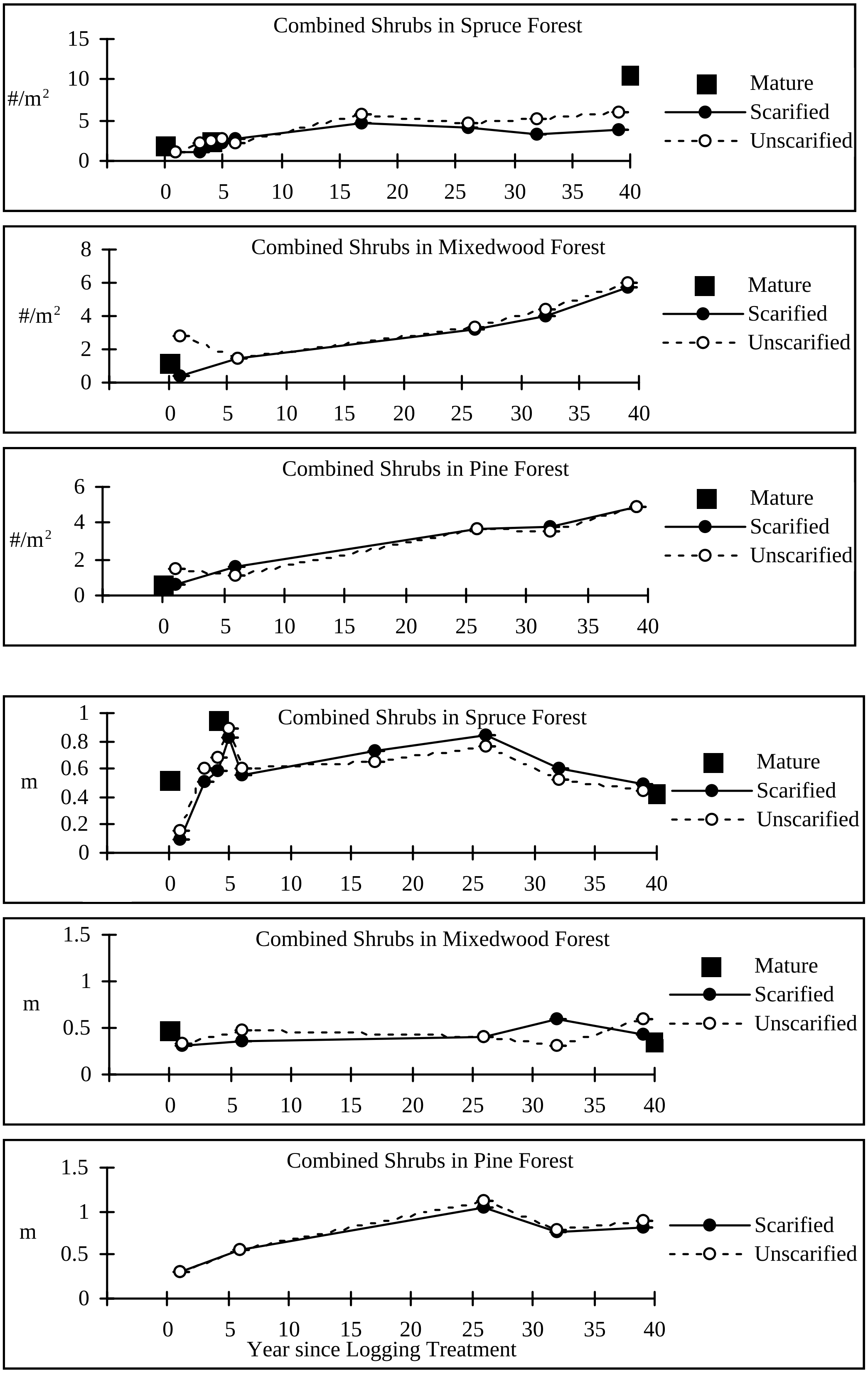


Figure 13. Mean density and height of all shrubs in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

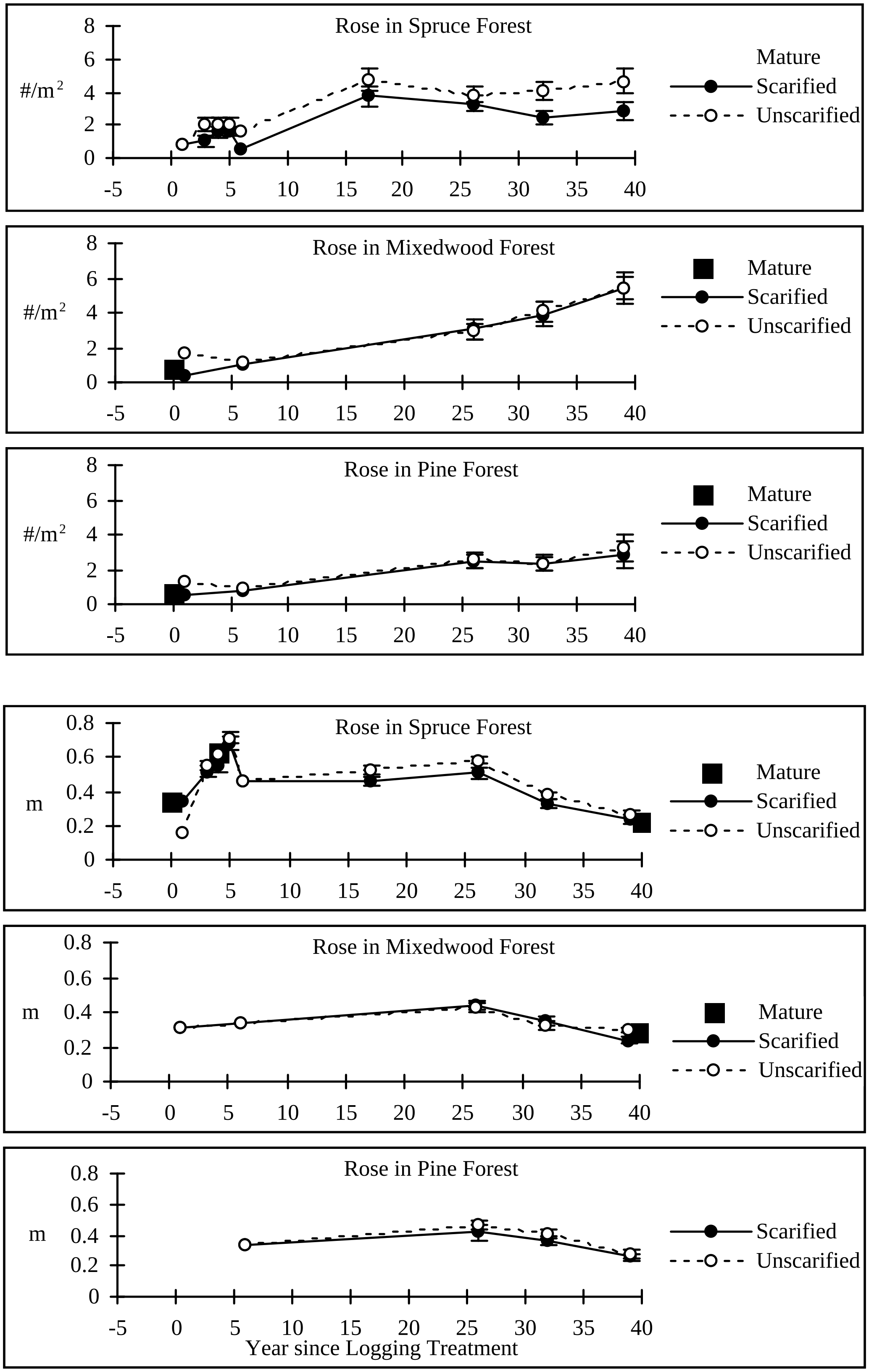


Figure 14. Mean density and height of rose in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

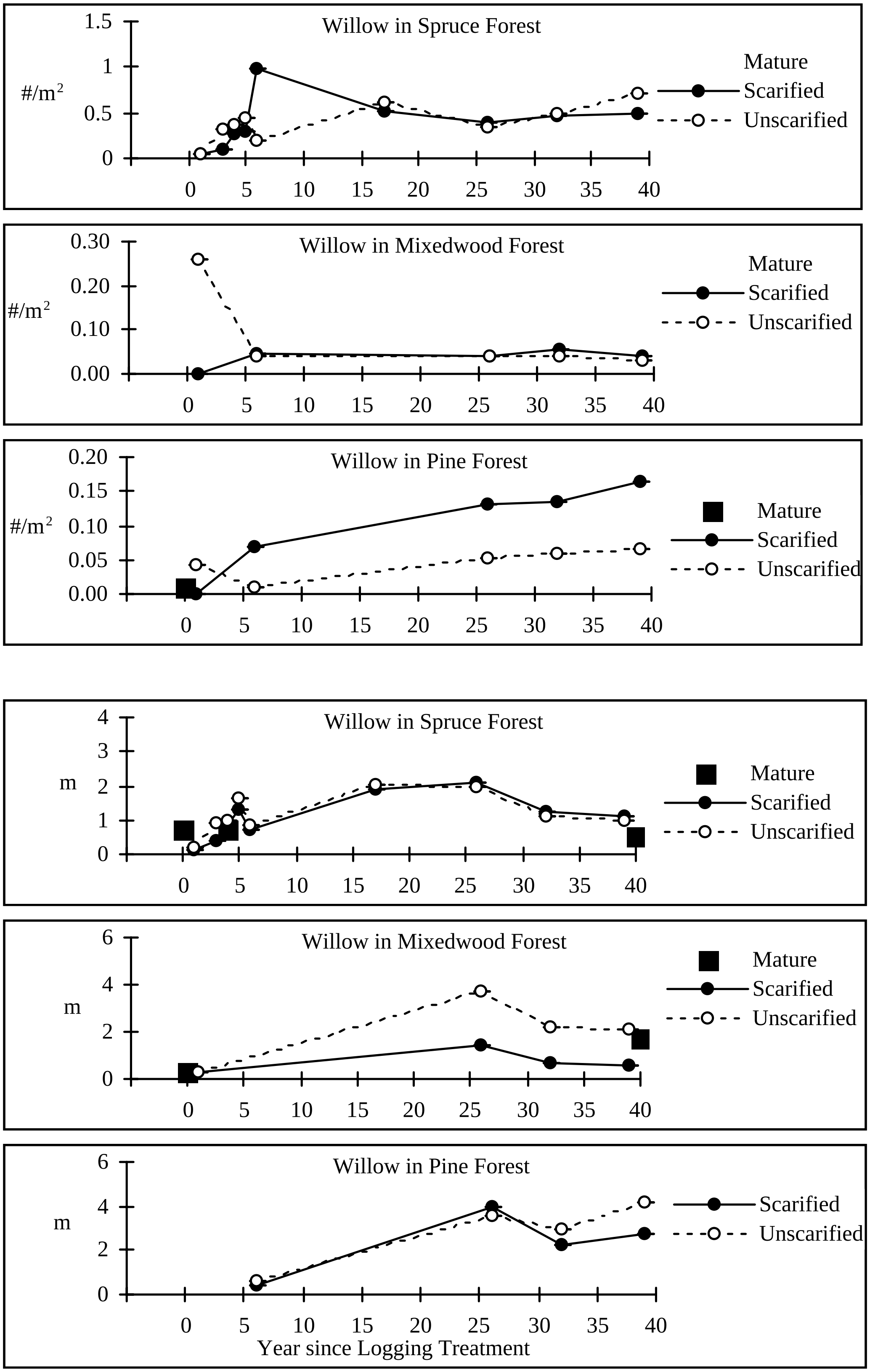


Figure 15. Mean density and height of willow in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6 for **MIXEDWOOD** and **PINE** forests.

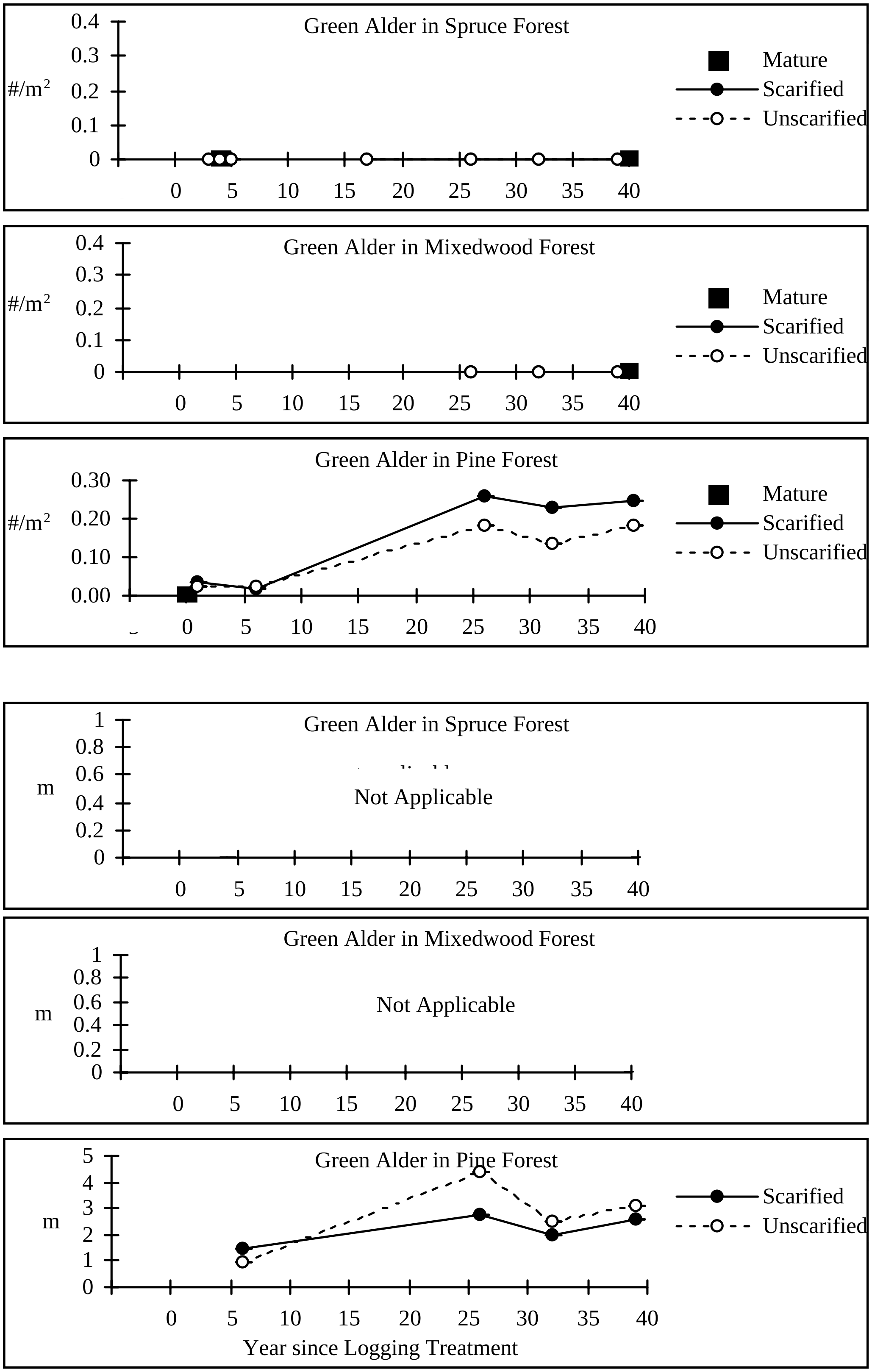


Figure 16. Mean density and height of alder in SPRUCE, MIXEDWOOD, and PINE forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

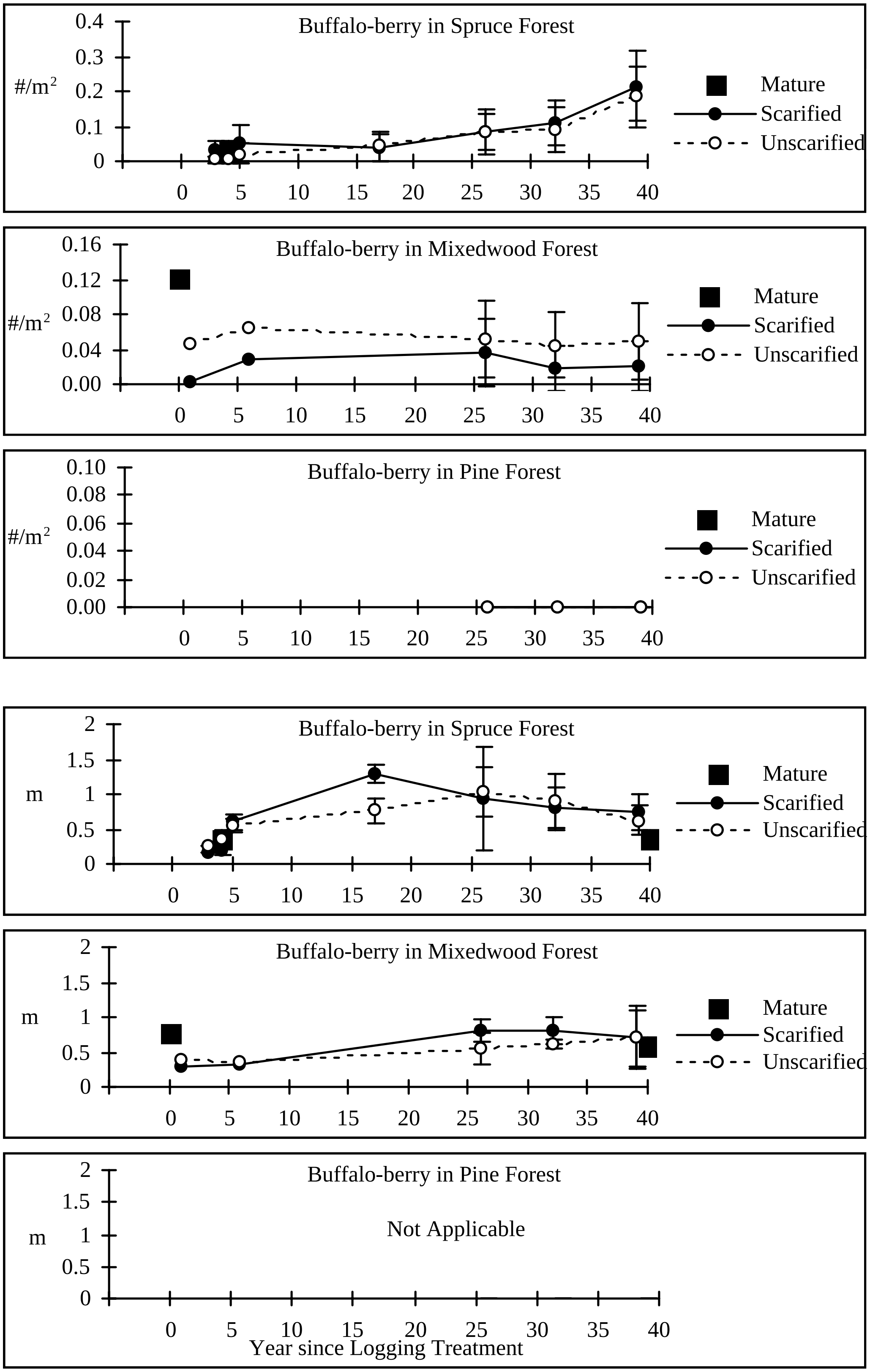


Figure 17. Mean density and height of buffalo-berry in SPRUCE, MIXEDWOOD, and PINE forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

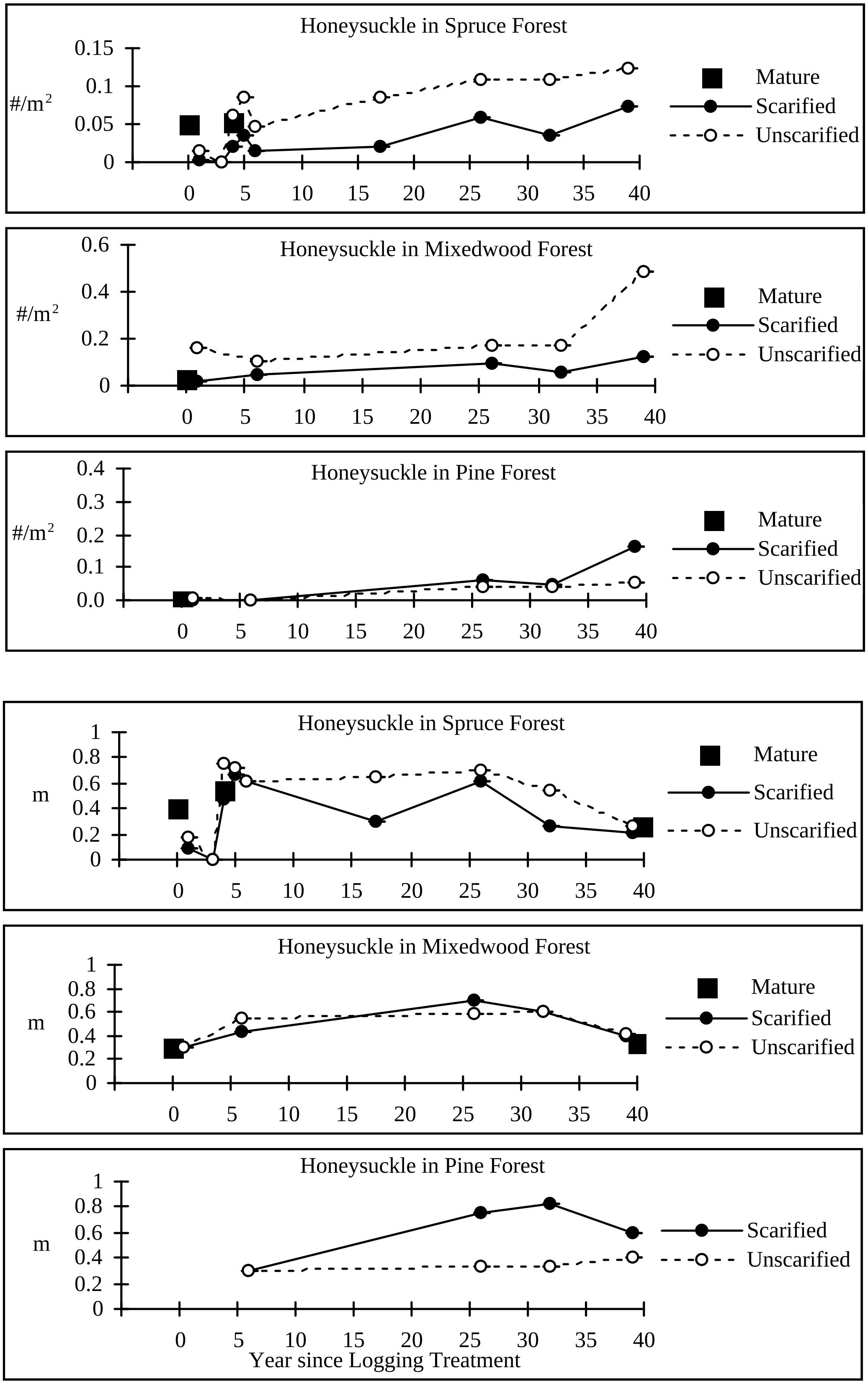


Figure 18. Mean density and height of honeysuckle in SPRUCE, MIXEDWOOD, and PINE forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

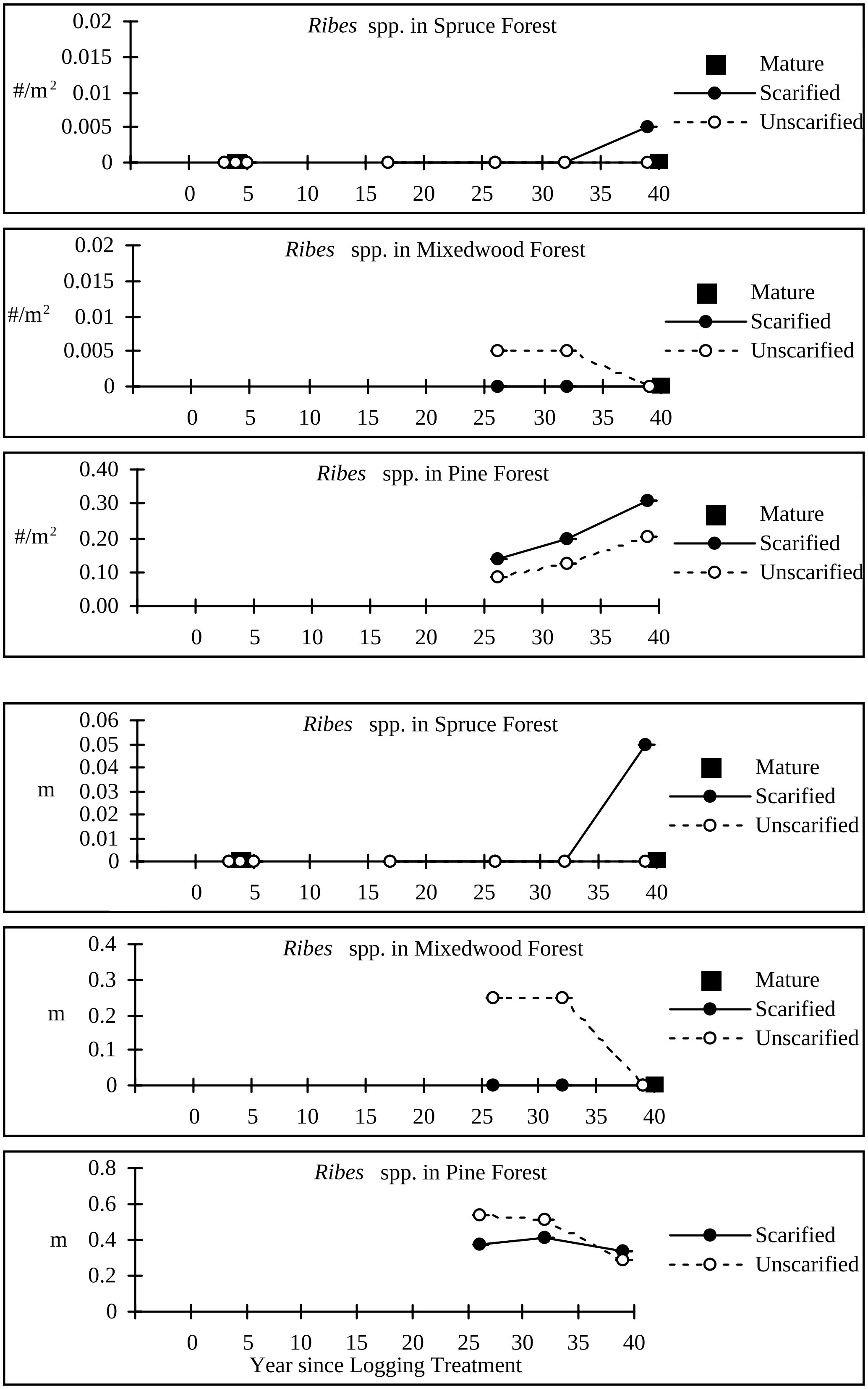


Figure 19. Mean density and height of *Ribes* spp. in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

Successional and Treatment Response of Trees

The following results on tree densities are stratified by tree height as defined by: seedlings (0–2 m), saplings (2-6 m) subcanopy (6–10) and canopy (>10 m).

SPRUCE Forest

Total white spruce densities on cutblocks remained very low during Yrs 1–5, increased during Yrs 5–17 and thereafter stabilized (Figure 20). Densities were consistently higher on scarified cutblocks while height was consistently taller on unscarified cutblocks. Higher white spruce density on scarified cutblocks was caused by high numbers of seedling and sapling individuals (Table 4, Figure 24, Figure 31). In contrast, unscarified cutblocks had higher numbers of subcanopy and canopy trees. This size class profile indicates that survivorship of white spruce seedlings on unscarified cutblocks during early post-logging stages was higher than on scarified cutblocks. It was the establishment and survival of these seedlings on unscarified cutblocks that accounted for the higher density of subcanopy and canopy trees by Yr 39.

Lodgepole pine did not occur in either mature or harvested spruce forests (Figure 21). Trembling aspen were not numerically important in post-harvested spruce cutblocks. Low densities of aspen occurred on scarified cutblocks at Yr 32 and these seedling/suckers were ~0.5 m by Yr 39. No seedlings/suckers of aspen occurred on unscarified spruce cutblocks (Figure 26). Balsam poplar seedlings/suckers were more abundant than aspen on spruce cutblocks and became established shortly following logging (Figure 23). Scarified cutblocks had higher initial densities than did unscarified cutblocks but densities had converged by Yr 17. Average height of poplar trees was marginally higher on unscarified than on scarified cutblocks. Densities of seedling, sapling and subcanopy poplar were marginally, though consistently, higher on scarified cutblocks (Figure 27).

On **SPRUCE** cutblocks during the later stages of the study (Yrs 32 and 39) conifer cover of the 2–10 m and 10 m+ strata were higher on unscarified than scarified cutblocks (Table 3, Figure 28). Neither cutblock treatments had re-established canopy cover of these height strata equal to those found in unharvested mature forests. In contrast, cover of conifer trees of 0–2 m were higher than unharvested mature forests and were higher on scarified than unscarified forests (Table 3, Figure 28).

On **SPRUCE** cutblocks during the later stages of the study (Yrs 32 and 39) canopy conifer density (>10 m) was higher on unscarified than scarified cutblocks but lower than densities found in unharvested mature forests (Table 4, Figure 34). Whereas densities of canopy and subcanopy conifers was generally higher on unscarified cutblocks, densities of sapling and seedling conifers was generally higher on scarified than unscarified cutblocks.

MIXEDWOOD Forest

Total white spruce densities on cutblocks remained very low during Yrs 1–32, then increased during Yrs 32–39 with densities consistently higher on unscarified cutblocks (Figure 20). Higher white spruce density on unscarified cutblocks was caused by high numbers of seedling, saplings, subcanopy, and canopy individuals (Table 4, Figure 24, Figure 29, Figure 32, Figure 35). Relative to scarified cutblocks, spruce on unscarified cutblocks were significantly taller (all height classes combined) and had higher densities in each of seedling, sapling, subcanopy and canopy strata. The above trends indicate good establishment and survivorship of white spruce on unscarified cutblocks and poor performance on scarified cutblocks. The white spruce canopy trees on unscarified cutblocks were residual unharvested trees; these individuals likely provided seed source and overstory protection for conifer seedlings.

Lodgepole pine densities were generally low (<0.04 trees/m^2) on regenerating mixedwood cutblocks and exhibited no difference between scarified and unscarified cutblocks (Figure 21). There is no evidence that they were becoming an important component of the tree community in these **MIXEDWOOD** cutblocks (Table 4, Figure 25).

Trembling aspen became established in **MIXEDWOOD** cutblocks immediately following harvest (Figure 22). Densities were generally higher on scarified cutblocks though seedling/sucker heights did not differ significantly between cutblock treatments. By Yr 39, aspen densities were ~0.4 trees/m^2 on scarified cutblocks, ~0.2 trees/m^2 on unscarified cutblocks and tree heights were 4–6 m. Higher aspen densities on scarified cutblocks were caused by greater abundance of seedling, sapling and subcanopy individuals, whereas canopy trees were equally abundant on both cutblock treatments (Figure 26). Balsam poplar seedlings/suckers remained of low density between Yrs 1–32 on both cutblock treatments and thereafter increased moderately to ~0.1 trees/m^2 (Figure 23). Heights of balsam poplar did not increase during Yrs 25–32 indicating that survivorship and/or growth was poor. Densities of seedling, sapling and subcanopy poplar were similarly low on both scarified and unscarified cutblocks (Figure 27).

On **MIXEDWOOD** cutblocks during the later stages of the study (Yrs 32 and 39) conifer cover of the 2–10 m and 10 m+ strata were significantly higher on unscarified than scarified cutblocks (Table 3, Figure 29). At this stage, canopy cover of these strata on unscarified cutblocks had equaled or surpassed values found in unharvested mature forests. Cover of smaller conifer trees (0–2 m) was higher in unharvested mature forests than in either scarified or unscarified cutblocks (Table 3, Figure 29).

On **MIXEDWOOD** cutblocks during the later stages of the study (Yrs 32 and 39) canopy (>10 m) and subcanopy (6–10 m) conifer density was higher on unscarified than scarified cutblocks. By Yr 39, densities of subcanopy and canopy conifer trees had exceeded densities measured in unharvested mature forests (Table 4, Figure 35). Whereas densities of sapling conifers was higher on scarified cutblocks in Yr 32, they were higher on unscarified cutblocks in Yr 39. Given that densities of subcanopy conifers had declined between Yr 32 and Yr 39 on scarified cutblocks, it is logical to conclude that mortality of young conifers on scarified cutblocks was proportionally higher than levels experienced on unscarified cutblocks. Increasing densities of seedling conifers in unharvested **MIXEDWOOD** forests and on scarified and unscarified cutblocks between Yrs 32 and 39 indicate favorable combinations of seed trees, overstory protection and germination substrate in each of these stands.

PINE Forest

White spruce densities on pine cutblocks remained very low throughout the study, and only achieved measurable densities by Yr 39 (Figure 20). Heights of white spruce at Yr 39 averaged 3–5 m and were consistently higher on scarified cutblocks (Figure 20). Densities of white spruce were consistently higher on unscarified pine cutblocks and these higher levels occurred for both seedling and sapling height classes (Table 4, Figure 24, Figure 33). Higher densities of white spruce on unscarified cutblocks may be related to improved resource availability associated with the lower densities of lodgepole pine on these cutblocks.

Lodgepole pine established quickly following logging on scarified cutblocks and more slowly on unscarified cutblocks (Figure 21). By Yr 32, total average densities of lodgepole pine on scarified and unscarified cutblocks had converged for all height classes (Figure 25). By Yr 39, densities of canopy lodgepole pine had increased to similar levels (0.05–0.19 trees/m^2) on both scarified and unscarified cutblocks. By the conclusion of the study, densities of seedling, sapling, subcanopy and canopy pine were not different between cutblock treatments. Heights of lodgepole pine averaged ~10 m on both cutblock treatments at Yr 39.

Trembling aspen established slowly on **PINE** cutblocks though somewhat faster on scarified cutblocks (Figure 22). Between Yrs 32–39 average densities had converged on scarified and unscarified treatments at ~0.08 trees/m^2. Treatment effects were pronounced when one considered tree strata as aspen on unscarified cutblocks were primarily seedlings and saplings, whereas aspen on scarified cutblocks were primarily subcanopy and canopy trees (Figure 26). This pattern suggests that scarification induced a successful suckering of aspen following harvest and that many of these initial individuals are now present as subcanopy and canopy trees. Balsam poplar seedlings/suckers established shortly following logging and more aggressively on scarified (Figure 23). During Yrs 27–39, poplar height did not differ between cutblock treatments. Demographic profiles of poplars indicate higher densities of subcanopy trees on scarified cutblocks during Yrs 27–39, but these individuals did not advance to canopy trees at a higher density than those on unscarified cutblocks (Figure 27). It would appear that balsam poplar will diminish in abundance as succession proceeds in these **PINE** cutblocks.

Total conifer densities were similar in both cutblock treatments at Yr 39 for both canopy (900–950/ha) and subcanopy (400/ha) trees.

On **PINE** cutblocks during the later stages of the study (Yrs 32 and 39) conifer cover of all height classes (0–2, 2–10 and 10 m+) did not differ between scarified and unscarified cutblocks. For both cutblock treatments between Yrs 32 and 39, there was clear evidence of trees in the 2–10 m height strata graduating to the >10 m strata. There was also evidence of continued recruitment of young pine on both scarified and unscarified cutblocks between Yrs 32 and 39 (Table 3, Figure 30).

On **PINE** cutblocks during the later stages of the study (Yrs 32 and 39) conifer density of canopy and subcanopy strata did not differ between scarified and unscarified cutblocks forests (Table 4, Figure 36). Although highly variable, density of sapling and seedling conifers was generally higher on unscarified cutblocks than on scarified cutblocks. Whereas the conifers on scarified cutblocks were generally even height (and presumably even-aged), conifers on unscarified cutblocks had greater representation among each height class strata.

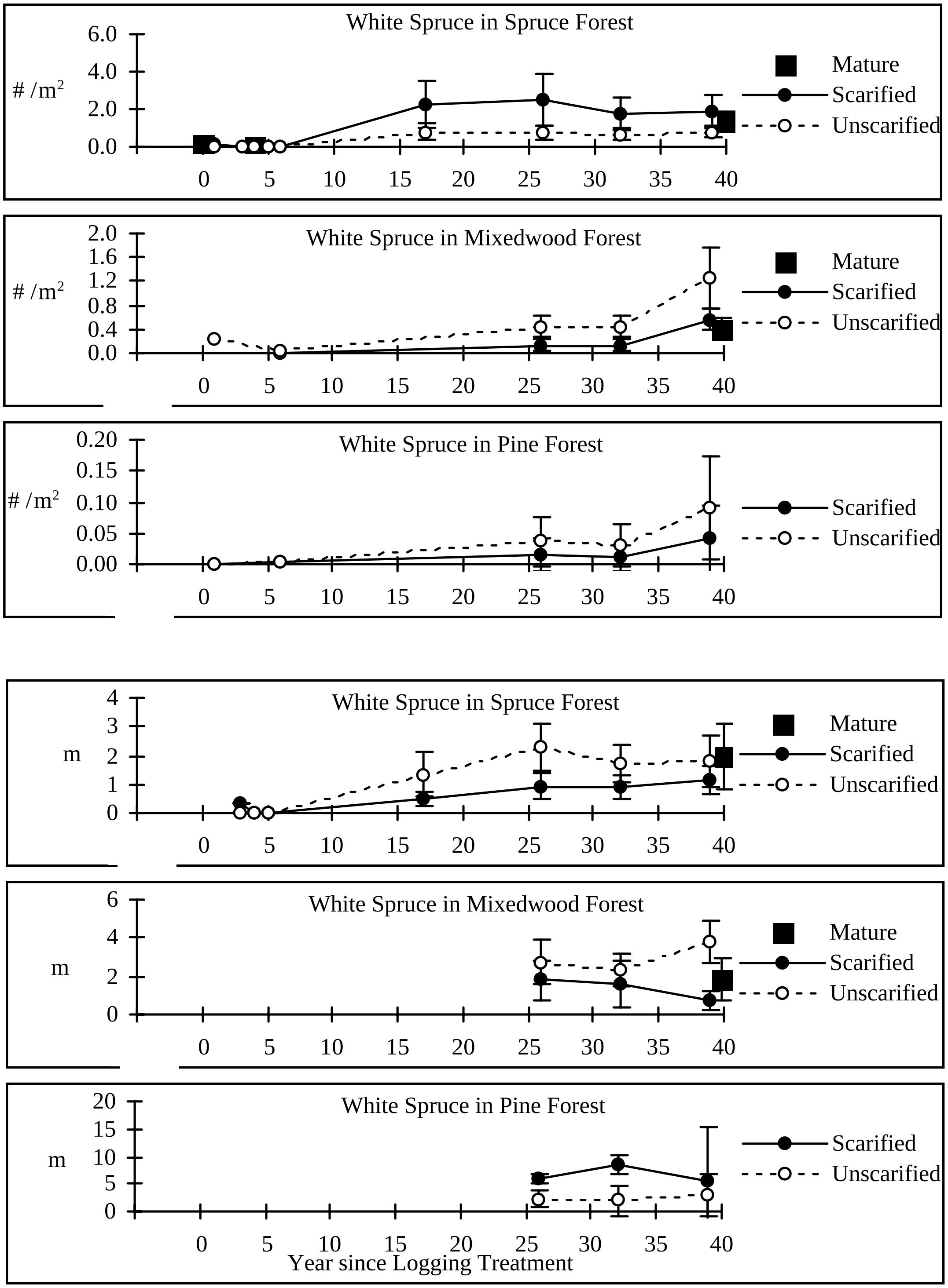


Figure 20. Density and height of white spruce in SPRUCE, MIXEDWOOD, and PINE forests following logging. Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

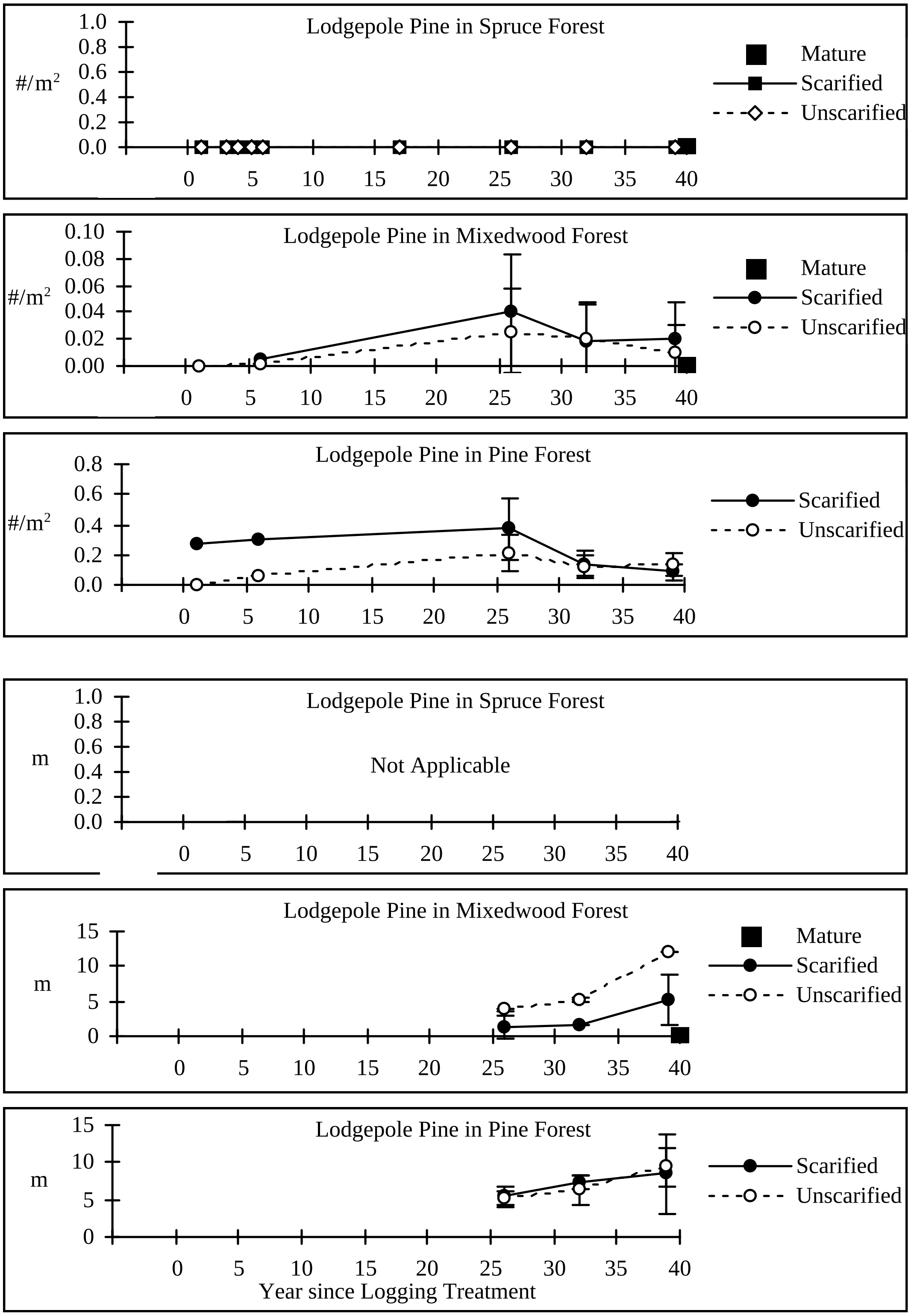


Figure 21. Density and height of lodgepole pine in SPRUCE, MIXEDWOOD, and PINE forests following logging; Yrs 1–39 (1955–1995). Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

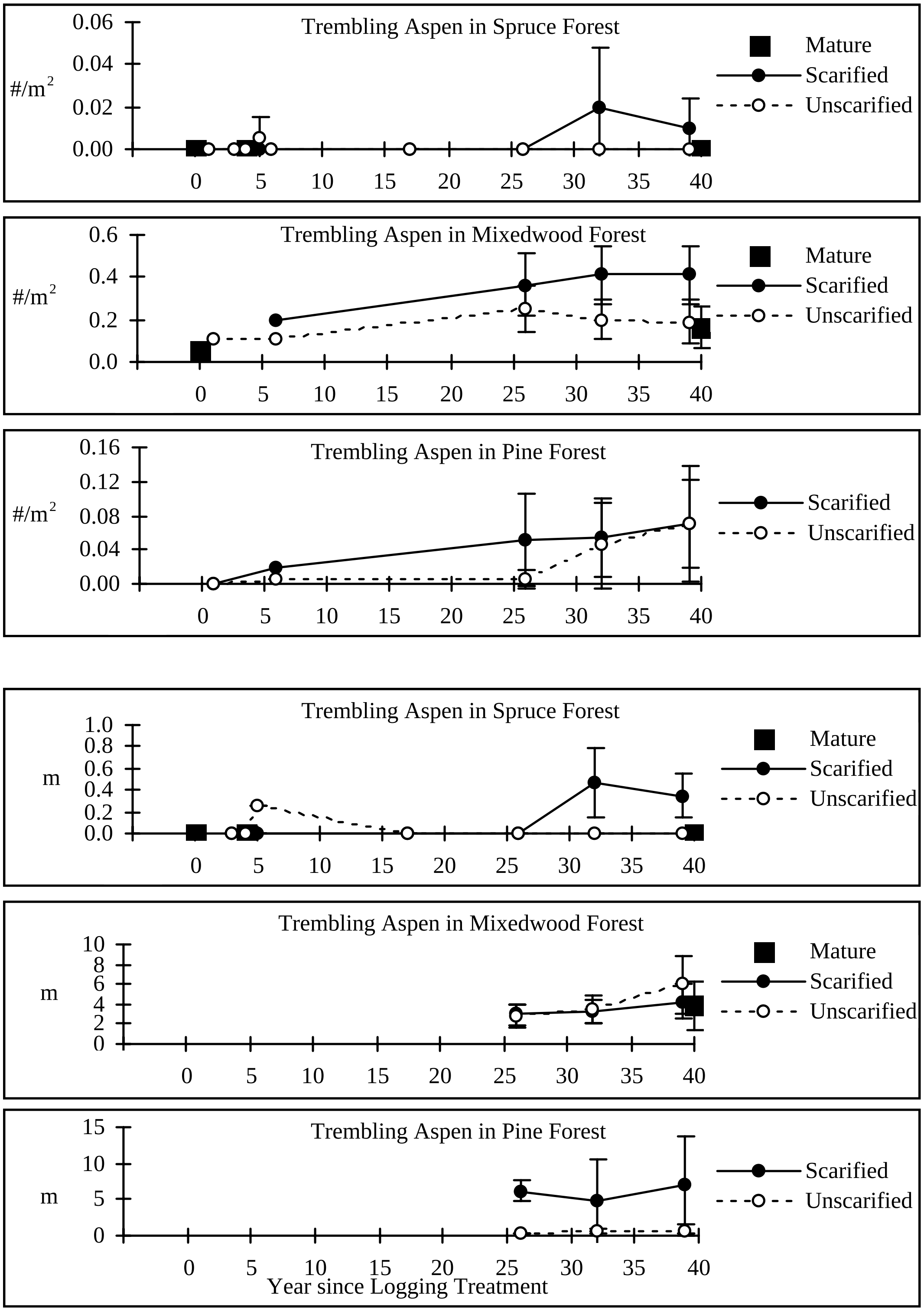


Figure 22. Density and height of trembling aspen in SPRUCE, MIXEDWOOD, and PINE forests following logging; Yrs 1–39 (1955–1995). Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

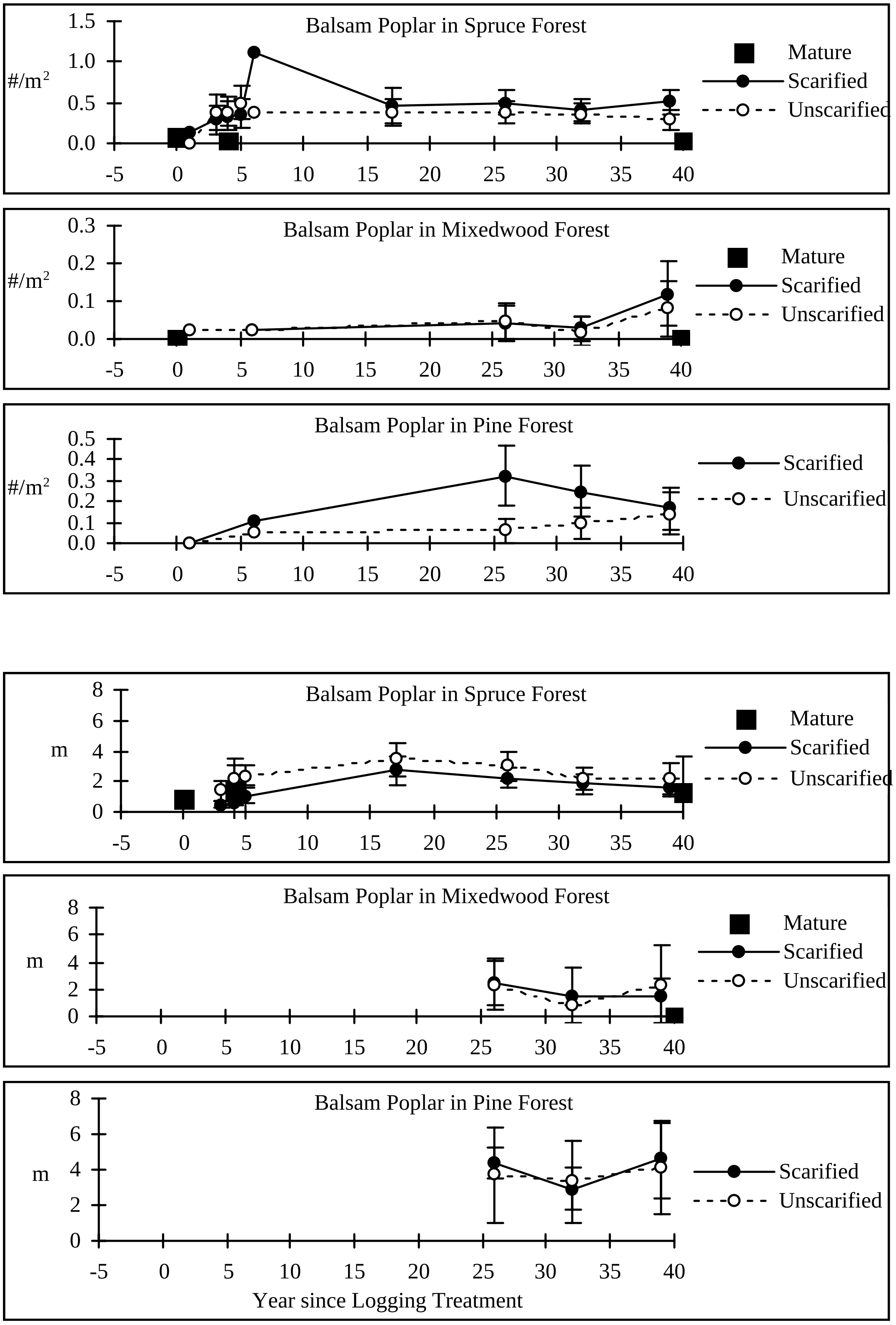


Figure 23. Total density and mean height of balsam poplar in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests following logging; Yrs 1–39 (1955–1995). Means ± 2 S.E. presented. No measure of variation available for Yrs 1 or 6.

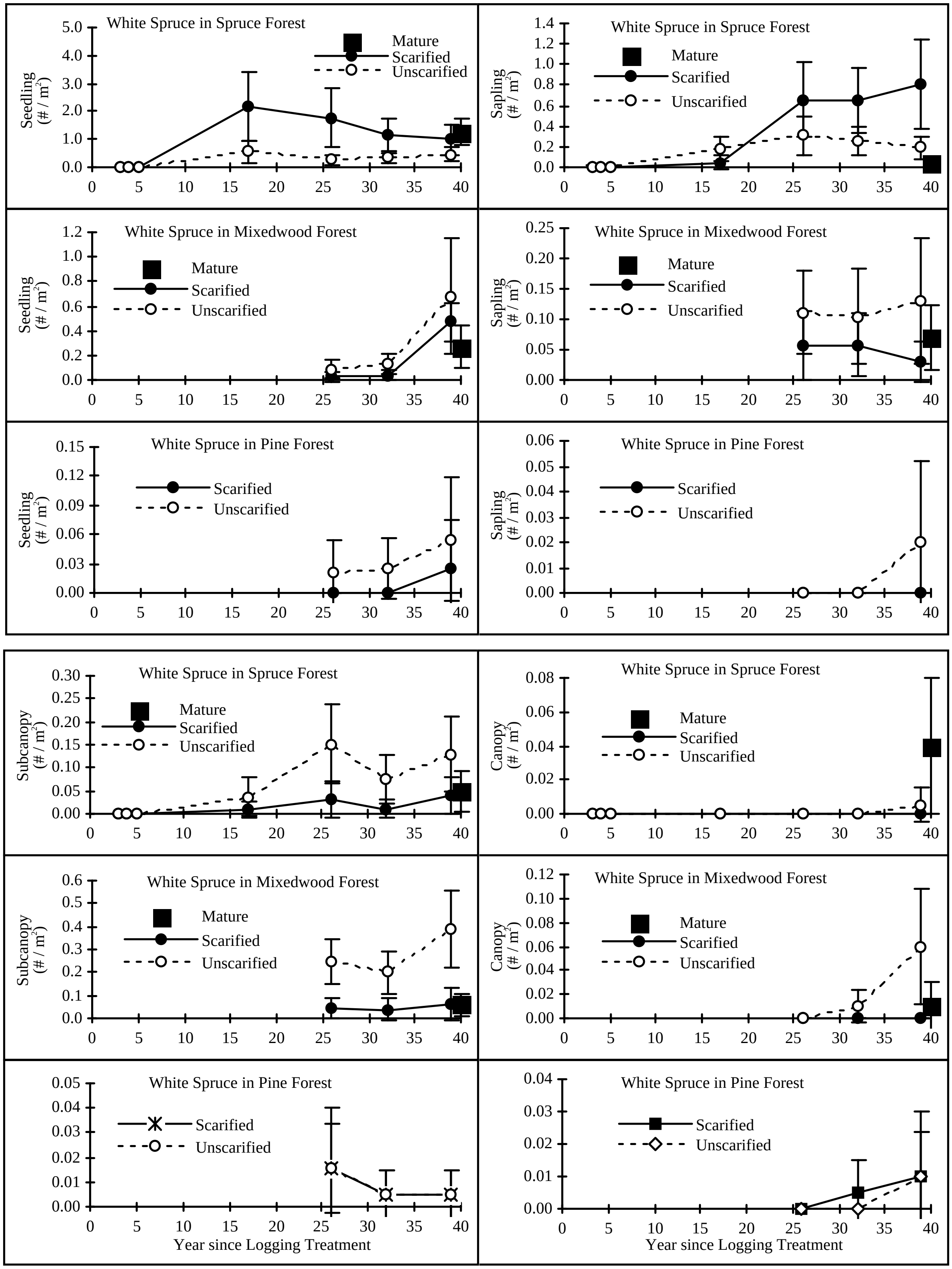


Figure 24. Density (± 2. S.E.) of white spruce in seedling (0–2 m), sapling (2–6 m), subcanopy (6–10 m) and canopy (>10 m) strata in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests following logging; Yrs 1–39 (1955–1995).

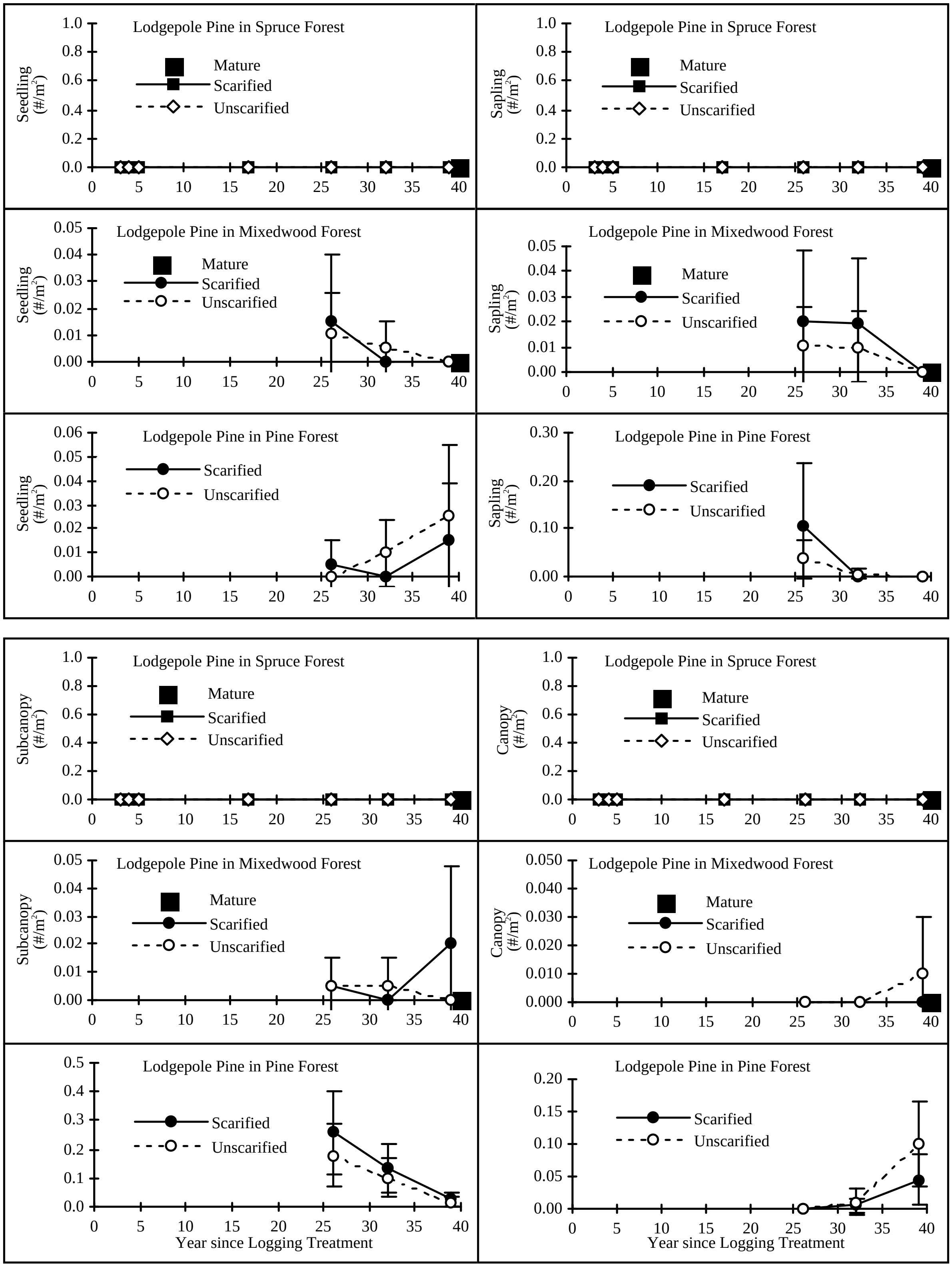


Figure 25. Density (± 2. S.E.) of lodgepole pine in seedling (0–2 m), sapling (2–6 m), subcanopy (6–10 m) and canopy (>10 m) strata in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests following logging; Yrs 1–39 (1955–1995).

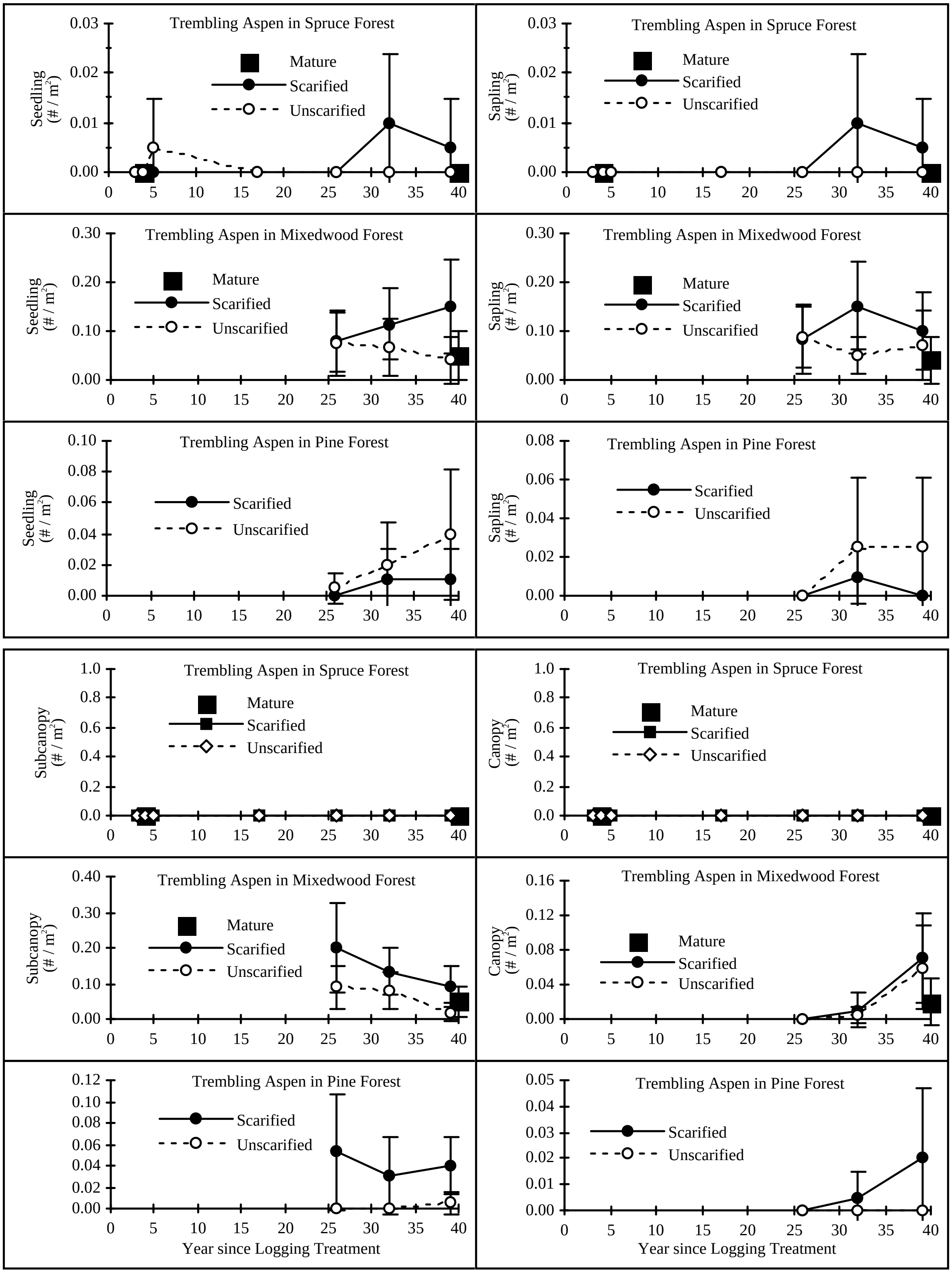


Figure 26. Density (± 2. S.E.) of trembling aspen in seedling (0–2 m), sapling (2–6 m), subcanopy (6–10 m) and canopy (>10 m) strata in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests following logging; Yrs 1–39 (1955–1995).

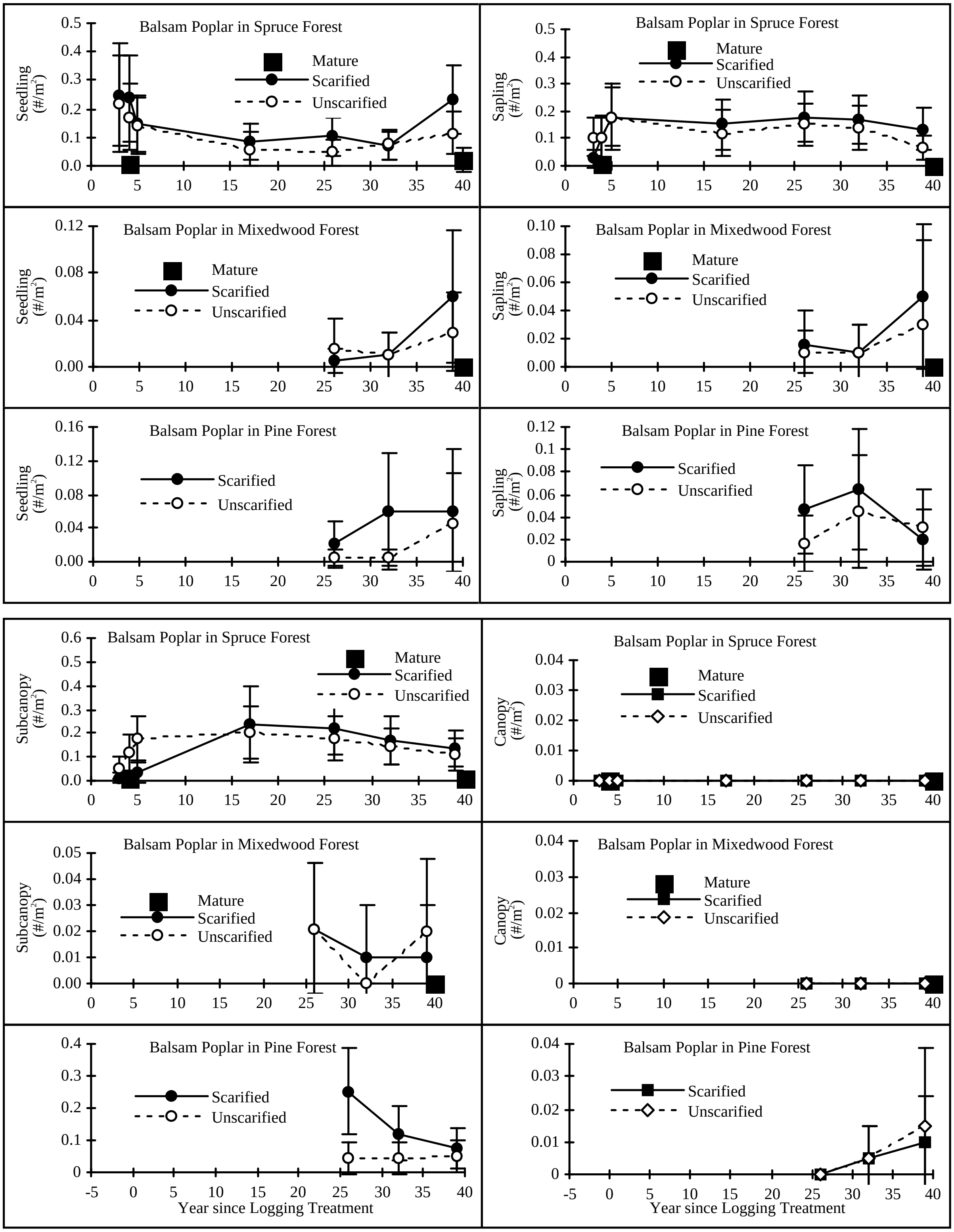


Figure 27. Density (± 2. S.E.) of balsam poplar in seedling (0–2 m), sapling (2–6 m), subcanopy (6–10 m) and canopy (>10 m) strata in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests following logging; Yrs 1–39 (1955–1995).

Table 3. Cover[1] (%) of conifers in mature forests and scarified and unscarified cutblocks during Yrs 32 and 39 (1988–1995).

Forest	Treatment	Year	Total Conifer Cover		Cover >2 m		Cover >6 m		Cover >10 m	
			Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Spruce	Mature	32	71.9	11.8	69.2	11.5	61.1	10.2	41.7	7.3
Spruce	Mature	39	62.9	11.4	59.1	11.1	48.8	8.8	33.9	5.8
Spruce	Scarified	32	12.0	2.3	5.5	2.0	1.8	1.5	0.0	0.0
Spruce	Scarified	39	22.8	3.5	11.8	2.8	5.0	2.3	0.8	0.9
Spruce	Unscarified	32	19.3	4.2	15.6	4.0	8.0	3.1	1.6	1.5
Spruce	Unscarified	39	32.1	6.6	27.3	6.4	18.0	5.7	10.1	4.3
Mixedwood	Mature	32	70.1	10.0	63.5	9.8	44.0	8.7	25.4	6.9
Mixedwood	Mature	39	81.5	11.2	75.5	10.8	49.0	8.8	25.3	5.0
Mixedwood	Scarified	32	22.4	7.5	18.9	7.4	8.4	4.6	0.0	0.0
Mixedwood	Scarified	39	15.8	5.0	14.9	4.9	10.5	4.5	6.8	3.7
Mixedwood	Unscarified	32	80.4	10.2	78.2	10.0	46.5	7.9	17.1	4.4
Mixedwood	Unscarified	39	146.7	20.4	143.9	20.4	117.3	18.3	84.2	15.9
Pine	Scarified	32	49.4	5.7	48.8	5.7	29.7	5.2	3.1	2.4
Pine	Scarified	39	109.5	20.5	109.5	20.5	107.9	20.3	98.9	19.4
Pine	Unscarified	32	39.9	6.4	37.1	6.4	34.9	6.3	7.7	3.3
Pine	Unscarified	39	114.6	17.9	114.2	17.9	113.3	17.9	103.7	17.6

[1] conifer cover values for each category include all trees above the category upper level; i.e., 2 m, 6 m and 10 m.

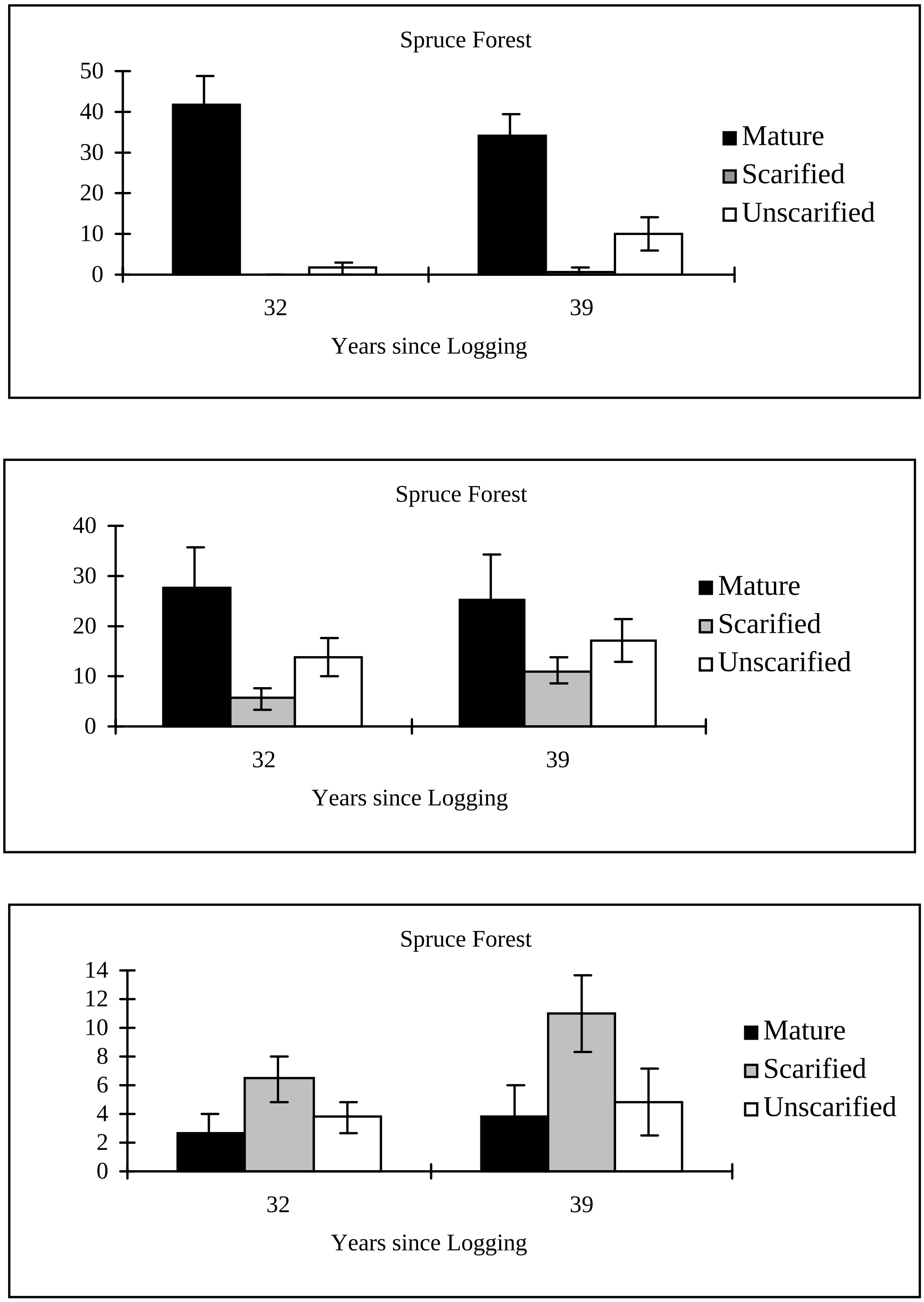
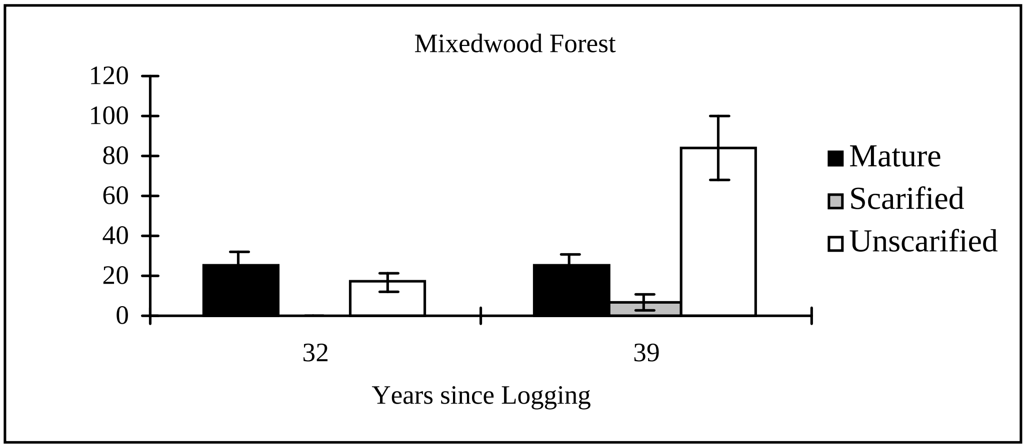
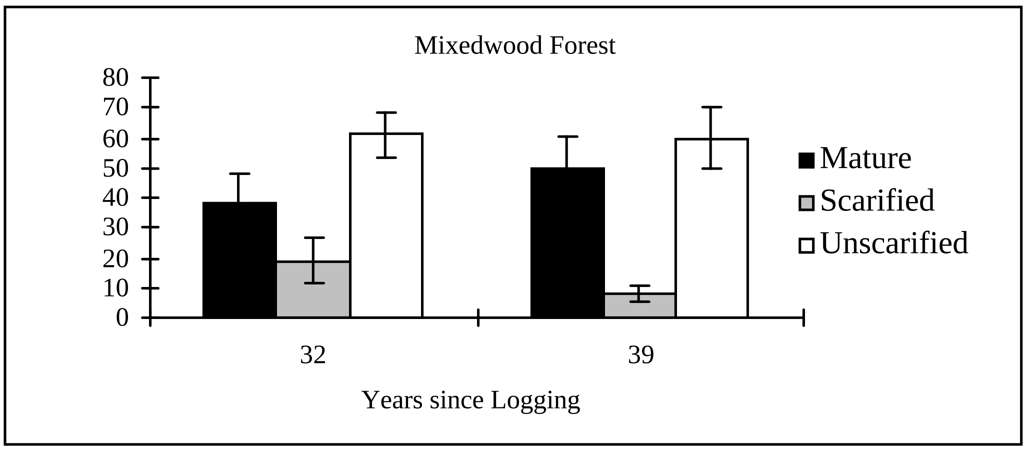


Figure 28. Conifer cover (± 2. S.E.) in mature SPRUCE forest and SPRUCE cutblocks during Yrs 32 and 39 (1988–1995).





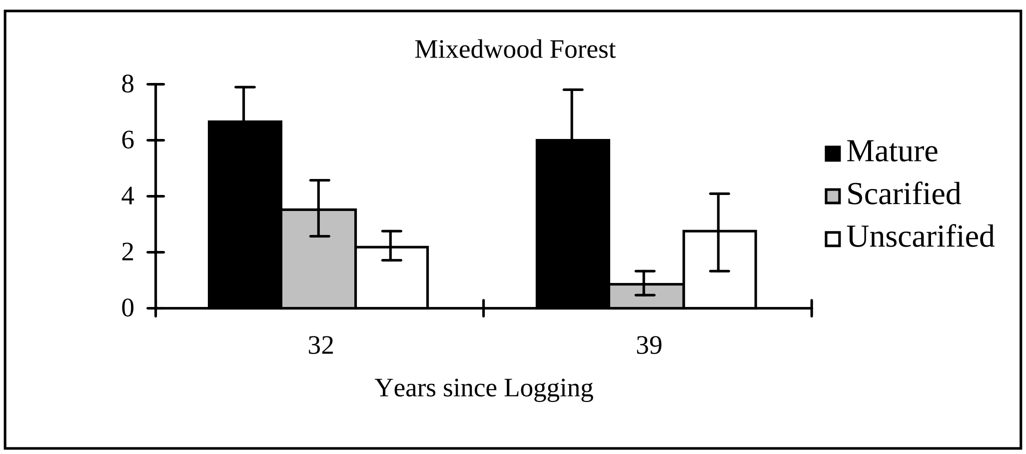


Figure 29. Conifer cover (± 2. S.E.) in mature **MIXEDWOOD** forest and **MIXEDWOOD** cutblocks during Yrs 32 and 39 (1988–1995).

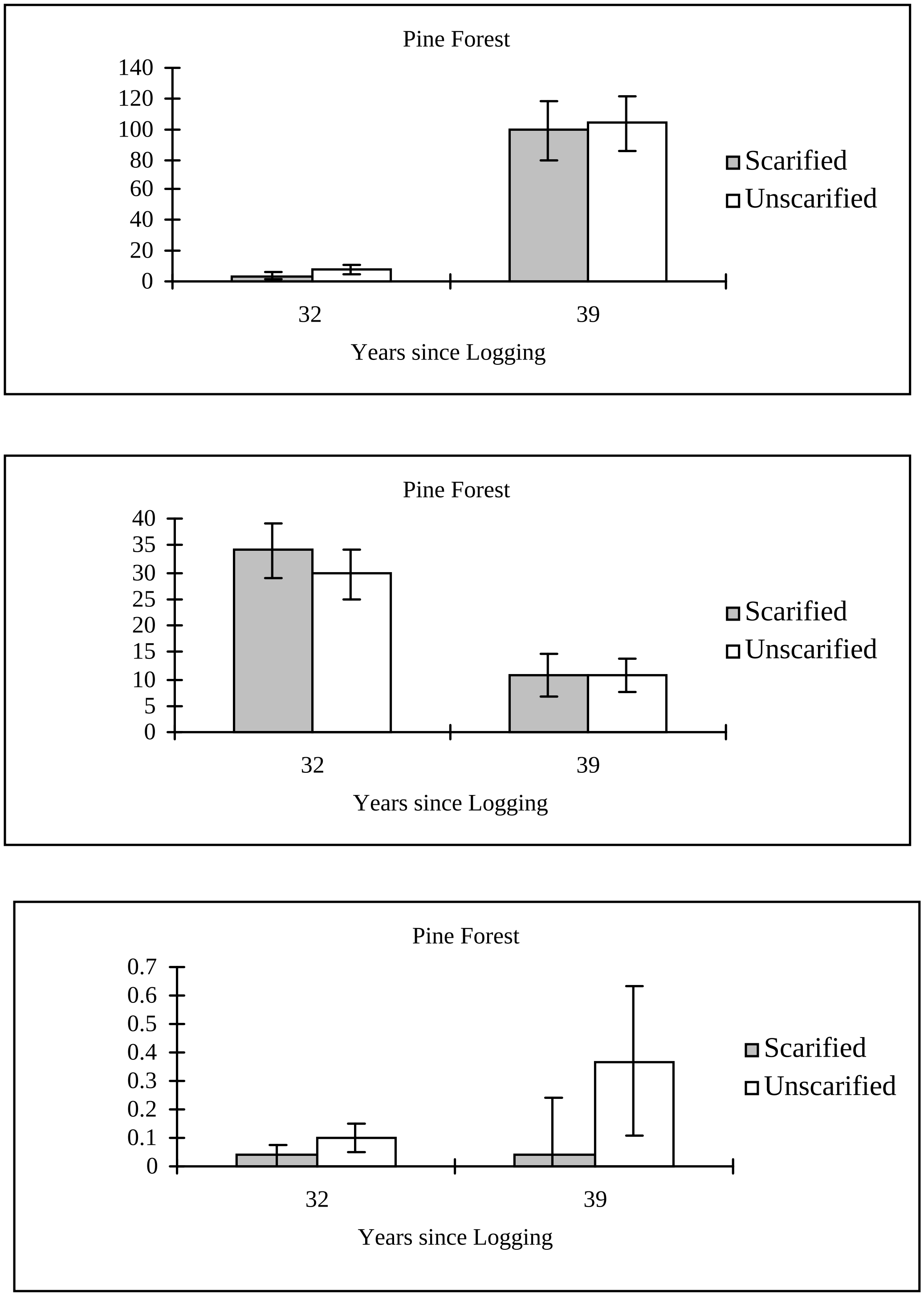


Figure 30. Conifer cover (± 2. S.E.) in PINE cutblocks during Yrs 32 and 39 (1988–1995).

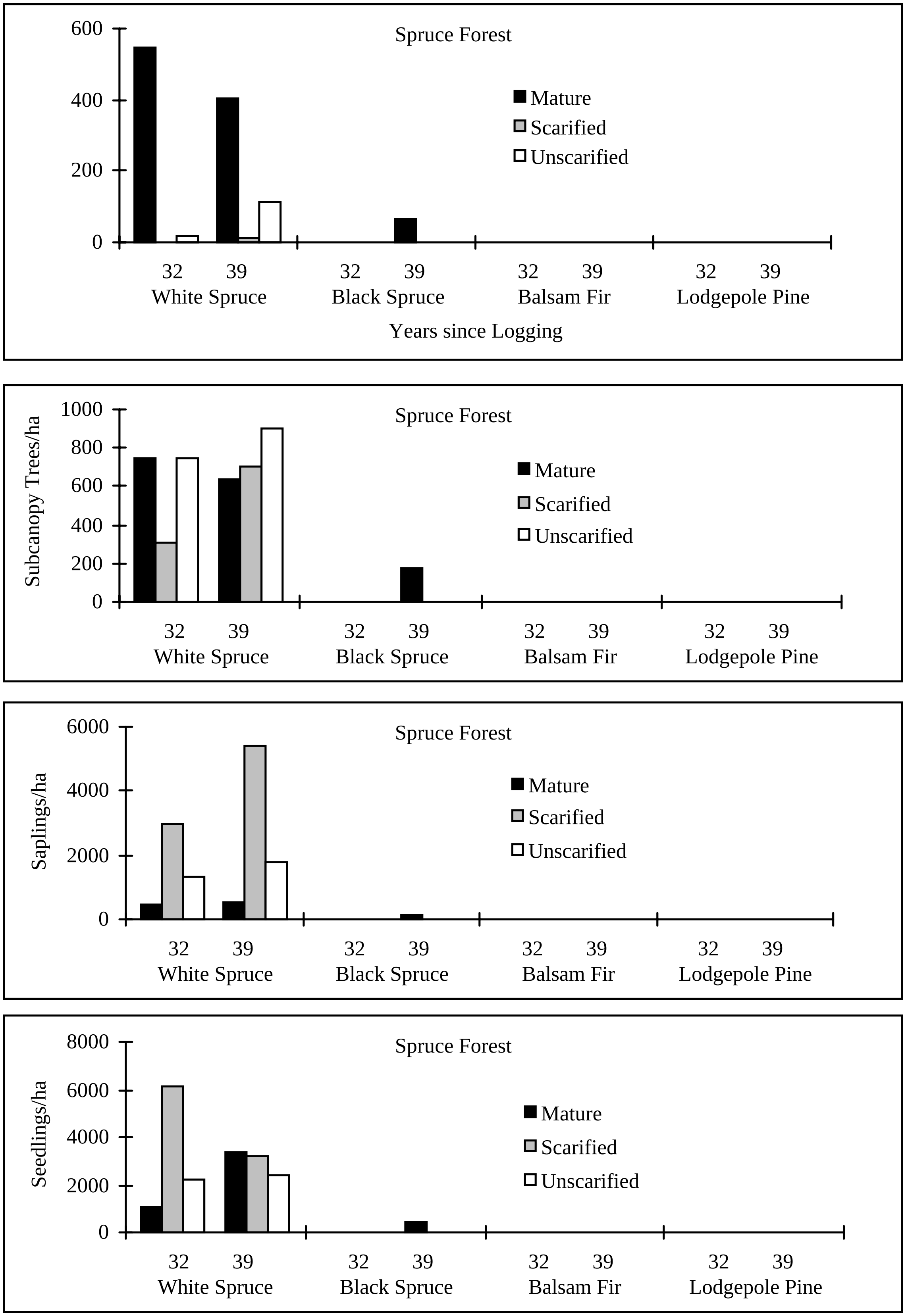


Figure 31. Conifer densities in SPRUCE forests during Yrs 32 and 39 (1988–1995).

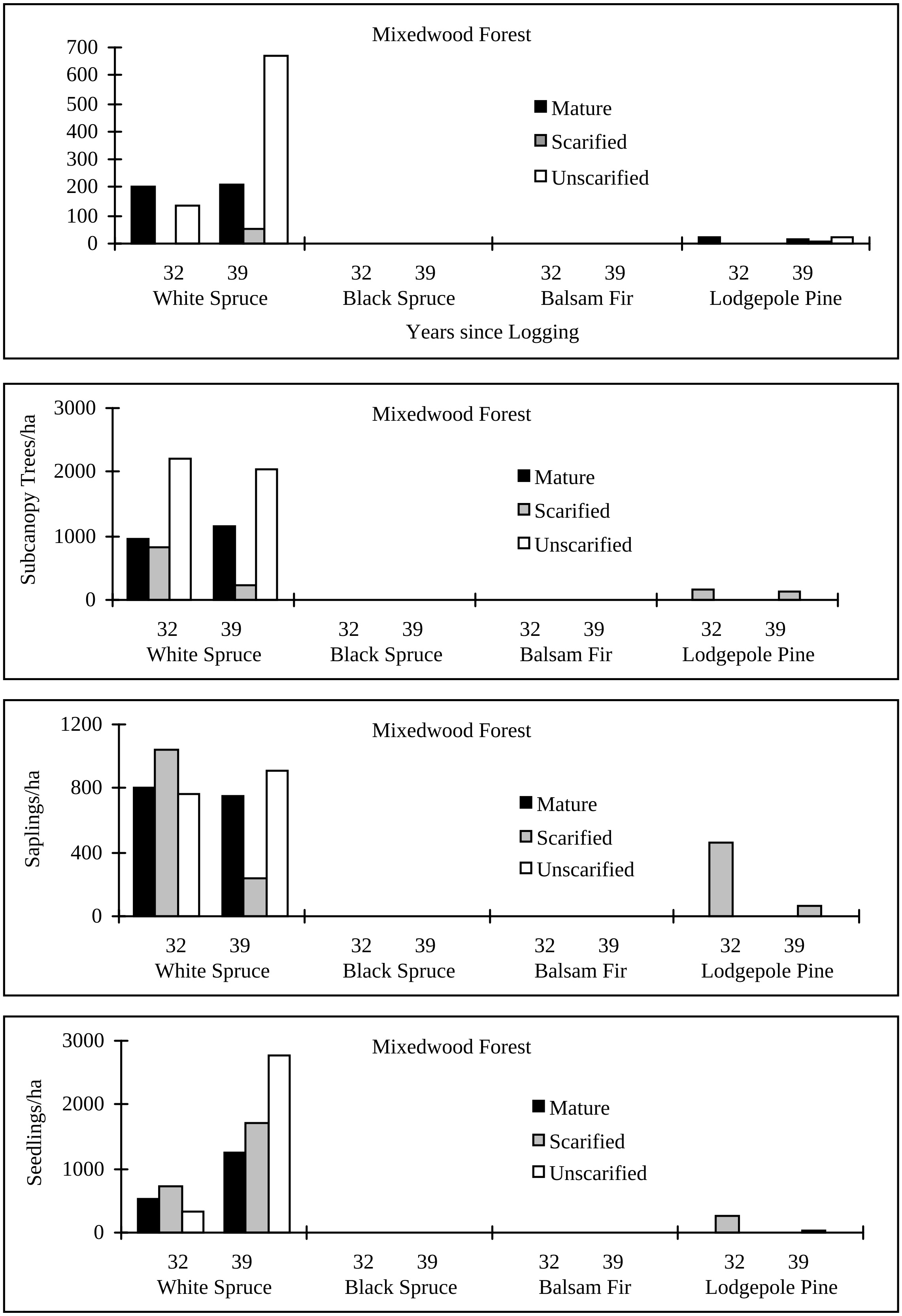


Figure 32. Conifer densities in **MIXEDWOOD** forests during Yrs 32 and 39 (1988–1995).

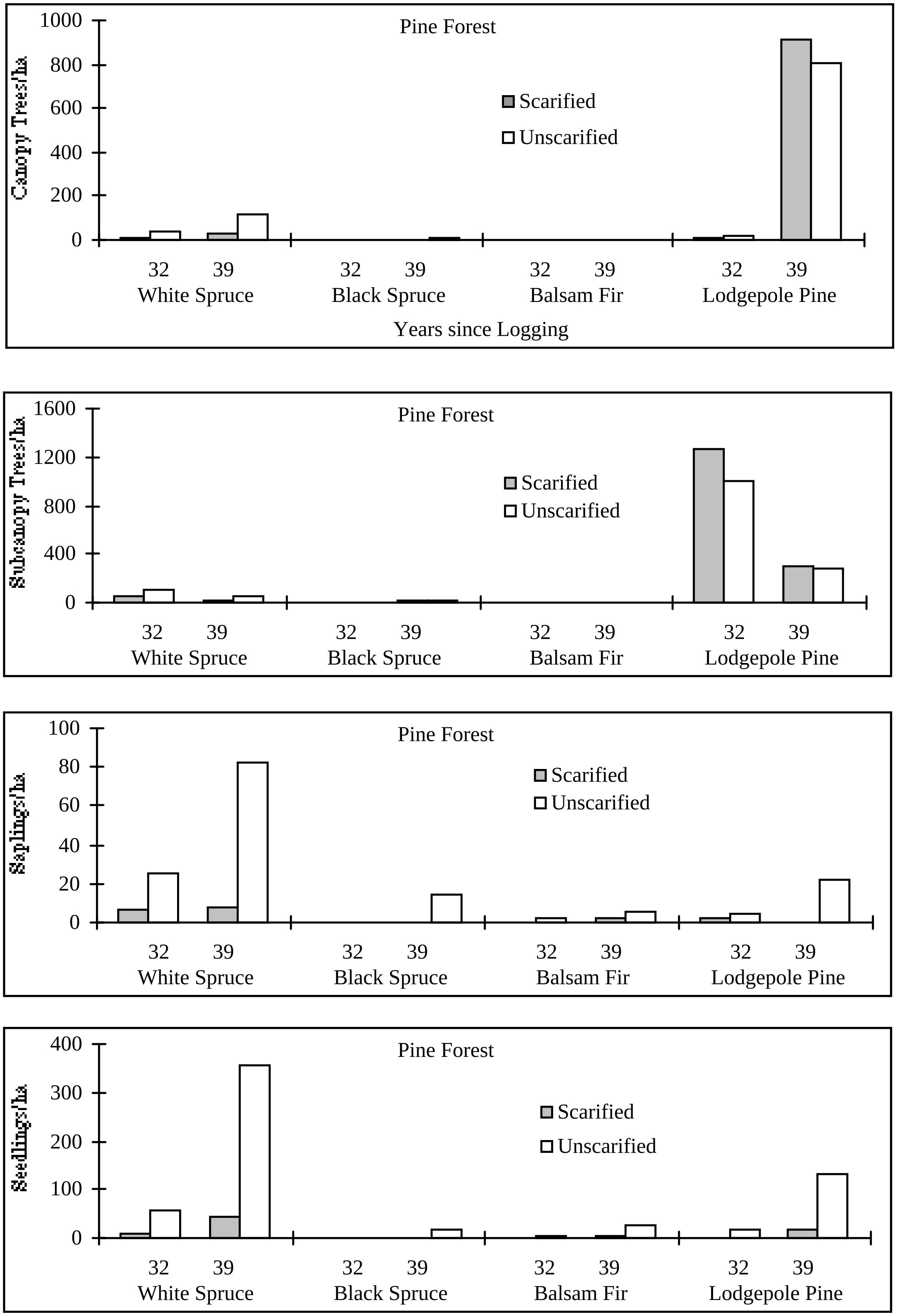


Figure 33. Conifer densities in PINE forests during Yrs 32 and 39 (1988–1995).

Table 4. Conifer densities (#/ha) within each height stratum (average of Yrs 32 and 39)[1].

Forest	Treatment	Year	Species	Seedling (0-2 m)	Sapling (2-6 m)	Subcanopy (6–10 m)	Canopy (>10 m)
Spruce	Mature	32	Pine	0	0	0	0
Spruce	Mature	39	Pine	0	0	0	0
Spruce	Mature	32	W./B. Spruce	1,040	436	752	548
Spruce	Mature	39	W. Spruce	3,414	538	636	406
Spruce	Mature	39	B. Spruce	418	112	178	64
Spruce	Scarified	32	Pine	0	0	0	0
Spruce	Scarified	39	Pine	0	0	0	0
Spruce	Scarified	32	W. Spruce	6,173	2,997	309	0
Spruce	Scarified	39	W. Spruce	3,232	5,418	698	10
Spruce	Scarified	32	B. Spruce	0	0	0	0
Spruce	Scarified	39	B. Spruce	0	0	0	0
Spruce	Unscarified	32	Pine	0	0	0	0
Spruce	Unscarified	39	Pine	0	0	0	0
Spruce	Unscarified	32	W. Spruce	2,234	1,308	742	18
Spruce	Unscarified	39	W. Spruce	2,422	1,752	902	112
Spruce	Unscarified	32	B. Spruce	0	0	0	0
Spruce	Unscarified	39	B. Spruce	0	0	0	0
Mixedwood	Mature	32	Pine	0	0	12	20
Mixedwood	Mature	39	Pine	0	0	8	14
Mixedwood	Mature	32	W./B. Spruce	540	804	960	204
Mixedwood	Mature	39	W. Spruce	1,268	754	1,170	208
Mixedwood	Mature	39	B. Spruce	6	6	6	0
Mixedwood	Scarified	32	Pine	260	460	170	0
Mixedwood	Scarified	39	Pine	20	68	116	4
Mixedwood	Scarified	32	W. Spruce	710	1,040	810	0
Mixedwood	Scarified	39	W. Spruce	1,708	236	244	52
Mixedwood	Scarified	32	B. Spruce	0	0	0	0
Mixedwood	Scarified	39	B. Spruce	0	0	0	0
Mixedwood	Unscarified	32	Pine	0	0	12	0
Mixedwood	Unscarified	39	Pine	0	0	0	20
Mixedwood	Unscarified	32	W. Spruce	342	760	2,206	138
Mixedwood	Unscarified	39	W. Spruce	2,780	904	2,040	672
Mixedwood	Unscarified	32	B. Spruce	0	0	0	0
Mixedwood	Unscarified	39	B. Spruce	0	0	0	0
Pine	Scarified	32	Pine	1	2	1,268	13
Pine	Scarified	39	Pine	18	0	306	910
Pine	Scarified	32	W./B. Spruce	7	7	47	8
Pine	Scarified	39	W. Spruce	44	8	24	26
Pine	Scarified	39	B. Spruce	0	0	26	2
Pine	Unscarified	32	Pine	18	4	1,000	24
Pine	Unscarified	39	Pine	130	22	280	810
Pine	Unscarified	32	W./B. Spruce	55	25	107	34
Pine	Unscarified	39	W. Spruce	356	82	54	116
Pine	Unscarified	39	B. Spruce	16	14	16	8

[1] During Yr 32, white spruce and black spruce were not reliably distinguished during data collection and are therefore presented as a single taxal group.

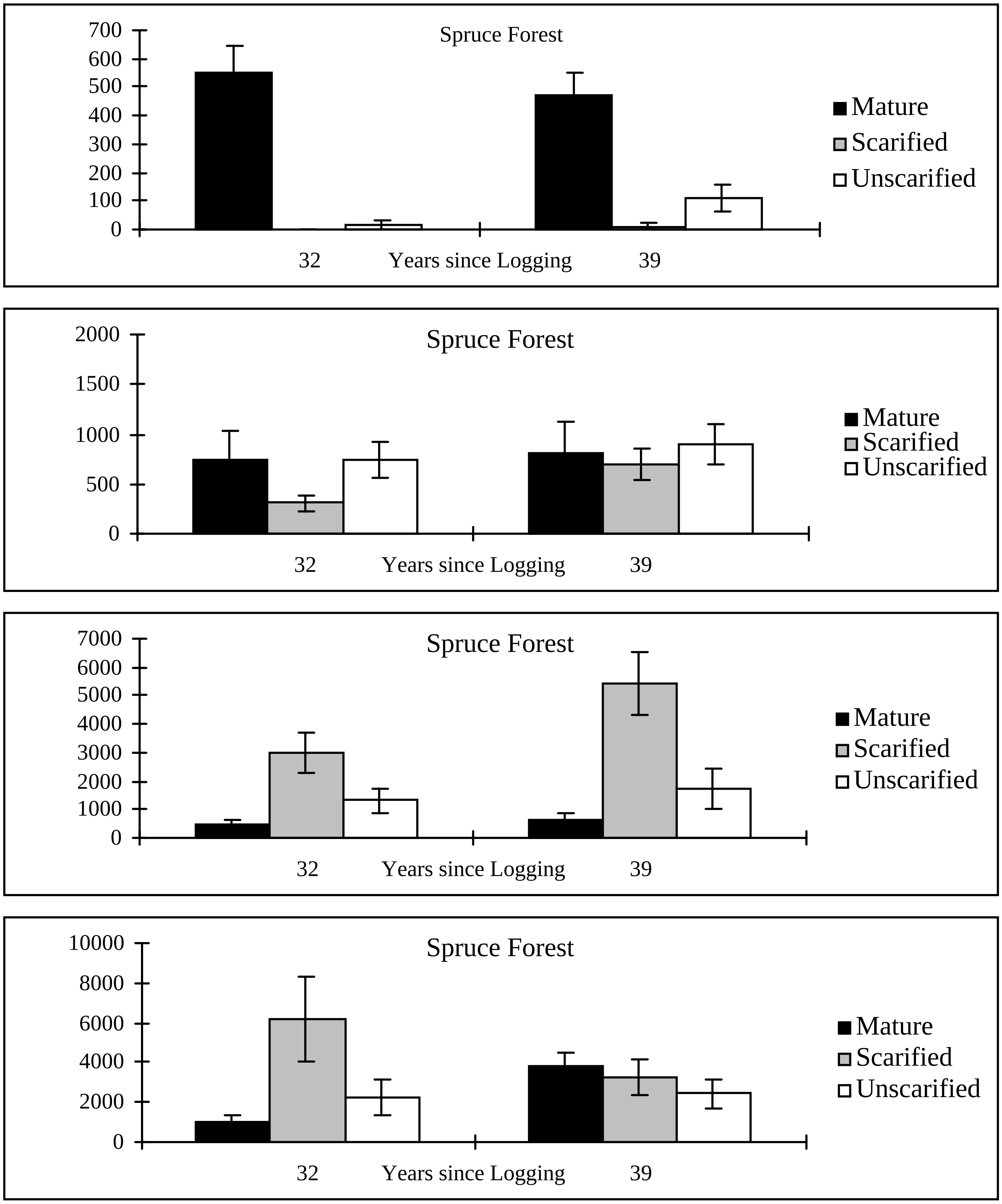


Figure 34. Total conifer density (± 2. S.E.) in Yrs 32 and 39 in SPRUCE forests in relation to treatment type.

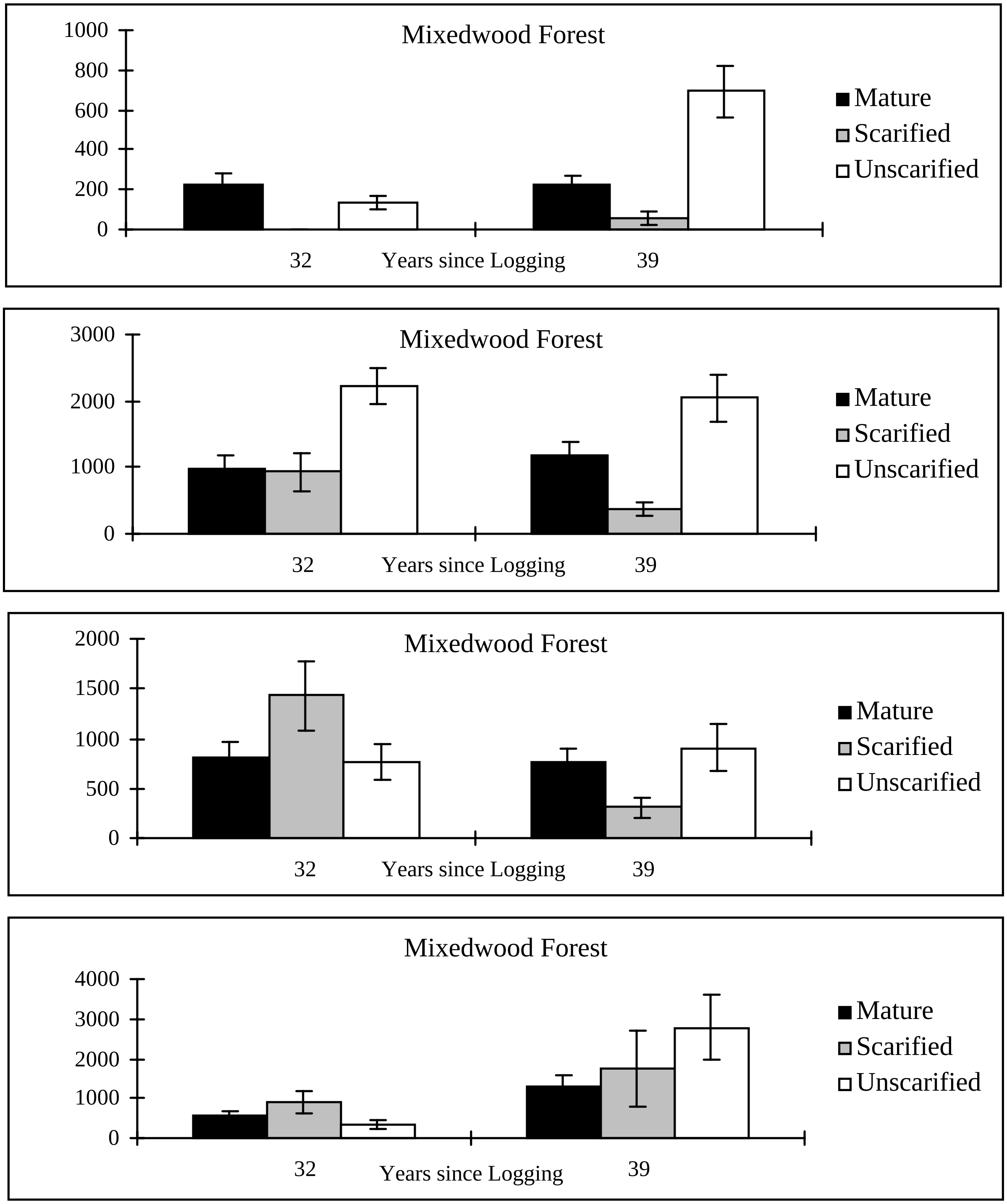


Figure 35. Total conifer density (± 2. S.E.) in Yrs 32 and 39 in **MIXEDWOOD** forests in relation to treatment type.

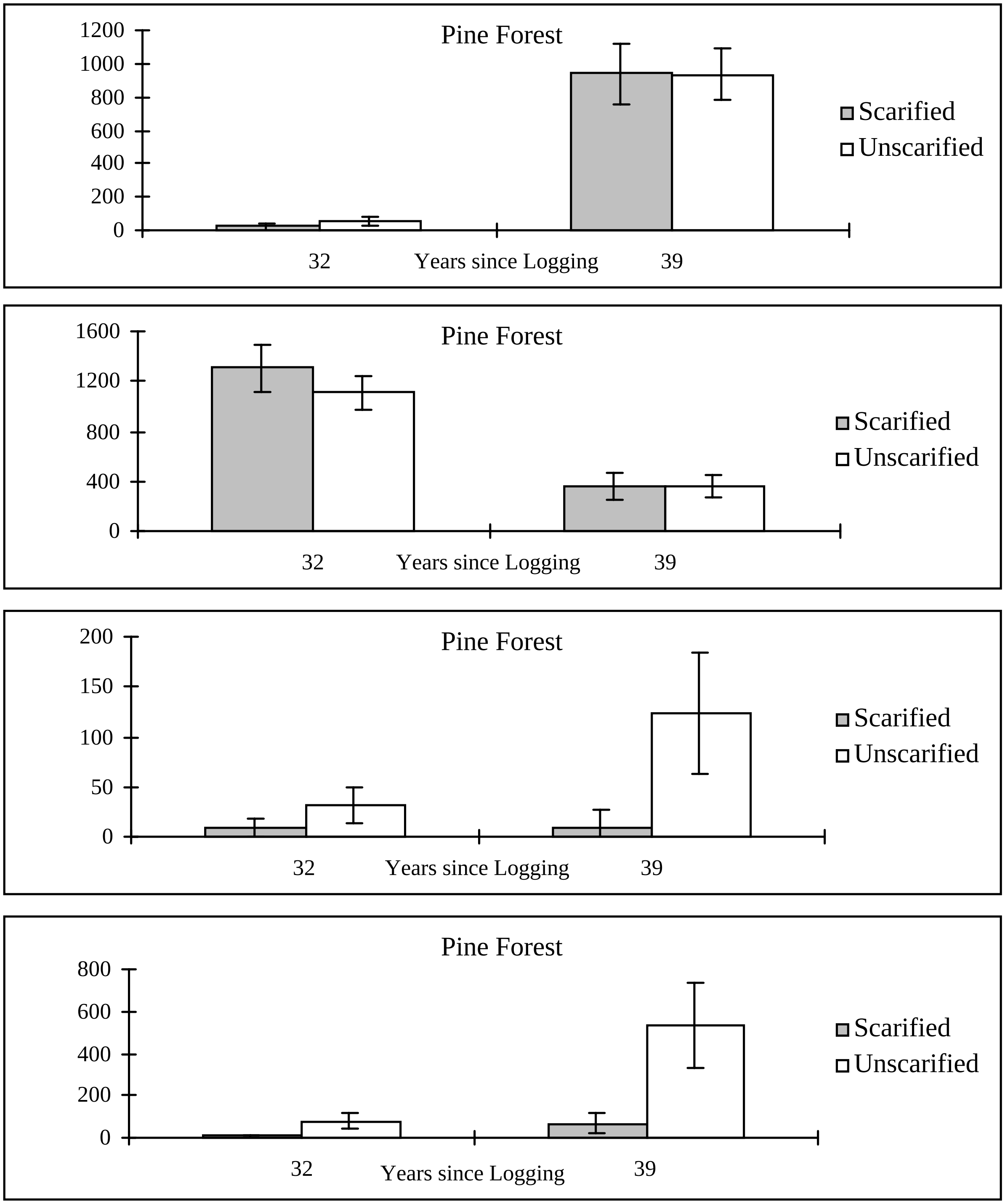


Figure 36. Total conifer density (± 2. S.E.) in Yrs 32 and 39 in PINE forests in relation to treatment type.

Species Richness and Similarity

<u>**SPRUCE** Forest</u>

Plant species richness increased with spruce cutblock age throughout post-harvest succession and also in mature unharvested forest as it progressed through post-rotational seral stages (Table 5, Figure 37). Species richness achieved maximum levels at Yr 32 in both scarified and unscarified cutblocks; both at values much higher than recorded in the mature forest (Figure 37). Forb species were the highest contributor to species richness, followed by shrubs, graminoids (grasses, sedges, rushes), dwarf shrubs, trees, and fern/allies. Increased post-harvest species richness occurred primarily through the addition of forb species. No major differences in species richness of plant groupings was observed between scarified and unscarified cutblocks at any seral stage.

Patterns in diversity indices (Shannon, Simpson) exhibited similar patterns reflecting the arrival of new species following harvest and a progressive change to a more equitable distribution of individual plants among species. Whereas a relatively few species dominated young post-harvest seral stages, later seral stages contained more even distribution of species, hence higher Shannon Species Evenness values (Figure 49). During young post-harvest seral stages (Yrs 3–5) scarified cutblocks had lower diversity and evenness indices than did unscarified cutblocks. This pattern suggests that a few species became established immediately following scarification and persisted as dominants on these cutblocks for several years. This interpretation is supported by similarity analyses (

Figure 51) which showed that scarified and unscarified cutblocks were most dissimilar shortly after logging.

Graminoid species achieved highest species richness at Yr 5 in both scarified and unscarified cutblocks, but did not experience a major loss of species subsequently (Figure 41). In general, unscarified cutblocks had higher evenness and diversity values than did scarified cutblocks. Forb species richness increased throughout the study, although values did not change between Yrs 32 and 39 (Figure 43). No clear differences in forb diversity or evenness were seen between scarified and unscarified cutblocks.

Non-woody plant species (forbs, graminoids) richness increased throughout the study (Figure 45). In general, unscarified cutblocks had higher evenness and diversity values for non-woody plant species than did scarified cutblocks.

Shrub species achieved highest richness on cutblocks at Yr 26 and appeared to have stabilized by Yr 32 (Figure 47). Diversity indices increased during early post-harvest years (3–5) presumably through arrival of new species, in both scarified and unscarified cutblocks. No difference in species richness of shrubs was observed between scarified and unscarified cutblocks throughout the study.

Woody species (shrubs, trees) increased in richness throughout the study, and had achieved levels similar to the unharvested mature forest by Yr 26 (Figure 49). No major differences in diversity or evenness indices were observed between scarified and unscarified cutblocks.

<u>**MIXEDWOOD** Forest</u>

Relative to unharvested major mixedwood forests, regenerating cutblocks had significantly higher species richness but did not differ in diversity or similarity indices (Table 6, Figure 38, Figure 40). Whereas species richness increased on scarified cutblocks between Yrs 26–39, it decreased slightly on unscarified cutblocks. Increased richness on scarified cutblocks occurred primarily through the addition of forb species. By the conclusion of the study, there were 17 fewer species on unscarified cutblocks. During the period of study on **MIXEDWOOD** cutblocks, diversity and evenness values did not differ appreciably between scarified and unscarified cutblocks. Forb species were the greatest contributor to species richness, followed by graminoids (grasses, sedges, rushes), shrubs, trees, dwarf shrubs and fern/allies (Table 6, Figure 38).

Patterns in Shannon diversity index were dissimilar between scarified and unscarified cutblocks, reflecting the addition of new species. Distribution of plants among species were similar between scarified and unscarified cutblocks, and this was reflected in similar evenness values (Figure 40).

Graminoid species richness increased during Yrs 26–39 on scarified cutblocks, but had stabilized on unscarified cutblocks (Figure 42). Both cutblock treatments had far higher species richness (n=9-11) than mature **MIXEDWOOD** forests (n=3). In general, scarified cutblocks had higher evenness and diversity values than did unscarified cutblocks. Forb species richness increased on scarified cutblocks during Yrs 26–39, but remained stable on unscarified cutblocks (Figure 44). No conspicuous difference in trends of diversity or evenness values for forb species occurred for cutblock treatments.

Non-woody plant species (forbs, graminoids) richness and diversity (Shannon) increased for scarified cutblocks during Yrs 26–39, but remained stable on unscarified cutblocks (Figure 46).

There were fewer shrub species (n=4–6) on regenerating cutblocks than in mature mixedwood forest (n=7). Diversity and evenness values were higher on unscarified cutblocks than on scarified cutblocks (Figure 48). Woody species (shrubs, trees) richness did not change on scarified cutblocks between Yrs 26–39, but declined on unscarified cutblocks (Figure 50). No major differences in trends in diversity or evenness indices were observed between cutblock treatments for woody species during this period.

PINE Forest

Total plant species richness increased on both scarified and unscarified cutblocks between Yrs 26–39 (Table 7, Figure 38, Figure 40). Regenerating scarified cutblocks had significantly higher species richness than did unscarified cutblocks. Increased richness occurred primarily through the addition of forb species. By the conclusion of the study, there were 11 fewer species on unscarified cutblocks. During the period of study on pine cutblocks, diversity and evenness values were moderately higher on scarified than on unscarified cutblocks. Forb species were the greatest contributor to species richness, followed by shrubs, graminoids (grasses, sedges, rushes), trees, fern/allies and dwarf shrubs (Table 7, Figure 38).

Temporal patterns in Shannon diversity index were dissimilar between scarified and unscarified cutblocks, reflecting the addition of new species. Distribution of plants among species were similar between scarified and unscarified cutblocks, and this was reflected in similar evenness values (Figure 40).

Graminoid species richness increased during Yrs 26–39 on scarified and unscarified cutblocks (Figure 42). In general, scarified and unscarified cutblocks had similar evenness and diversity values. Forb species richness increased on scarified and unscarified cutblocks during Yrs 26–39, but was higher on scarified cutblocks (Figure

44). No conspicuous difference in trends of diversity or evenness values for forb species occurred for cutblock treatments.

Non-woody plant species (forbs, graminoids) richness and diversity (Shannon) increased for scarified and unscarified cutblocks during Yrs 26–39, and was higher for scarified cutblocks (Figure 46).

Similar species richness (X=8–9) of shrub species occurred on scarified and unscarified cutblocks with no clear temporal trend for either cutblock treatment. In general, diversity and evenness values were higher for scarified than unscarified cutblocks (Figure 48). Woody species (shrubs, trees) richness was similar between scarified and unscarified cutblocks (Figure 50) and showed a slight increase between Yrs 26–39. Diversity and evenness values were higher on scarified than unscarified cutblocks.

Table 5. Average species richness in mature **SPRUCE** forest and scarified and unscarified cutblocks.

	Mature		Scarified						Unscarified					
Yr	5	40	4	5	6	26	32	39	4	5	6	26	32	39
Conifer Trees	1	2	0.5	0	0	1	1	1	0	0	0	1	1	1
Hardwood Trees	0.5	2	1	1	1.5	1.5	2	2	1	1	1.5	1	1	2
Shrubs	6.5	5	3	5	5	7.5	6	6	2.5	5.5	6	7.5	7.5	6.5
Dwarf Shrubs	1	1	0.5	0.5	0.5	2.5	2	2.5	2	2	2	3	3	3
Ferns	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0
Fern Allies	0	4	0	0	0	1	1	1.5	0	0	0	1	1	1
Forbs	9	26	15	14.5	18	42.5	51.5	50.5	14	16.5	14	40	48	48.5
Grasses	3	1	3	3	3.5	3.5	5	4.5	6.5	6	5.5	5.5	5	4
Rush	0.5	1	0	0	0	0.5	0	0	0.5	0.5	1.5	0.5	1	1
Sedge	3	3	1	2.5	4.5	2	3	3.5	1	2.5	4	3	3.5	3.5
Grand Total	23.5	45	24	26.5	33	62	71.5	72	27.5	34	34.5	62.5	71	70.5

Table 6. Average species richness in mature **MIXEDWOOD** forest and scarified and unscarified cutblocks.

	Mature	Scarified			Unscarified		
Yr	40	26	32	39	26	32	39
Conifer Trees	1	2	2	2	2	2	2
Hardwood Trees	1	2	2	2	2	2	2
Shrubs	7	5.5	5	5	5.5	5	4
Dwarf Shrubs	1	1	1	1	1.5	1	1
Ferns	0	0	0	0	0	0	0
Fern Allies	0	0	0	0	0	0.5	0
Forbs	21	30	35	46	31.5	32	32
Grasses	2	7.5	9	9	7	6	8
Rush	0	0	0	0	0	0	0
Sedge	1	1	1	2	1.5	2	1
Grand Total	34	49	55	67	51	50.5	50

Table 7. Average species richness on scarified and unscarified **PINE** cutblocks.

	Scarified			Unscarified		
Yr	26	32	39	26	32	39
Conifer Trees	2	2.5	2.5	2	2	3
Hardwood Trees	2	2	2	1.5	2	2
Shrubs	8.5	8.5	9	8	7.5	9
Dwarf Shrubs	2	2	2	2	1.5	2
Ferns	0	1	1	0	0.5	0.5
Fern Allies	1	1.5	5	1	1	3
Forbs	29	33	41	26	30.5	31.5
Grasses	4.5	5	5.5	4	4	5.5
Rush	0.5	0	0	0.5	0	0
Sedge	1	1	1.5	1	2	1.5
Grand Total	50.5	56.5	69.5	46	51	58

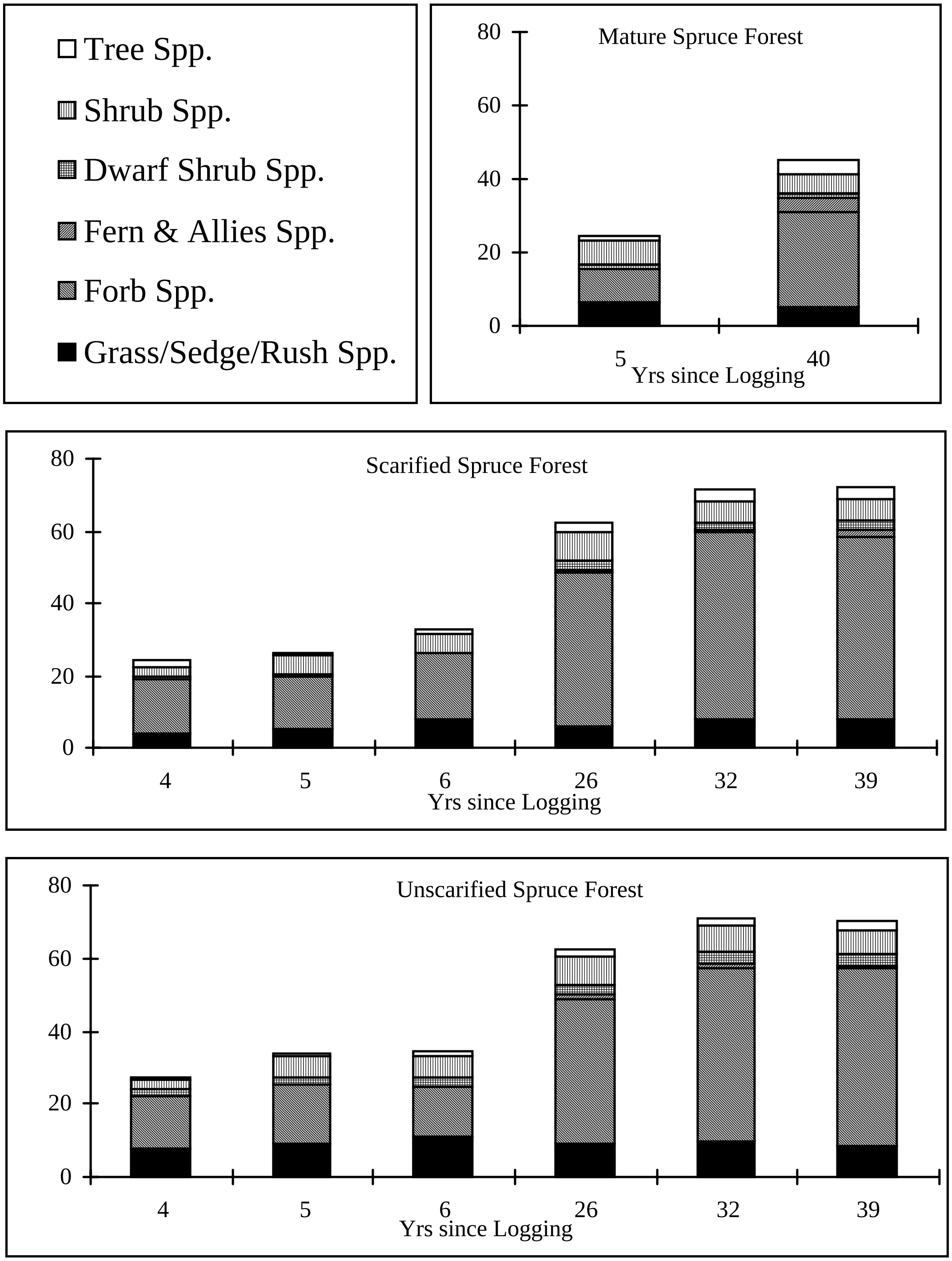


Figure 37. Plant species richness in mature SPRUCE forest and cutblocks following logging treatment; Yrs 4–39.

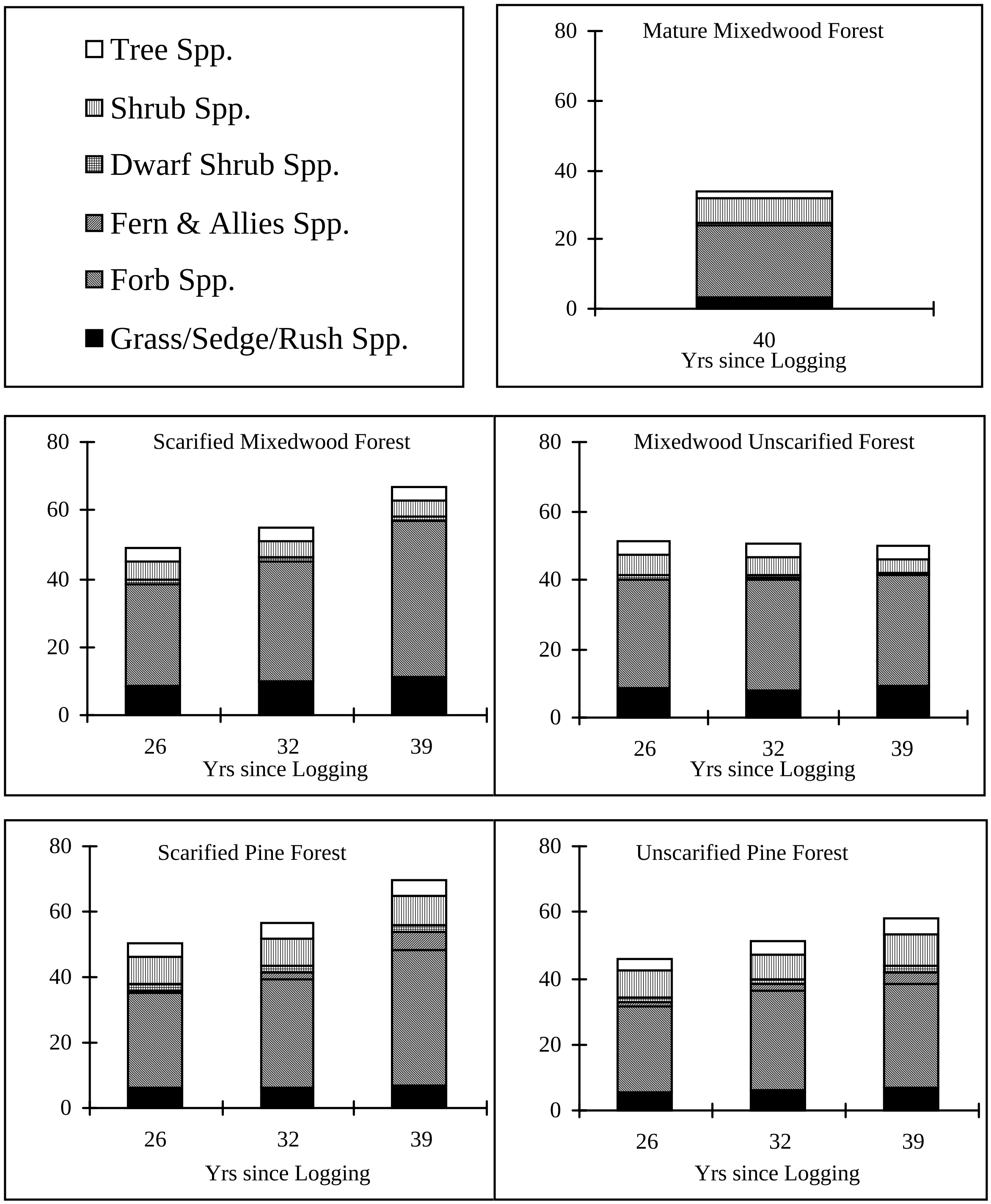


Figure 38. Plant species richness in **MIXEDWOOD** and **PINE** forests following logging treatment; Yrs 26–39 (1982–1995).

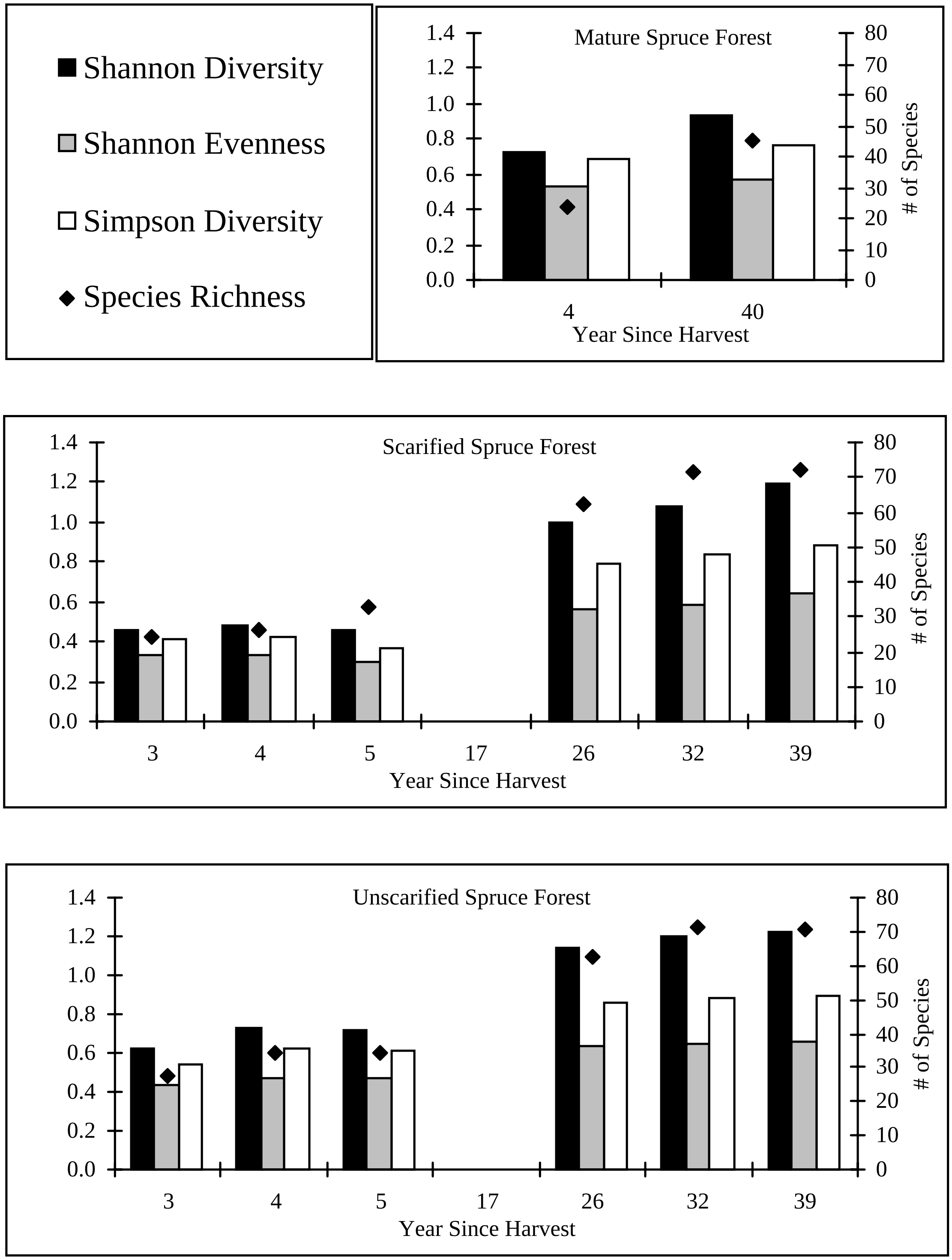


Figure 39. Total plant species richness and diversity indices in the SPRUCE forest; Yrs 3–39 (1955–1995).

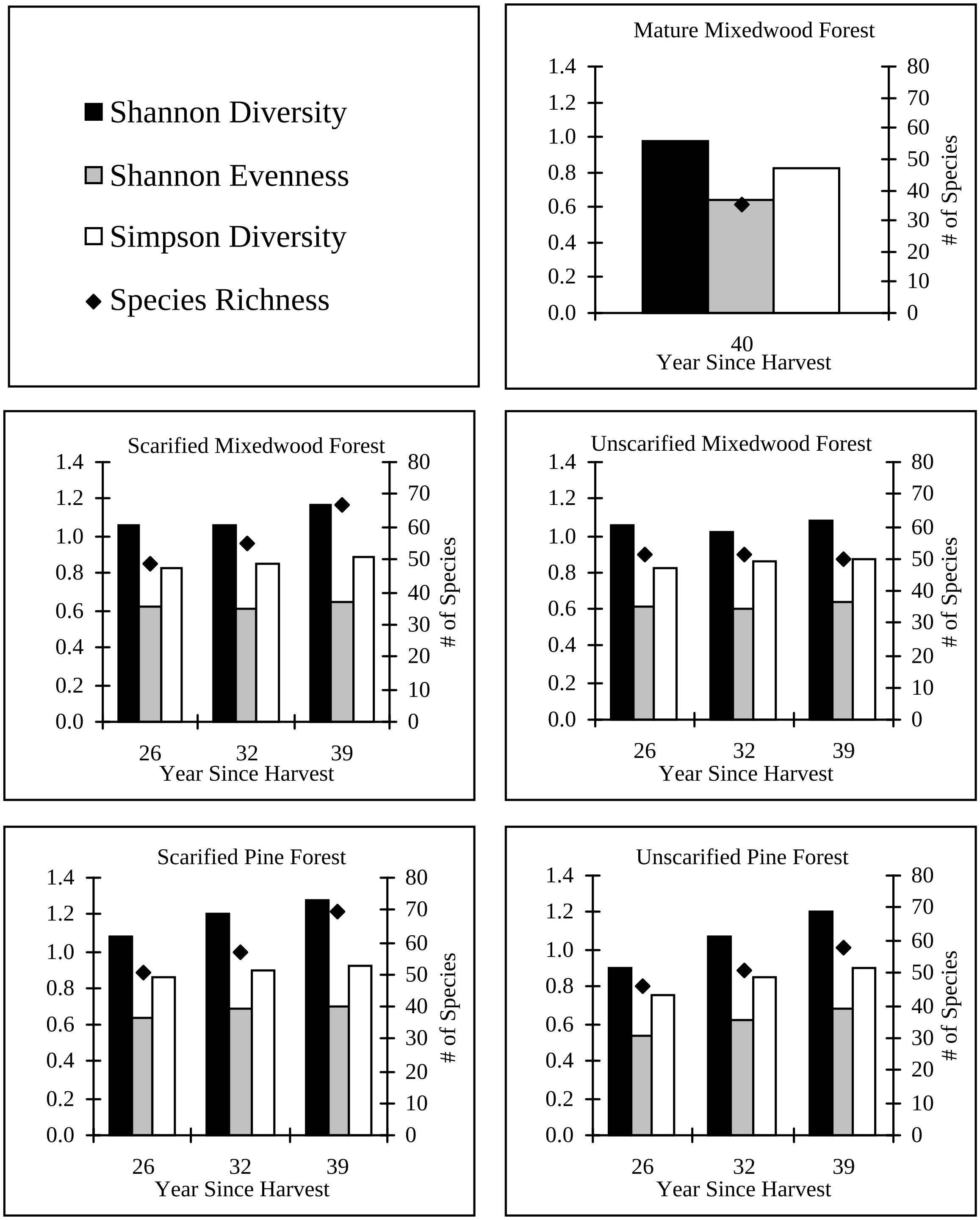


Figure 40. Total plant species richness and diversity indices in **MIXEDWOOD** and **PINE** forests; Yrs 26–39 (1982–1995).

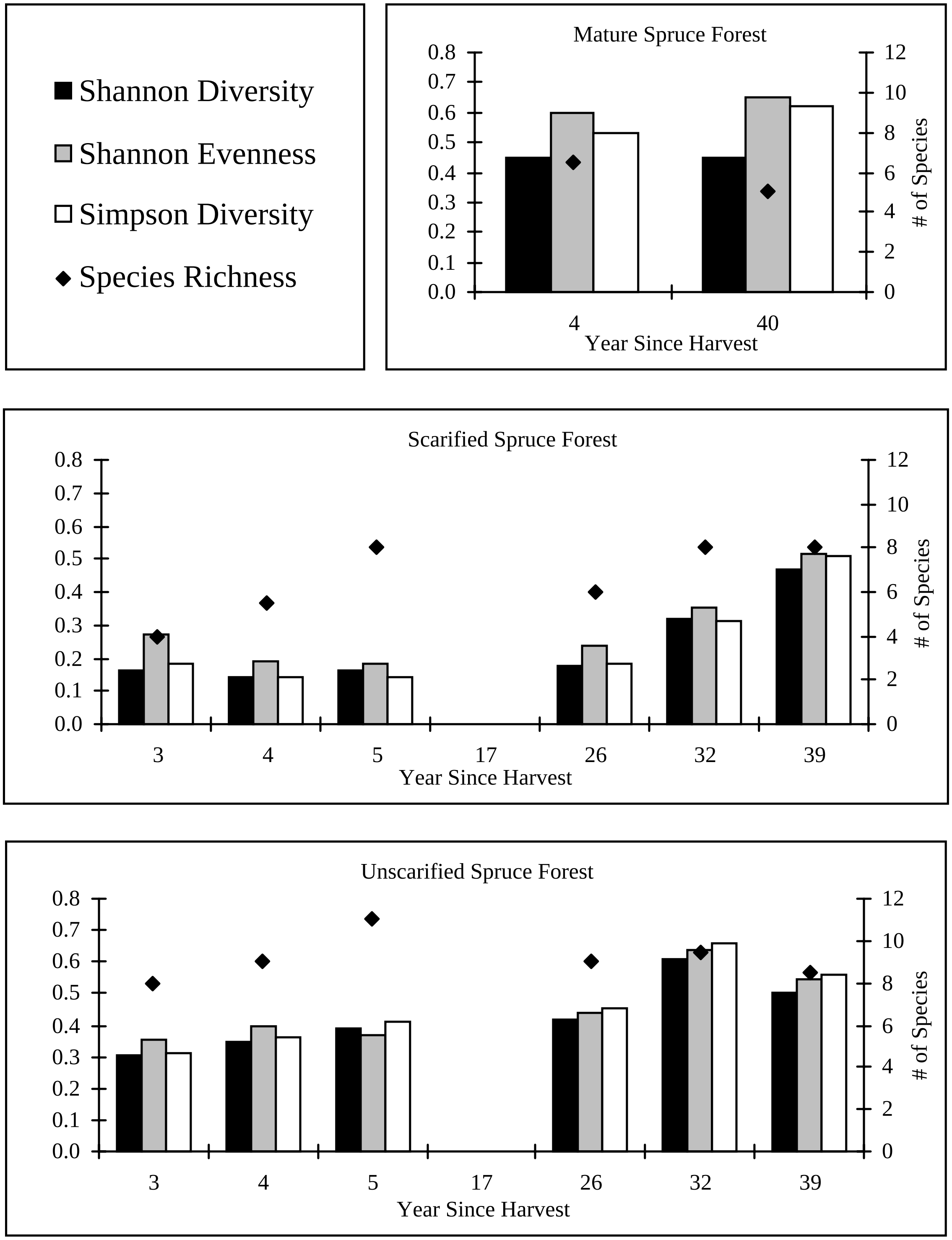


Figure 41. Graminoid species richness and diversity indices in SPRUCE forests; Yrs 3–39.

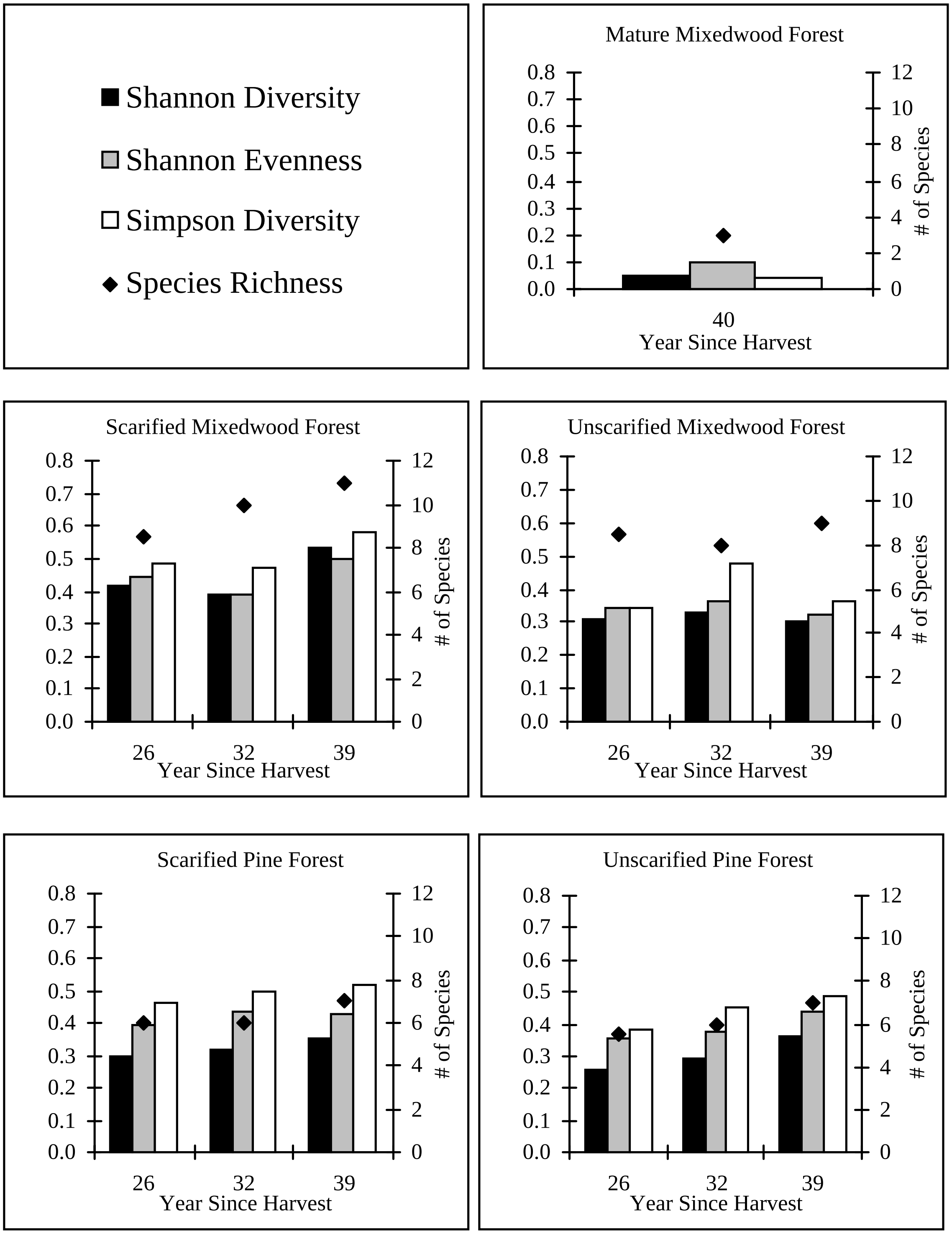


Figure 42. Graminoid species richness and diversity indices in **MIXEDWOOD** and **PINE** forests; Yrs 26–39 (1982–1995).

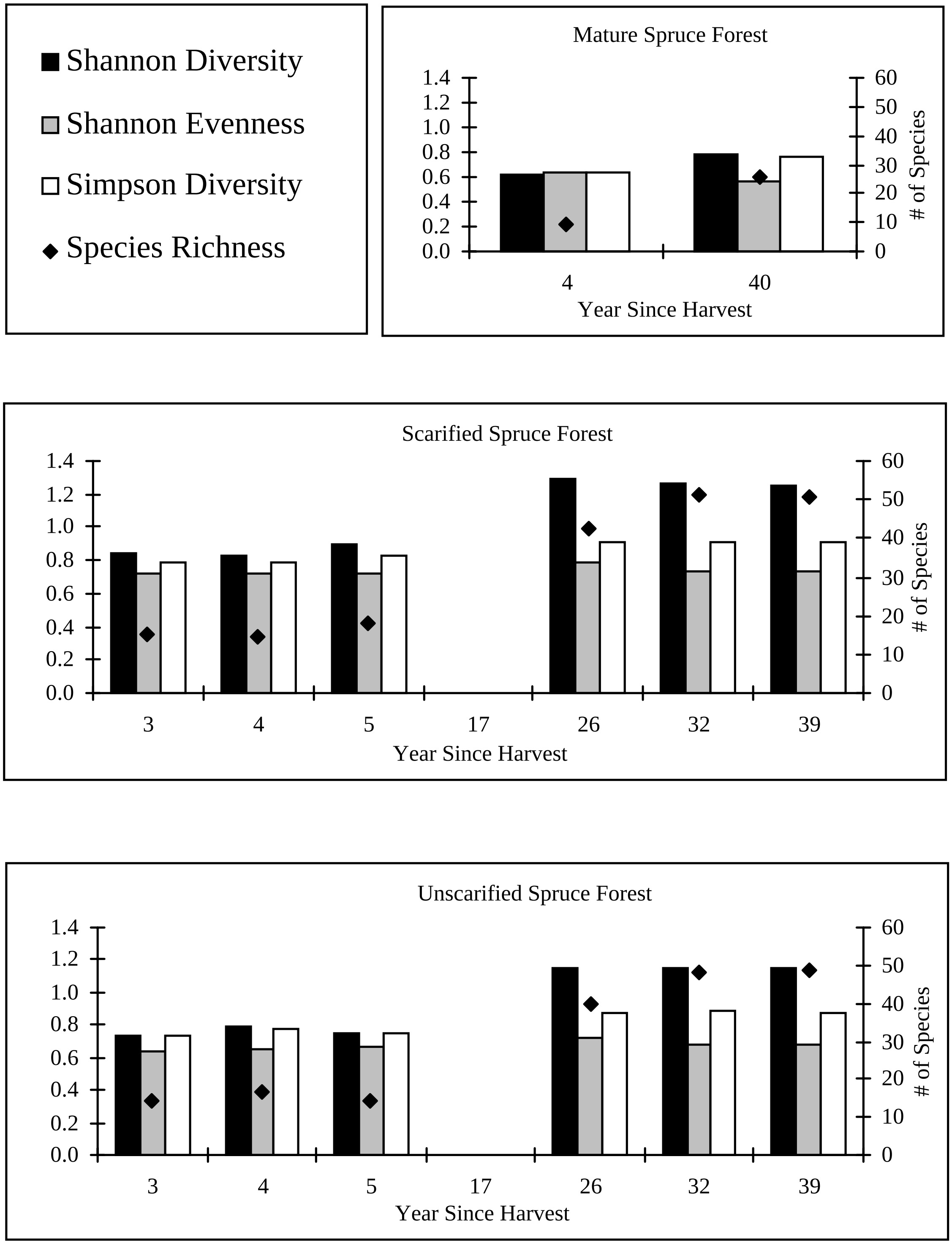


Figure 43. Forb species richness and diversity indices in SPRUCE forests; Yrs 26–39 (1982–1995).

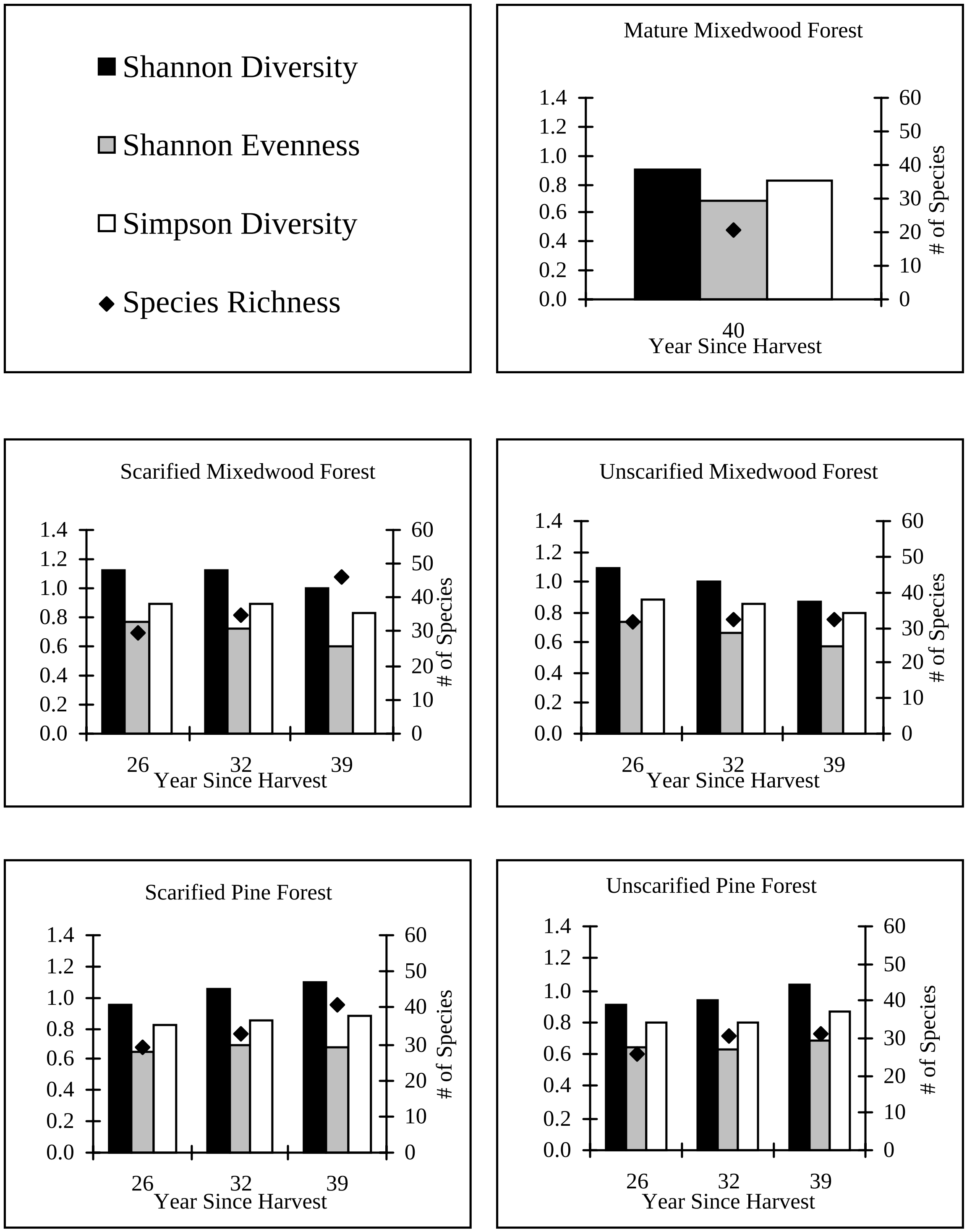


Figure 44. Forb species richness and diversity indices in **MIXEDWOOD** and **PINE** forests; Yrs 26–39 (1982–1995).

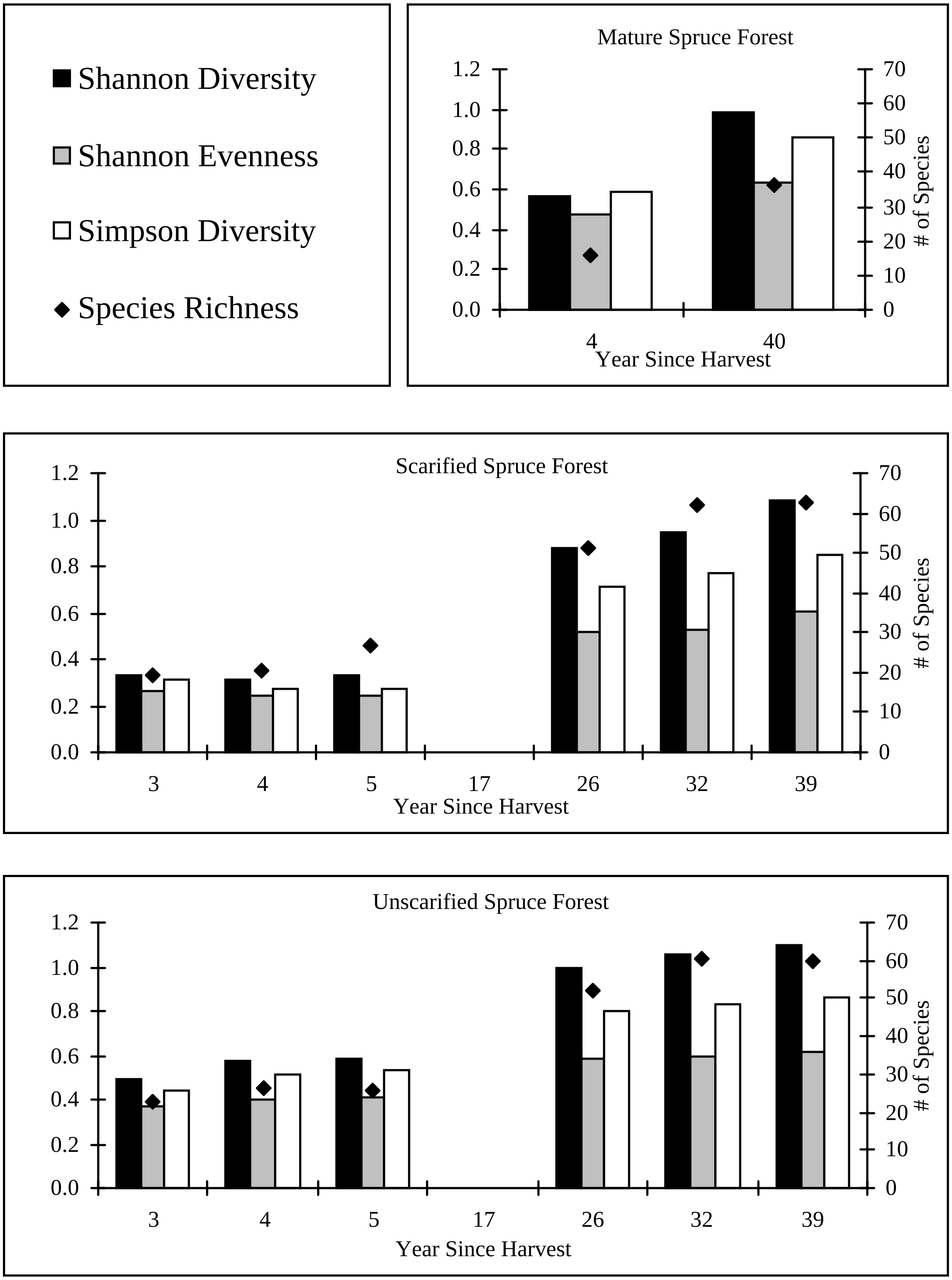


Figure 45. Non-woody plant (forbs, graminoids) species richness and diversity indices in SPRUCE forests; Yrs 3–39.

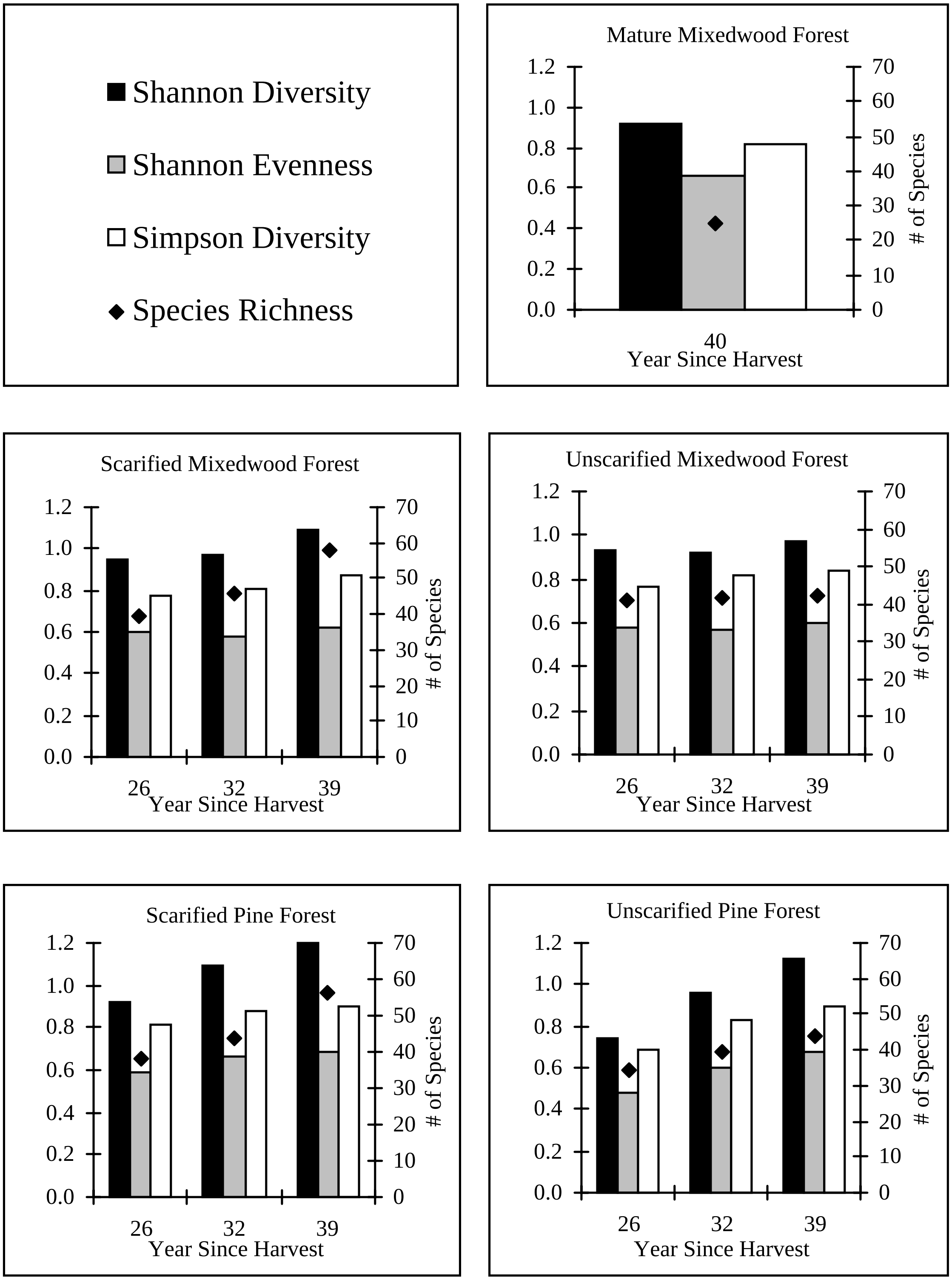


Figure 46. Non-woody plant (forbs, graminoids) species richness and diversity indices in **MIXEDWOOD** and **PINE** forests; Yrs 26–39 (1982–1995).

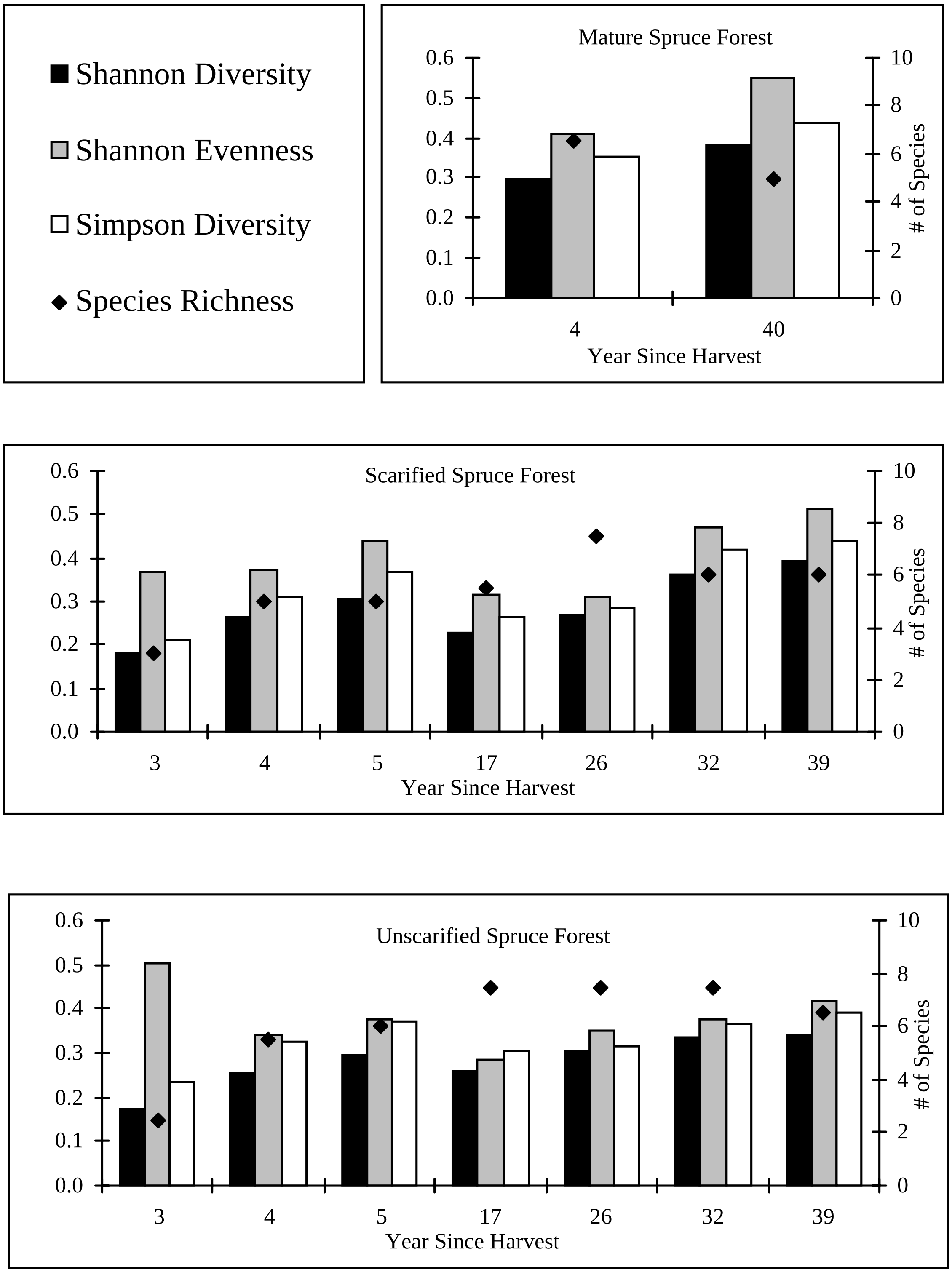


Figure 47. Shrub species richness and diversity indices in **SPRUCE** forests; Yrs 3–39.

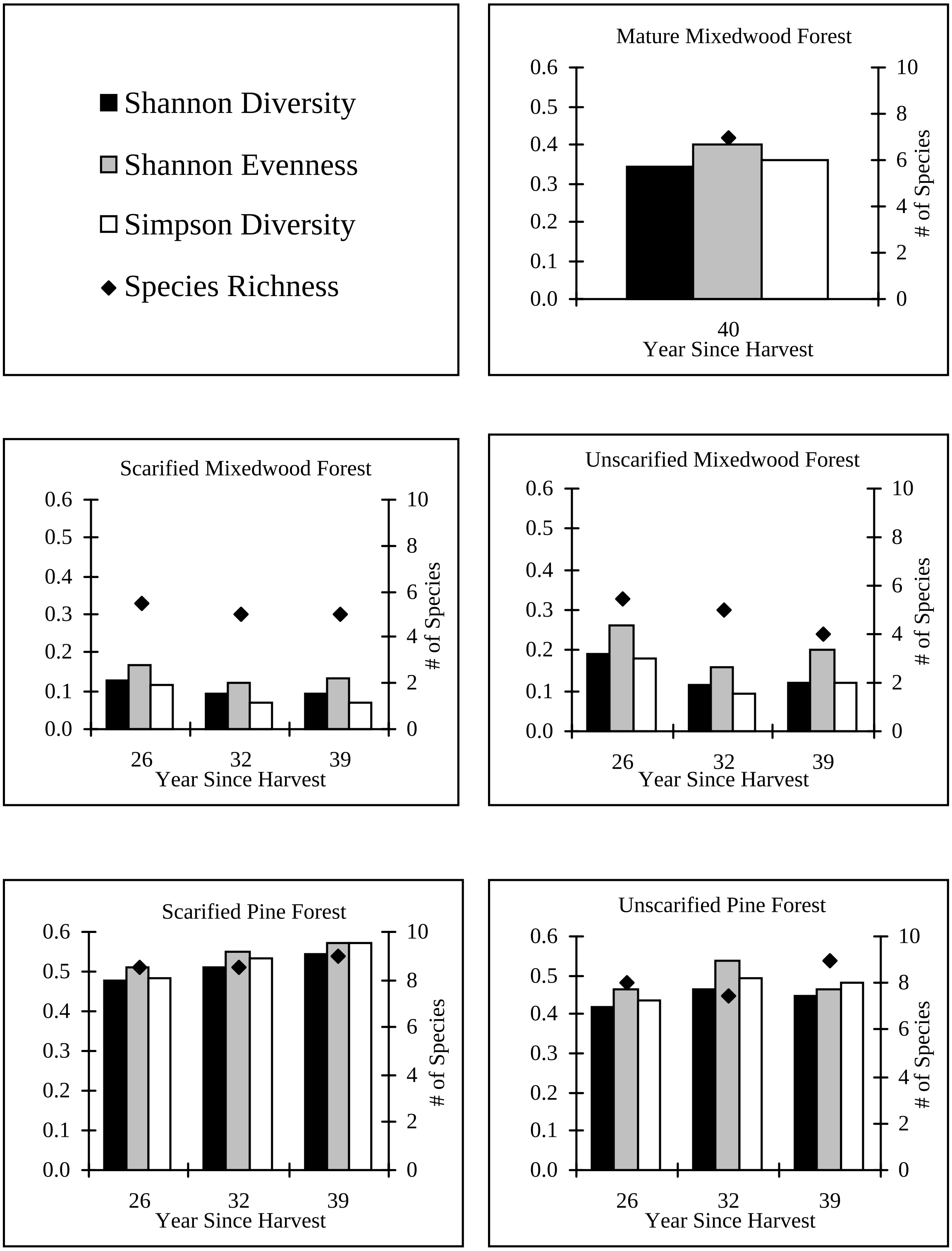


Figure 48. Shrub species richness and diversity indices in **MIXEDWOOD** and **PINE** forests; Yrs 26–39 (1982–1995).

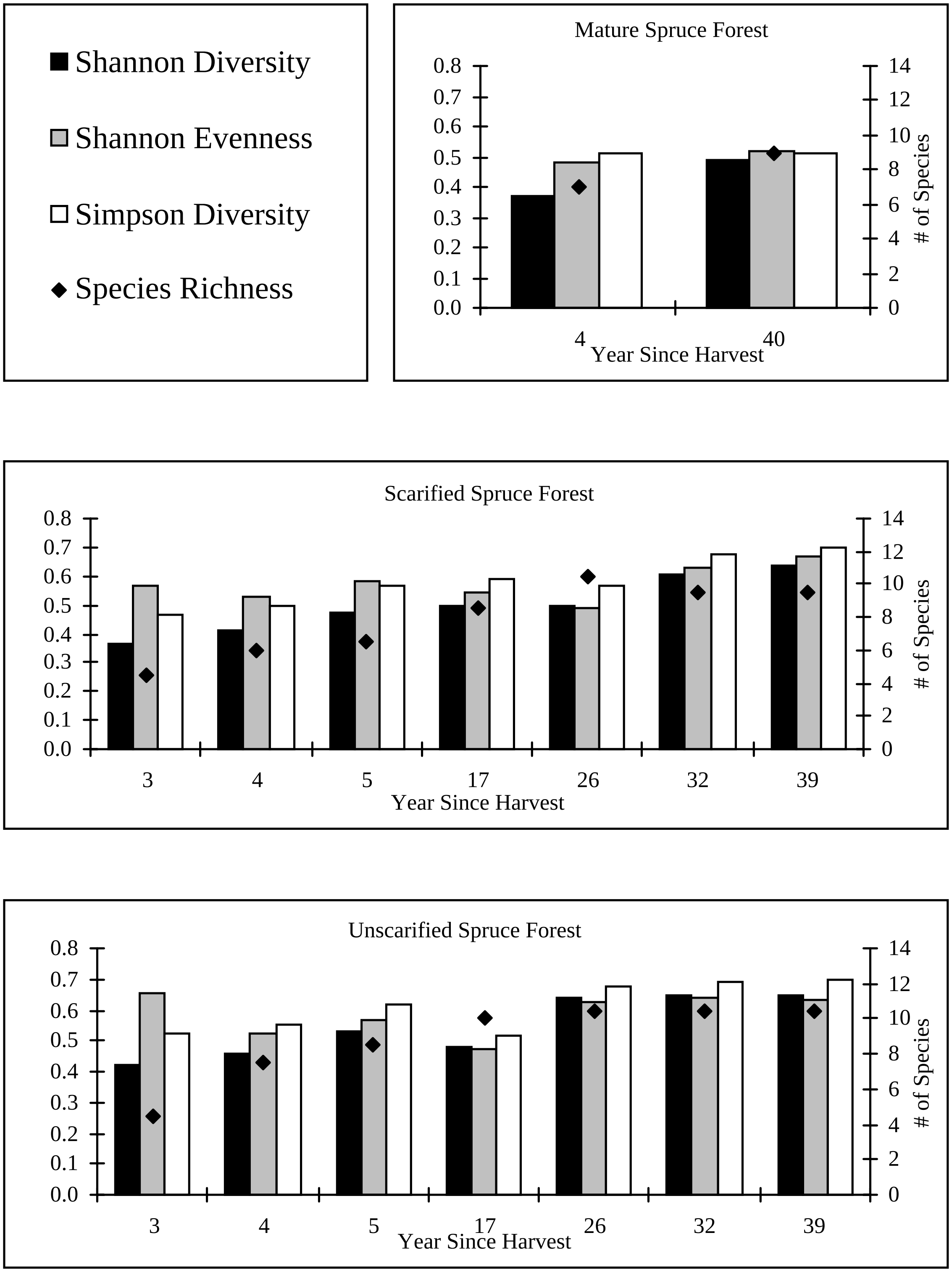


Figure 49. Woody species (shrubs and trees) richness and diversity indices in SPRUCE forests; Yrs 3–39.

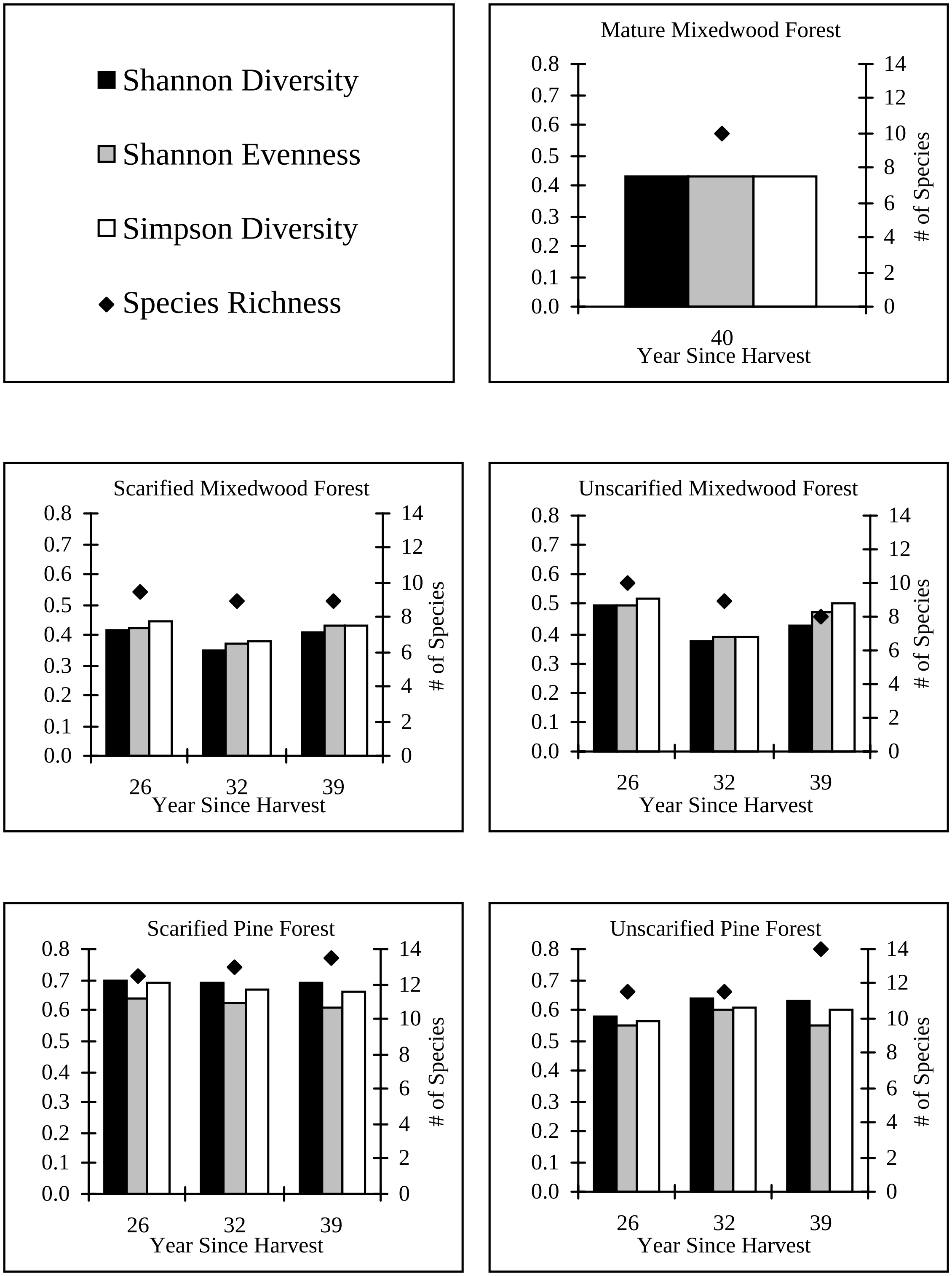


Figure 50. Woody species (shrubs and trees) richness and diversity indices in **MIXEDWOOD** and **PINE** forests; Yrs 26–39 (1982–1995).

Table 8. Similarity indices of plant species on scarified and unscarified treatments for **SPRUCE**, **MIXEDWOOD** and **PINE** forests; Yrs 1–39 (1955–1995).

Forest	Year	Scarified versus Unscarified
Spruce	3	0.686
Spruce	4	0.723
Spruce	5	0.739
Spruce	26	0.909
Spruce	32	0.851
Spruce	39	0.771
Mixedwood	26	0.687
Mixedwood	32	0.820
Mixedwood	39	0.768
Pine	26	0.840
Pine	32	0.812
Pine	39	0.813

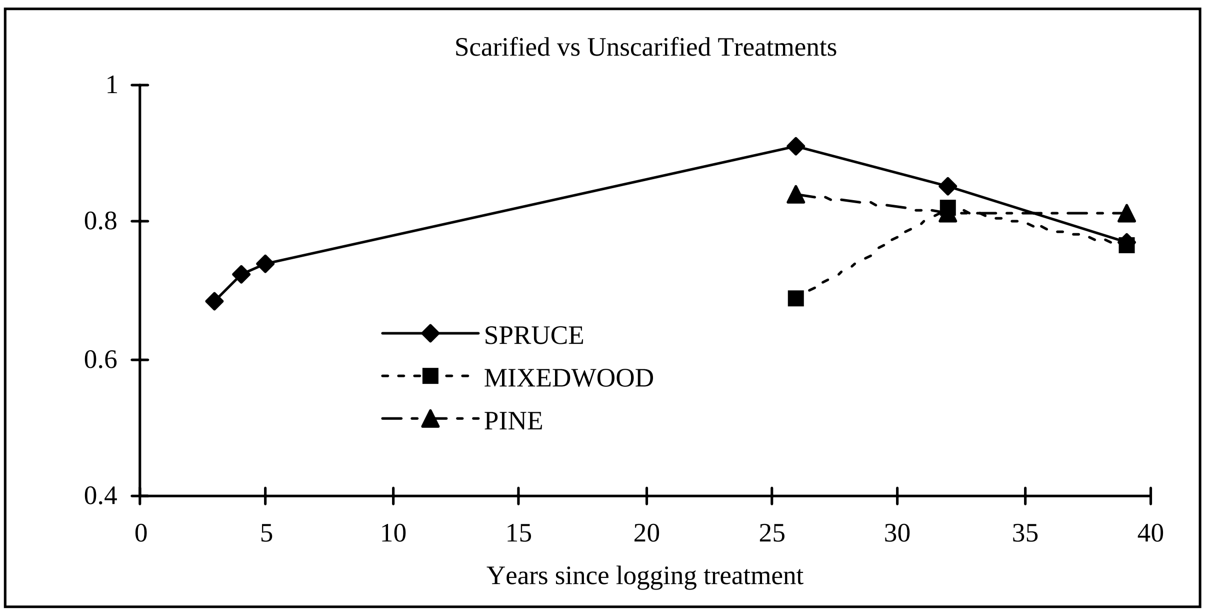


Figure 51. Similarity indices of plant species on scarified and unscarified treatments for **SPRUCE**, **MIXEDWOOD** and **PINE** forests; Yrs 1–39 (1955–1995).

Browse Biomass and Density

SPRUCE Forests

Browse biomass was low immediately following logging of the **SPRUCE** cutblocks and then increased sharply during Yrs 1–9 (Table 9, Figure 52). Maximum browse biomass levels occurred at Yr 17 for unscarified (1,068 kg/ha) and Yr 26 for scarified (934 kg/ha) cutblocks. Browse biomass levels were higher on unscarified than scarified cutblocks during Yrs 1–17 and did not differ appreciably during Yrs 26–39. Browse species composition varied considerably between cutblock treatments (Figure 55). Ranked order of browse species on unscarified cutblocks was willow, balsam poplar, saskatoon, rose, and black birch. Ranked order of browse species on scarified cutblocks was willow, balsam poplar, rose, black birch, paper birch, low-bush cranberry and honeysuckle. Major differences between cutblock treatments were the absence of saskatoon on scarified cutblocks, the absence of paper birch and low-bush cranberry on unscarified cutblocks, and the higher biomass of black birch on scarified cutblocks. Stem density patterns differed somewhat from stem biomass patterns (Figure 55, Figure 58). In general, unscarified cutblocks had higher browse stem densities than did scarified cutblocks. Browse density declined immediately following logging, then increased and peaked at Yr 17. Ranked order of major browse species density was rose, aspen/balsam poplar, and willow. Species composition of browse stem density did not differ between cutblock treatments.

MIXEDWOOD Forests

Browse biomass during Yr 9 and Yrs 26–32 was significantly higher on scarified than unscarified cutblocks (Figure 53), Browse biomass on scarified cutblocks declined from 610 to 243 kg/ha between Yrs 26–39 but remained above the low browse biomass levels of unscarified cutblocks. Ranked order of browse species on scarified cutblocks was balsam poplar, trembling aspen, willow, rose, and honeysuckle (Figure 56). Ranked order of browse species on unscarified cutblocks was rose, balsam poplar, honeysuckle, willow and trembling aspen. Major differences in browse biomass between cutblock treatments was the rapid response of poplar, aspen and willow to the scarification treatment. Stem density patterns differed somewhat from stem biomass patterns (Figure 56, Figure 58). Stem density analyses showed that rose stems were most abundant and that their densities did not differ between cutblock treatments. The major differences were for aspen and poplar, whose densities were far lower than rose, but whose biomass was far greater. Densities of aspen and poplar leaders were far lower in the unscarified than scarified cutblocks.

PINE Forests

Browse biomass during Yrs 26–32 was higher on unscarified than scarified cutblocks (Table 9). Whereas browse biomass on scarified cutblocks remained at similar levels through Yr 39, levels on unscarified cutblocks declined significantly (from 1,235 to 406 kg/ha) from Yrs 32 to 39 to levels below those of the scarified cutblock (Figure 54). Ranked order of browse species on scarified cutblocks was alder, willow, low-bush cranberry, rose, poplar and gooseberry (Figure 57). Ranked order of browse species on unscarified cutblocks was alder, poplar, willow, low-bush cranberry, rose, and honeysuckle. Green alder was the dominant browse biomass on both cutblock treatments. Minor differences on cutblock treatments were the absence of honeysuckle and mountain ash on unscarified cutblocks. Browse stem density patterns (Figure 58) showed that rose had highest values, followed by low-bush cranberry and alder. Aspen and poplar stem densities were higher on scarified than unscarified cutblocks. Although alder stem densities were relatively low, their growth form and height contributed significant amounts of browse biomass.

Comparison of Forest Types

During Yrs 26–39, browse biomass generally declined for all forest types and cutblock treatments (Figure 52–Figure 54). During this period, browse biomass levels were highest in **PINE**, followed by **SPRUCE** and lowest in **MIXEDWOOD** forests. Whereas willow and trembling aspen/balsam poplar dominated browse biomass in **SPRUCE** and **MIXEDWOOD** cutblocks, alder was the dominant browse in **PINE** cutblocks. In contrast to trends in biomass during Yrs 26–39, stem densities generally increased. This comparison suggests a shift from tall low-density species (aspen, poplar, willow, alder) to short high-density species (rose, low-bush cranberry, currant and gooseberry).

Table 9. Browse production (kg/ha) in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests (Yrs 1–39).

Forest Type	Years since Logging Treatment	Browse Biomass (kg/ha) Scarified	Browse Biomass (kg/ha) Unscarified
SPRUCE	1	51	99
	5	433	470
	9	727	909
	17	858	1,068
	26	934	866
	32	906	834
	39	273	431
MIXEDWOOD	1	–	–
	5	–	–
	9	635	418
	17	–	–
	26	610	190
	32	406	88
	39	243	110
PINE	1	–	–
	5	–	–
	9	–	–
	17	–	–
	26	1,019	1,195
	32	927	1,235
	39	870	406

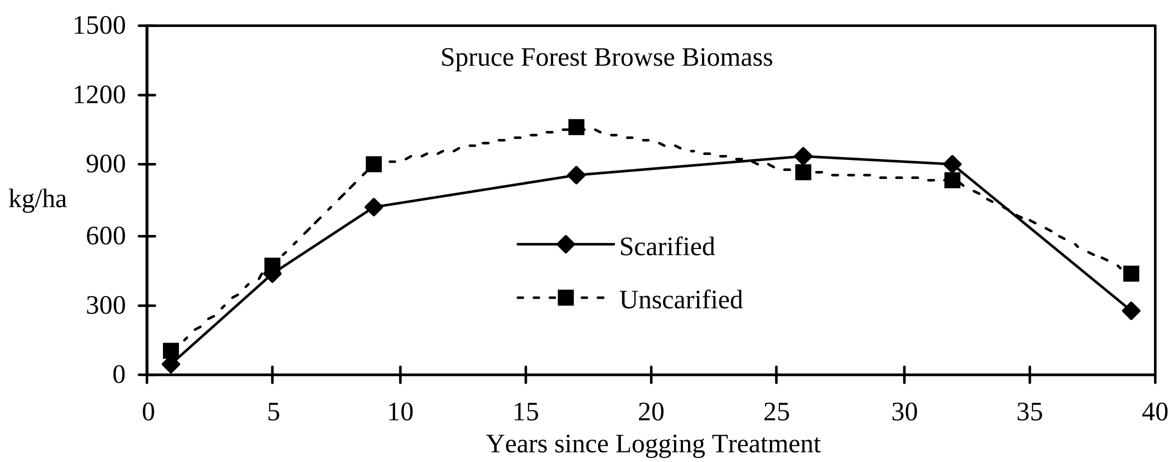


Figure 52. Browse biomass (kg/ha) in **SPRUCE** forest; Yrs 1–39 (1955–1995).

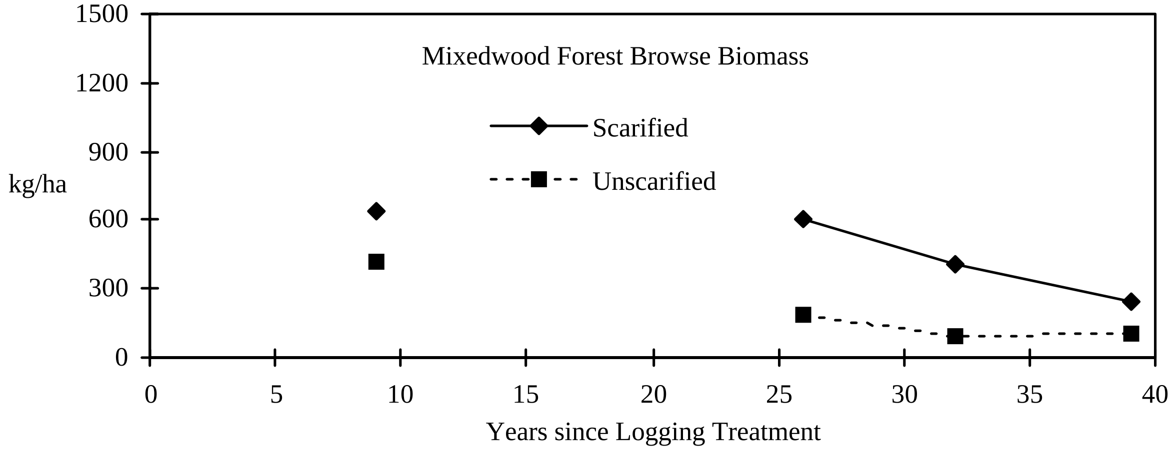


Figure 53. Browse biomass (kg/ha) in **MIXEDWOOD** forest; Yrs 9–39.

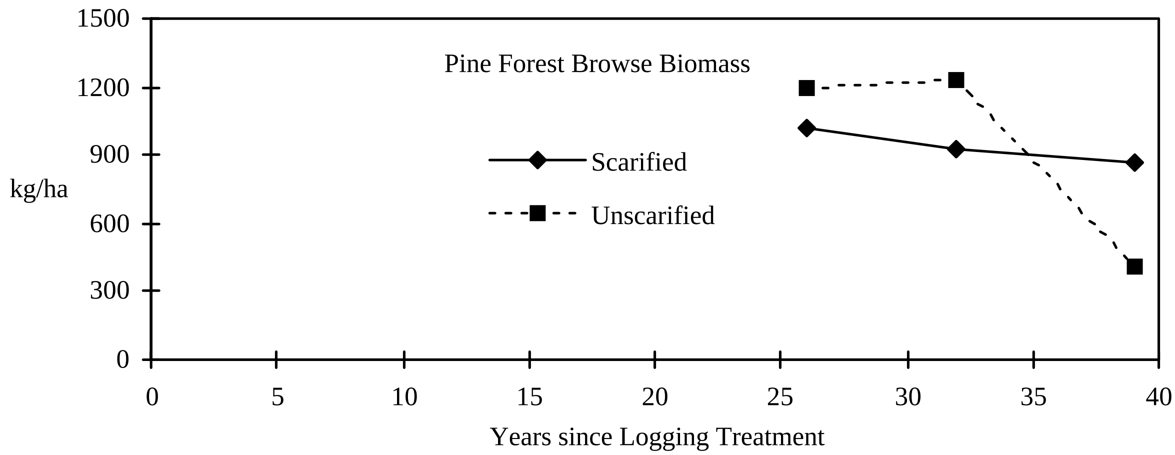


Figure 54. Browse biomass (kg/ha) in **PINE** forest; Yrs 26–39 (1982–1995).

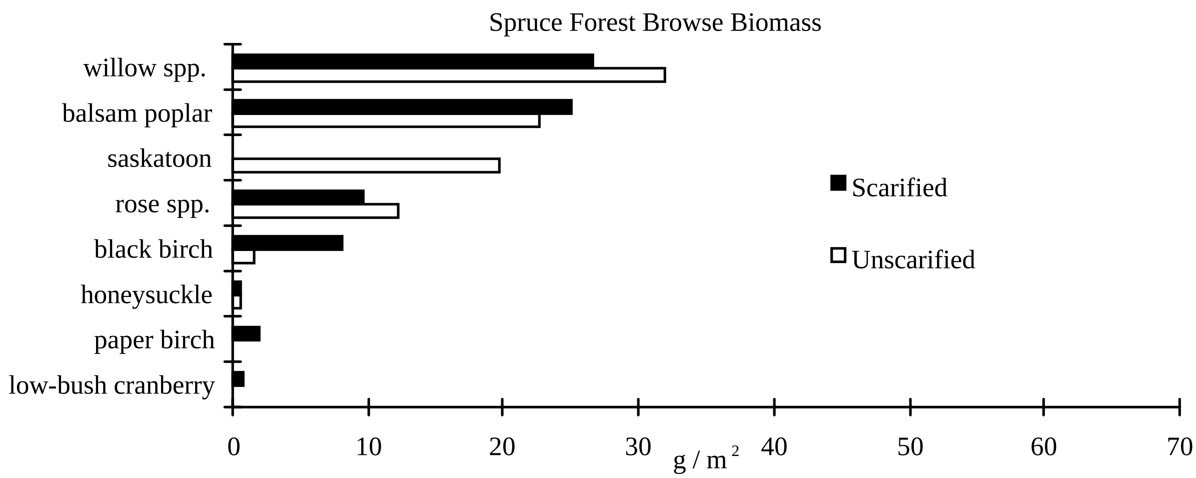


Figure 55. Average browse production (g/m^2) of major species in **SPRUCE** forest; averages of Yrs 26, 32, 39.

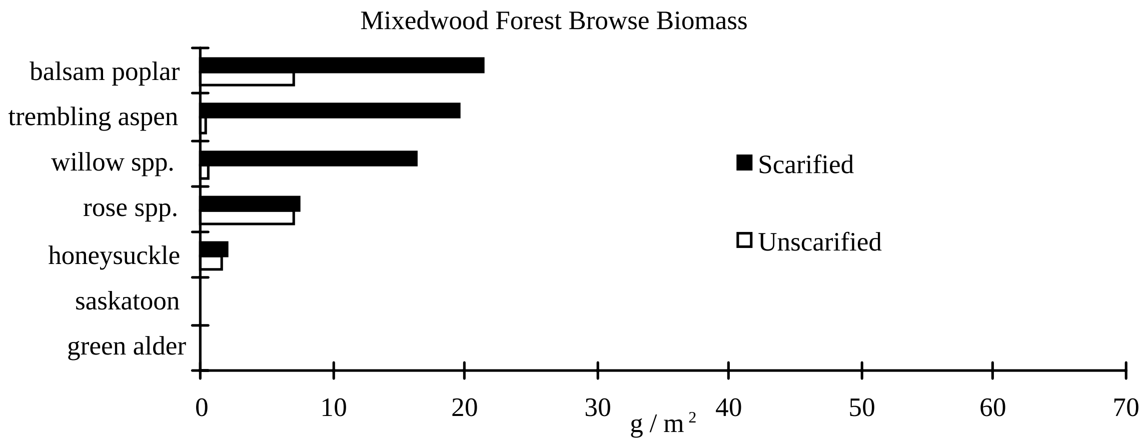


Figure 56. Average browse production (g/m^2) of major species in **MIXEDWOOD** forest; averages of Yrs 26, 32, 39.

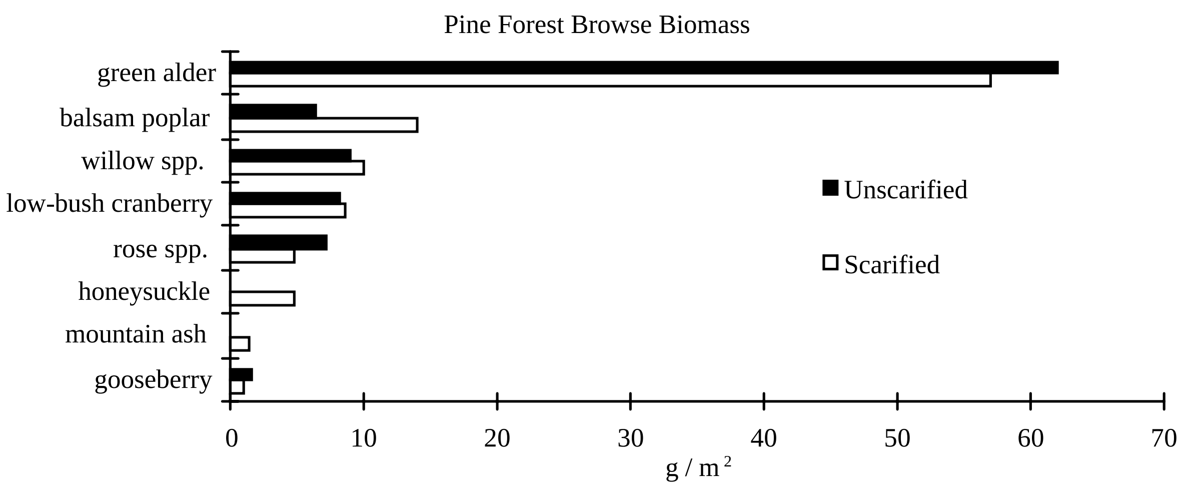


Figure 57. Average browse production (g/m^2) of major species in **PINE** forest; averages of Yrs 26, 32, 39.

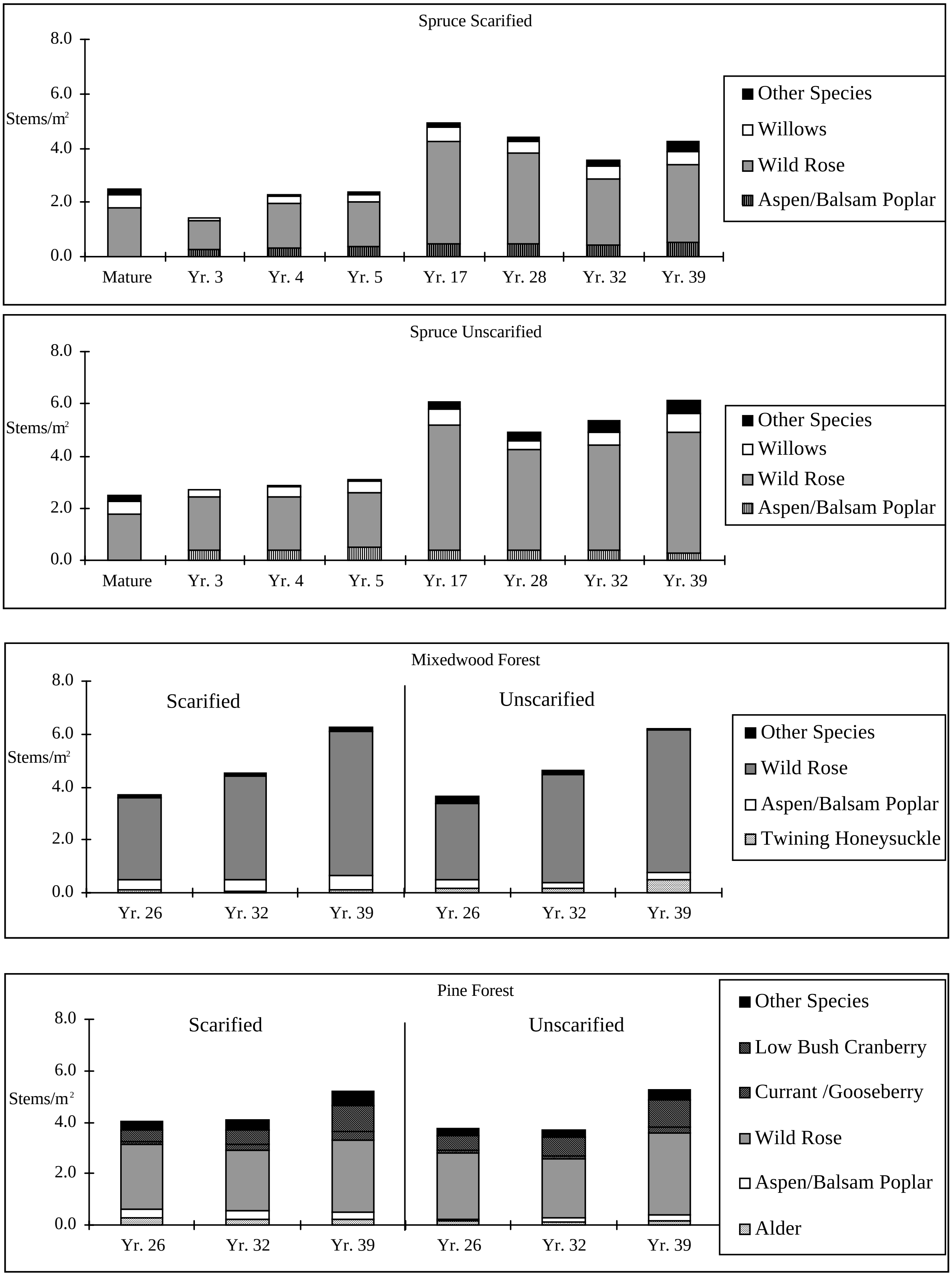


Figure 58. Density and relative contribution of browse species in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests; Yrs 26–39 (1982–1995).

Browse Use

SPRUCE Forest

Use of total shrub browse by herbivores was low immediately following logging, then increased gradually thereafter, peaking at a level of ~25% (Figure 59). No clear differences in use of total shrub browse occurred between scarified and unscarified cutblocks, although the trend was higher use on unscarified cutblocks during Yrs 6–32. At the conclusion of the study, percent browse use was similar between the mature forest and the regenerating cutblocks.

Rose was an important browse species and experienced high use on unscarified cutblocks immediately following logging. Use of rose declined in both scarified and unscarified cutblocks during Yr 4 and thereafter increased, with use marginally higher on unscarified cutblocks (Figure 60). Use of willow generally increased throughout the study and did not differ between cutblock treatments (Figure 61). Use of buffalo-berry was generally low (<3%) and marginally higher on unscarified than scarified cutblocks (Figure 63). Use of honeysuckle varied between 0–20% during the study and showed no difference between cutblock treatments (Figure 64).

MIXEDWOOD Forest

Relative to mature mixedwood forests, use of cutblock total shrub browse was initially (Yr 1) low, then increased slowly thereafter (Figure 59). Shrub use values were generally similar between cutblock treatments except for Yr 32 when use on scarified cutblocks were very high. Use of rose was initially low (Yr 1), then increased throughout the study. Rose use values declined in Yr 32, then increased in Yr 39 and were marginally higher on unscarified cutblocks (Figure 60). Use of willow was initially low on cutblocks, increased during Yrs 1–26, then declined to low levels by Yr 39. Use of willow was consistently higher on unscarified than scarified cutblocks (Figure 61). Use of buffalo-berry was initially low on cutblocks, increased during Yrs 1–26, then declined to low levels by Yr 39. Use of buffalo-berry was generally higher on unscarified than on scarified cutblocks (Figure 63). Honeysuckle was an important shrub browse species (Figure 64). Use was initially low (Yr 1), then increased to maximum levels at Yr 26. Use of honeysuckle was generally higher on scarified cutblocks. Use of *Ribes* spp. did not occur on scarified cutblocks, but was of moderate levels on unscarified cutblocks during Yr 26 (Figure 65).

PINE Forest

Use of total shrub browse by herbivores on **PINE** cutblocks was initially low (Yr 1), increased during Yrs 1–26, then declined during Yrs 26-39 (Figure 59). Patterns of use on scarified and unscarified cutblocks was generally similar. Rose was an important browse species; its use was initially low (Yr 1), increased during Yrs 1–26, then declined during Yrs 26–39 (Figure 40). Use of rose was generally higher on scarified cutblocks. Willow was widely and equally used in both scarified and unscarified cutblocks (Figure 61). Use values were low immediately following logging, increased during Yrs 1–26, and thereafter decreased. Alder was a dominant browse species on pine cutblocks that experienced low use immediately following logging, high use at Yr 26, and low use during Yrs 32–39 (Figure 62). Use of honeysuckle was moderate, peaking at Yr 26 on scarified cutblocks and Yr 39 on unscarified cutblocks (Figure 64). Use of Ribes spp. in both scarified and unscarified cutblocks was high during Yr 26, then declined thereafter (Figure 65).

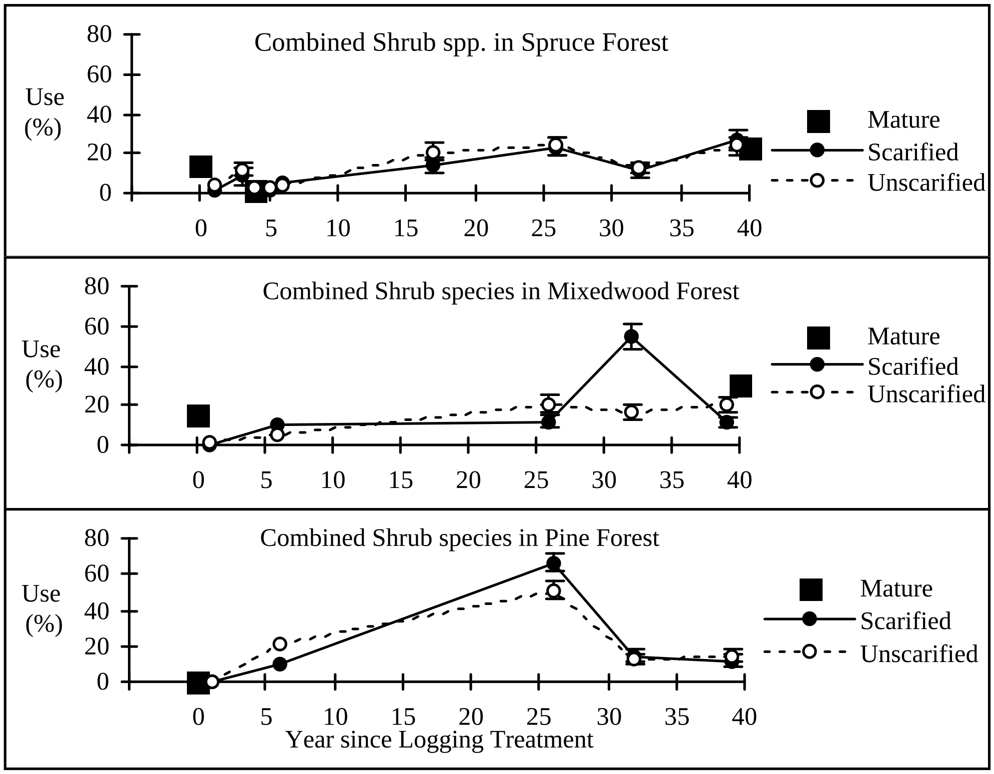


Figure 59. Browse use (%, ± 2. S.E.) of all shrub species in each forest type and cutblock treatment; Yrs 1–39 (1955–1995).

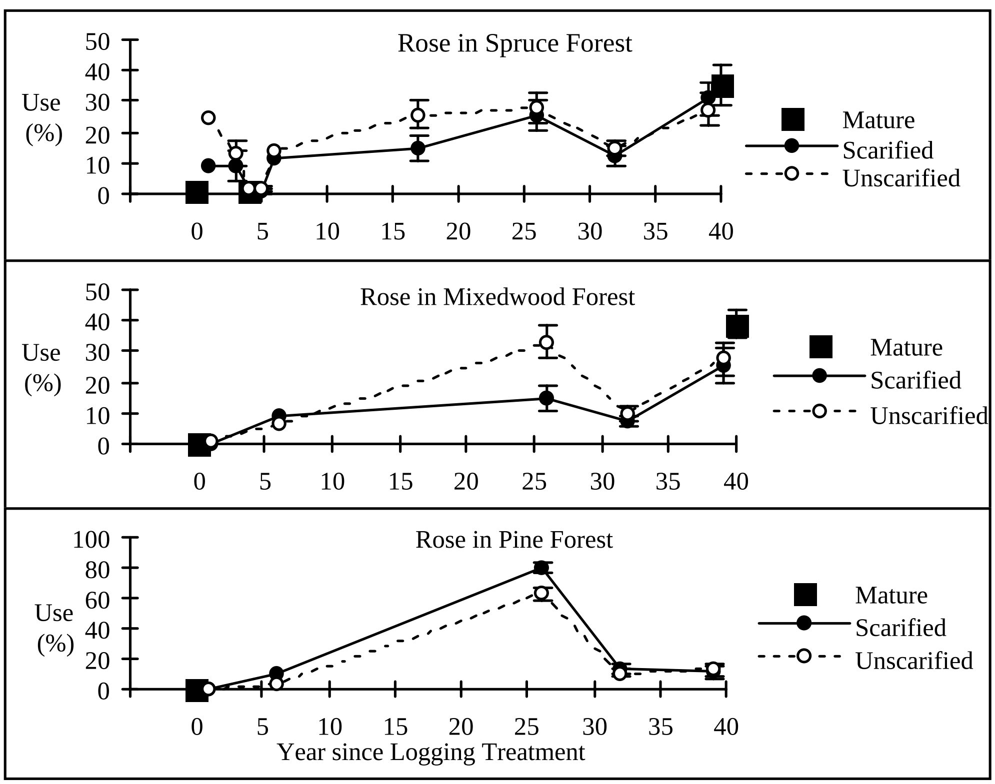


Figure 60. Browse use (%, ± 2. S.E.) of rose in each forest type and cutblock treatment; Yrs 1–39 (1955–1995).

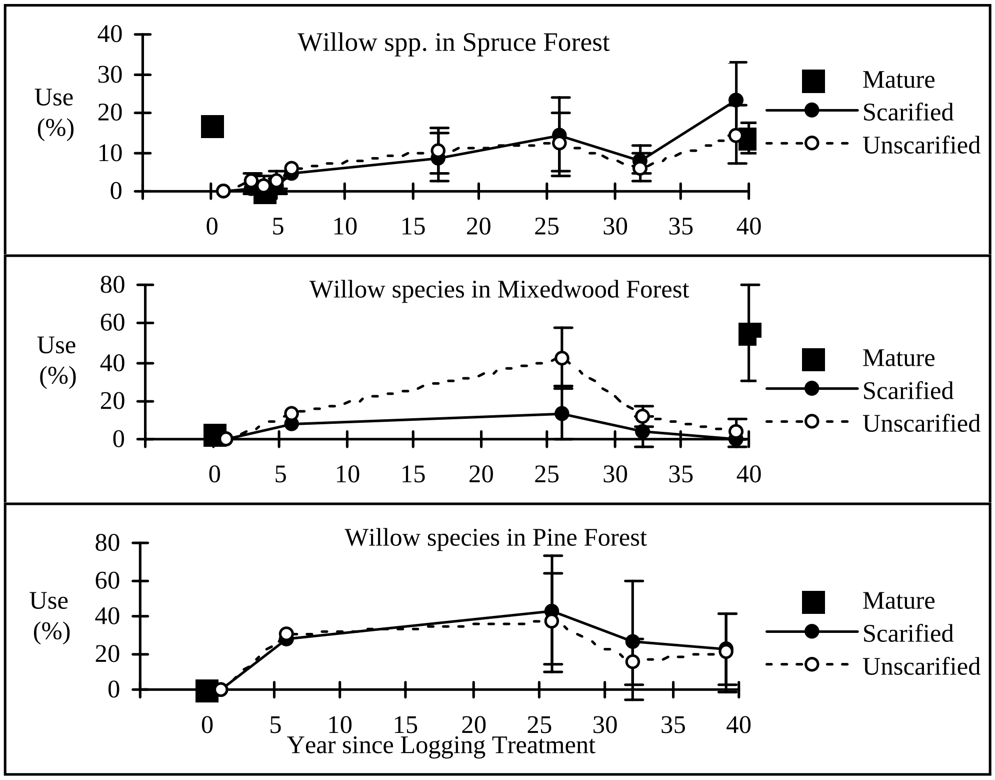


Figure 61. Browse use (%, ± 2. S.E.) of willow in each forest type and cutblock treatment; Yrs 1–39 (1955–1995).

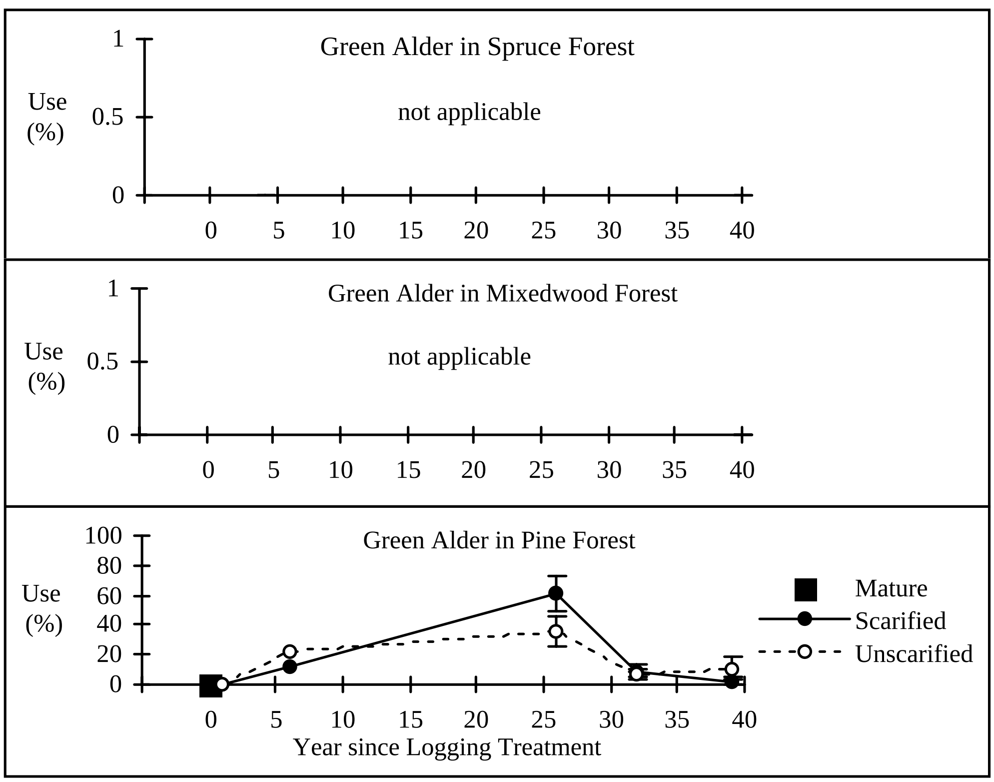


Figure 62. Browse use (%, ± 2. S.E.) of alder in each forest type and treatment; Yrs 1–39 (1955–1995).

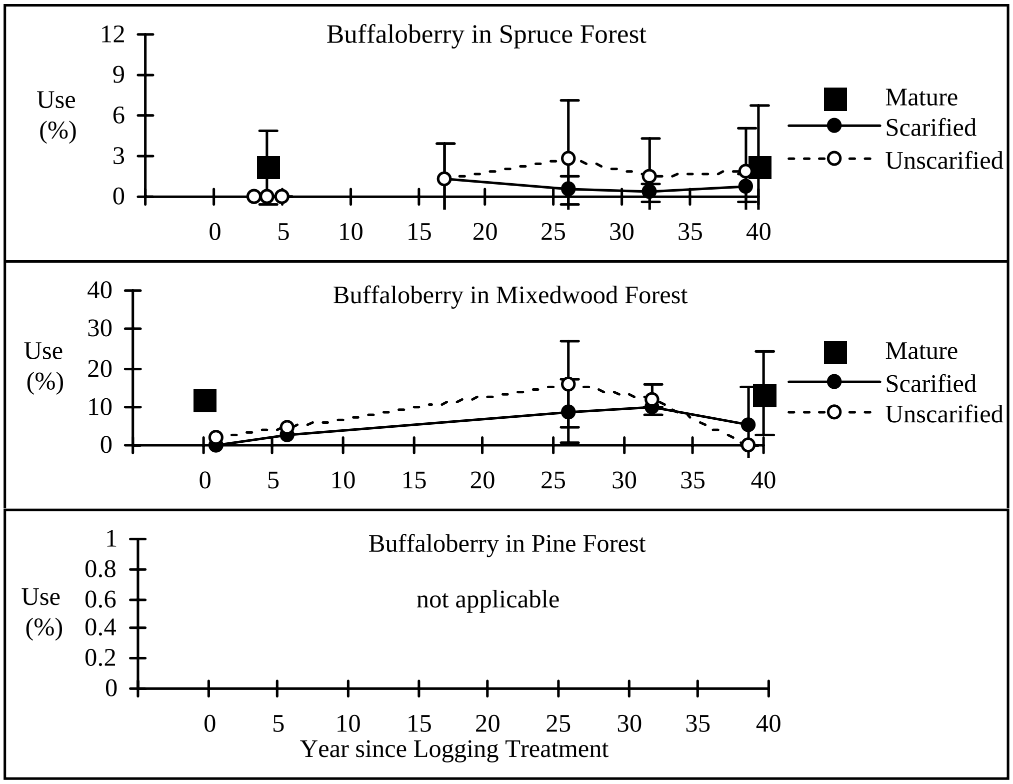


Figure 63. Browse use (%, ± 2. S.E.) of buffalo-berry in each forest type and cutblock treatment; Yrs 1–39 (1955–1995).

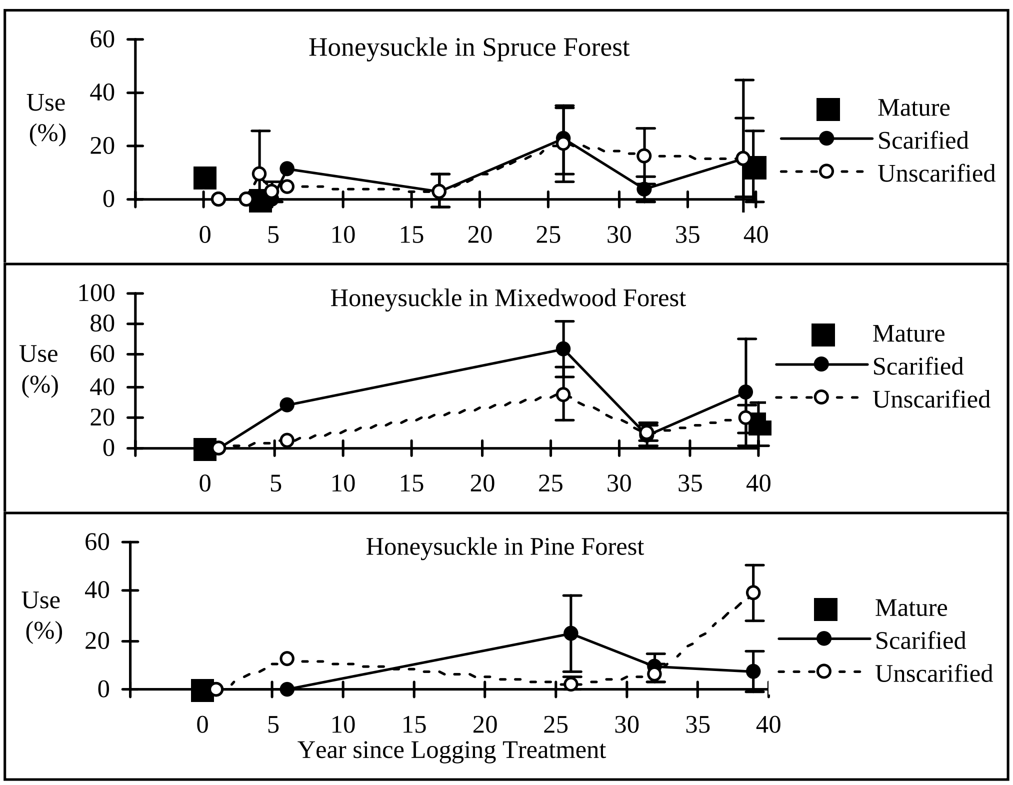


Figure 64. Browse use (%, ± 2. S.E.) of honeysuckle in each forest type and cutblock treatment; Yrs 1–39 (1955–1995).

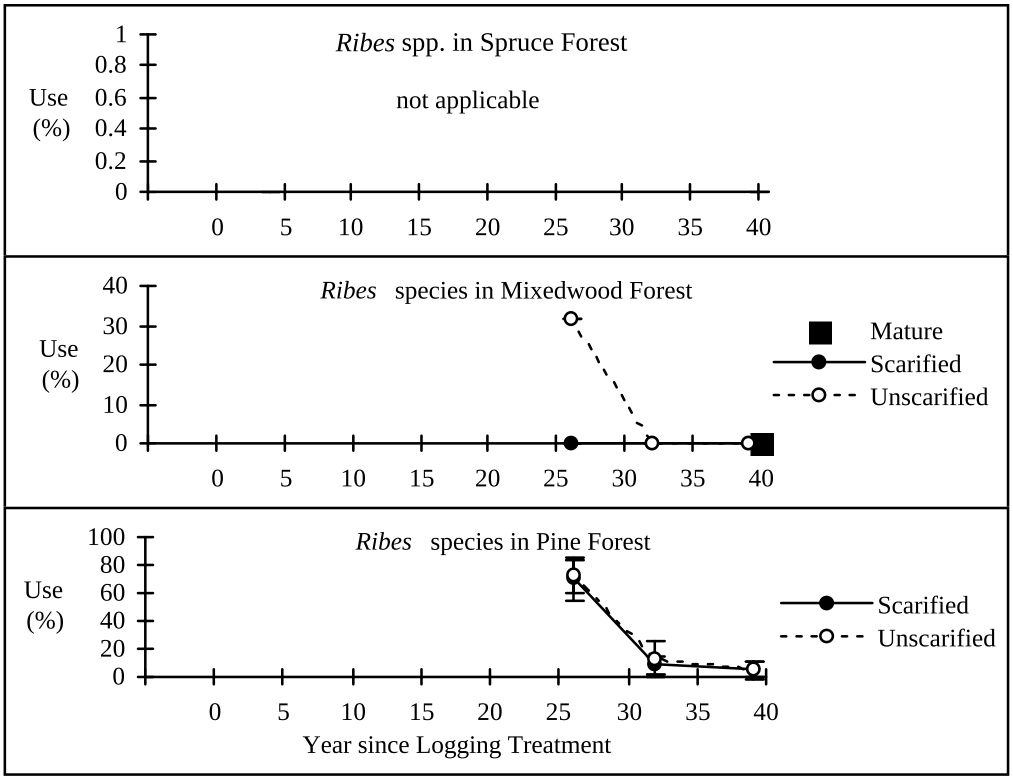


Figure 65. Browse use (%, ± 2. S.E.) of *Ribes* in each forest type and cutblock treatment; Yrs 1–39 (1955–1995).

Snags

Snag densities were significantly higher in mature forests than in regenerating cutblocks at Yrs 32 and 39 (Table 10, Figure 66). At Yrs 32 and 39 for all forest types, snags were more common on unscarified cutblocks than in ones subjected to scarification; this difference in snag density, however, had largely disappeared by Yr 39 for **MIXEDWOOD** and **PINE** cutblocks. Generally, snag densities declined between Yrs 32 and 39, suggesting that snag recruitment rates had dropped or that fall-over rates of snags had increased.

Snags containing cavities were equally common in mature forests and unscarified cutblocks for **SPRUCE** and **MIXEDWOOD** forests, but were absent (**SPRUCE, MIXEDWOOD**) or of low densities (**PINE**) on scarified cutblocks (Table 10, Figure 67). There appeared to be a slight decline in densities of snags with cavities on unscarified cutblocks of all forest types between Yrs 32 and 39. In **SPRUCE** or **MIXEDWOOD** cutblocks, it appeared that post-harvest green trees on unscarified cutblocks had not attained ages or conditions that could create snags. Similarly, it is logical to assume that most snags on unscarified cutblocks during Yrs 32 and 39 were residual trees at the time of the logging event.

White spruce was the predominant snag species in mature spruce and regenerating unscarified **SPRUCE** cutblocks (Table 11, Figure 68). Balsam poplar, left as residuals at harvest, were a secondary snag species in **SPRUCE** systems at Yr 32, but were no longer standing by Yr 39.

Species composition of snags in **MIXEDWOOD** stands was more diverse than in the **SPRUCE** forest, and included trembling aspen, white spruce, lodgepole pine and balsam poplar (Figure 69). In mature **MIXEDWOOD** forests at Yr 32, trembling aspen and pine snags were common but their contribution had declined by Yr 39, presumably reflecting mixedwood successional pathways leading to greater white spruce canopy cover. Trembling aspen, present as residuals at harvest, were the most common snag species in regenerating **MIXEDWOOD** cutblocks at Yr 32 and 39. Contributions of conifer species (white spruce and lodgepole pine) to snags increased in **MIXEDWOOD** cutblocks between Yrs 32 and 39.

In regenerating **PINE** cutblocks, snags were comprised of lodgepole pine, balsam poplar, and white spruce with lodgepole dominating all cutblocks except scarified cutblocks in Yr 32 where balsam poplar was most common (Table 11, Figure 70). Balsam poplar snags experienced high fall-down rates between Yr 32 and 39, and were replaced by lodgepole pine as the dominant snag species.

Snags with cavities in mature **SPRUCE** forests were exclusively white and black spruce, with black spruce having a higher percent of cavities than white spruce (Figure 71). Cavities in trembling aspen snags were conspicuously absent. In regenerating **MIXEDWOOD** cutblocks, cavity densities were higher than expected randomly in balsam poplar, while lodgepole pine were not as important as observed in mature mixedwood forests. Snags with cavities in regenerating **PINE** cutblocks were primarily lodgepole pine, though white spruce snags became a more common contributor of cavities between Yrs 32 and 39 (Table 12, Figure 71).

Cavities were not located randomly in snags relative to snag diameter for all forest types (Table 13, Figure 73). In mature **SPRUCE** and **MIXEDWOOD** forests, cavities were found preferentially in smaller diameter snags (15–25 cm) and were not observed in large diameter (>35 cm) snags. In regenerating **SPRUCE** cutblocks, cavities were preferentially found in mid-diameter snags (25–35 cm) in Yr 39. In regenerating **MIXEDWOOD** cutblocks, cavities were found in all snag diameter classes in proportion to availability in Yr 32, and found in large diameter snags (>35 cm) preferentially in Yr 39. In regenerating **PINE** cutblocks, cavities were found preferentially in the larger diameter snags (25–35 cm, >35 cm) in Yrs 32 and 39. The above pattern suggests that cavities were preferentially found in larger diameter snags in regenerating cutblocks of all forest types, but this pattern did not occur in mature unharvested forests.

Snags of the most advanced rot class (#6) were more common in mature **SPRUCE** and **MIXEDWOOD** forests than in regenerating Yr 39 cutblocks (Table 14, Figure 72, Figure 74). For mature **SPRUCE** and **MIXEDWOOD** forests, rot classes of snags were more variable than in regenerating cutblocks, indicating a more continual recruitment of snags from the green tree cohorts. For mature forests, cavities were only found in snags of advanced rot classes (Classes 4–5). In regenerating **SPRUCE** cutblocks, cavities were found only in snags of rot class 2 and appeared not to be occurring in the abundant snags of rot classes 3 and 4. This pattern was in contrast with the regenerating **MIXEDWOOD** cutblocks, whose cavities were only found in snags of rot class 5 and absent from the abundant solid snags. In regenerating **PINE** cutblocks, cavities were preferentially found in snags of advanced rot classes (4–6) and absent from solid snags.

Table 10. Average density (#/ha) of snags, cavity-containing snags, and cavities in SPRUCE, MIXEDWOOD, and PINE forest types during Yrs 32 and 39 (1988–1995).

Forest type	Treatment	Years Post-Logging	Total Snags	Snags with Cavities	Total Cavities
Spruce	Mature	32	24	5	9
Spruce	Mature	39	48	3	7
Spruce	Scarified	32	0	0	0
Spruce	Scarified	39	0	0	0
Spruce	Unscarified	32	22	5	7
Spruce	Unscarified	39	12	2	3
Mixedwood	Mature	32	38	3	6
Mixedwood	Mature	39	63	5	13
Mixedwood	Scarified	32	0	0	0
Mixedwood	Scarified	39	5	0	0
Mixedwood	Unscarified	32	11	4	11
Mixedwood	Unscarified	39	4	2	8
Pine	Scarified	32	15	1	1
Pine	Scarified	39	18	1	2
Pine	Unscarified	32	43	7	7
Pine	Unscarified	39	21	6	7

Table 11. Species composition of snags in SPRUCE, MIXEDWOOD, and PINE forests during Yrs 32 and 39.

Forest Type	Treatment	Yrs Post-Logging	White Spruce	Black Spruce	Lodgep. Pine	Trembling Aspen	Balsam Poplar	Unknown Tree Spp.	Total Snags
Spruce	Mature	32	21	0	0	0	2	0	23
Spruce	Mature	39	41	7	0	0	0	0	48
Spruce	Scarified	32	0	0	0	0	0	0	0
Spruce	Scarified	39	0	0	0	0	0	0	0
Spruce	Unscarified	32	20	0	0	0	2	0	22
Spruce	Unscarified	39	12	0	0	0	0	0	12
Mixedwood	Mature	32	12	0	9	17	0	0	38
Mixedwood	Mature	39	36	0	12	3	0	12	63
Mixedwood	Scarified	32	0	0	0	0	0	0	0
Mixedwood	Scarified	39	2	0	0	3	0	0	5
Mixedwood	Unscarified	32	2	0	2	5	1	1	11
Mixedwood	Unscarified	39	1	0	1	2	0	0	4
Pine	Scarified	32	0	0	3	0	12	0	15
Pine	Scarified	39	0	0	16	0	2	0	18
Pine	Unscarified	32	0	0	38	0	0	5	43
Pine	Unscarified	39	3	0	18	0	0	0	21

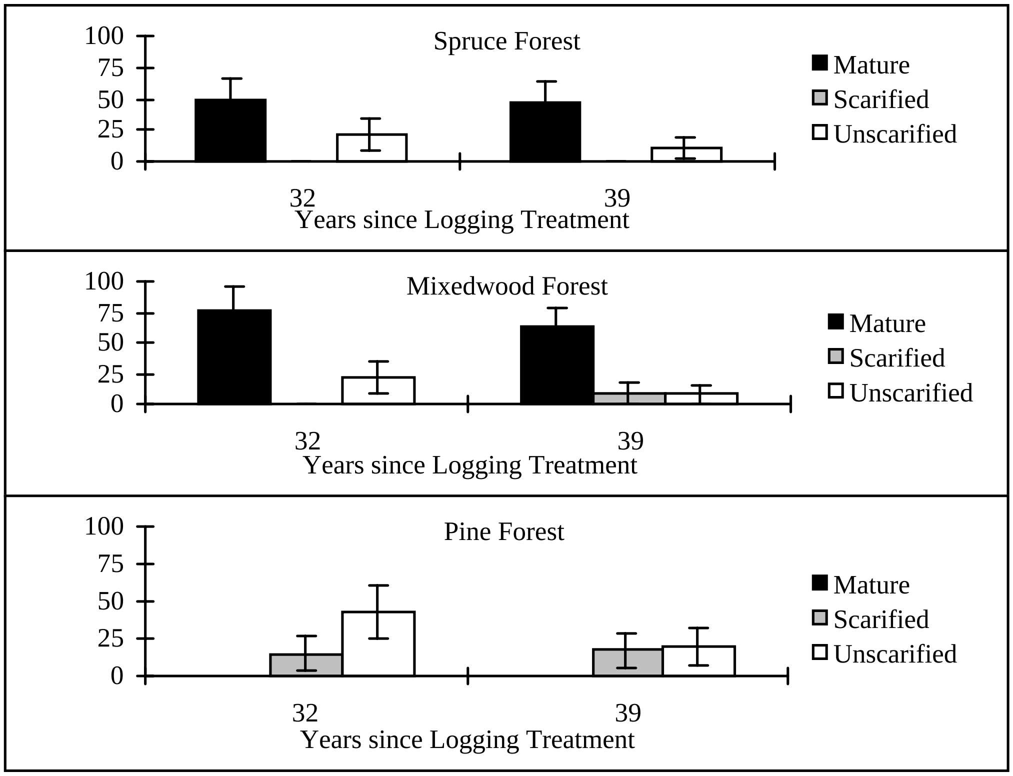


Figure 66. Snag density (± 2. S.E.) in **SPRUCE**, **MIXEDWOOD** and **PINE** forest types during Yrs 32 and 39 as affected by treatment.

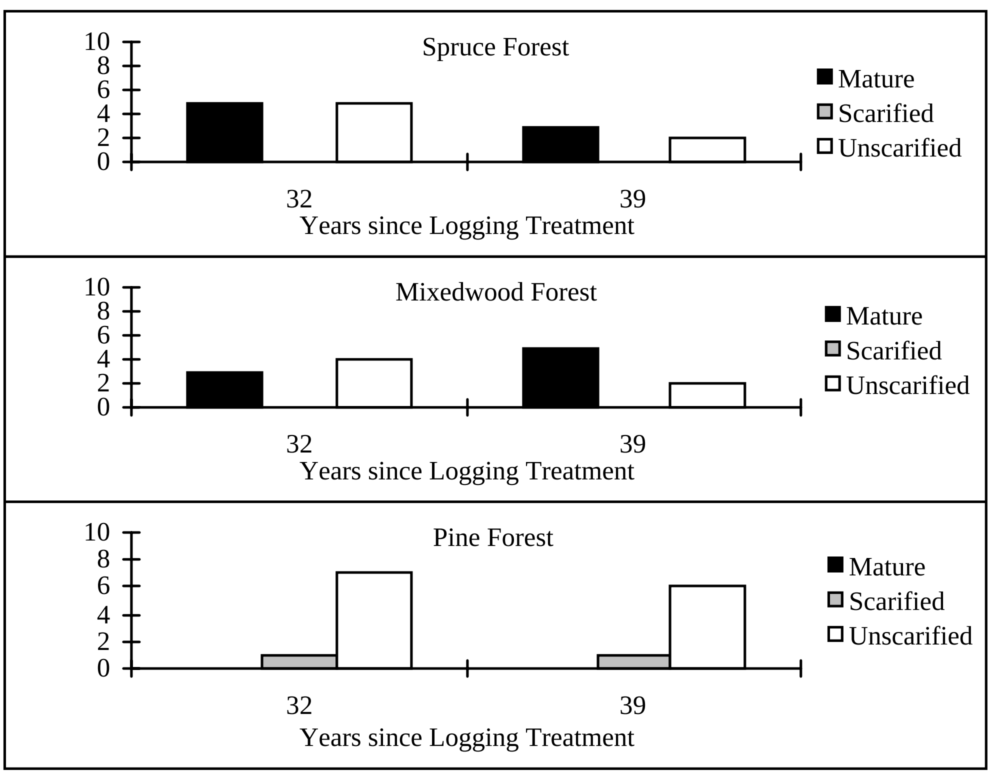


Figure 67. Density of snags with cavities in **SPRUCE**, **MIXEDWOOD** and **PINE** forest types during Yrs 32 and 39 as affected by treatment.

Table 12. Species composition of snags and cavity-containing snags in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests during Yrs 32 and 39 (1988–1995).

Forest Type	Treatment Type	Snag Species	All Snags Yr 32	With Cavities Yr 32	All Snags Yr 39	With Cavities Yr 39
Spruce	Mature	White Spruce	21	5	41	1
Spruce	Mature	Black Spruce	0	0	7	2
Spruce	Mature	Balsam Poplar	2	0	0	0
Spruce	Regenerating	White Spruce	20	5	12	2
Spruce	Regenerating	Balsam Poplar	2	0	0	0
Mixedwood	Mature	Lodgepole Pine	9	2	12	3
Mixedwood	Mature	White Spruce	12	1	36	1
Mixedwood	Mature	Trembling Aspen	17	0	3	0
Mixedwood	Mature	Unknown	0	0	12	1
Mixedwood	Regenerating	Lodgepole Pine	2	1	1	0
Mixedwood	Regenerating	White Spruce	2	1	3	1
Mixedwood	Regenerating	Balsam Poplar	1	1	0	0
Mixedwood	Regenerating	Trembling Aspen	5	0	5	1
Mixedwood	Regenerating	Unknown	1	1	0	0
Pine	Regenerating	Lodgepole Pine	41	8	34	6
Pine	Regenerating	White Spruce	0	0	3	1
Pine	Regenerating	Balsam Poplar	12	0	2	0
Pine	Regenerating	Unknown	5	0	0	0

Table 13. Comparison of snag and cavity-containing snag frequency relative to snag diameter (dbh) in **SPRUCE** (upper), **MIXEDWOOD** (middle), and **PINE** (lower) forests during Yrs 32 and 39 (1988–1995).

			Yr 32		Yr 39	
Forest Type	Treatment	Snag Diameter	All Snags	Snags with cavities	All Snags	Snags with cavities
Spruce	Mature	15–25 cm	18	5	25	2
Spruce	Mature	25–35 cm	4	0	13	1
Spruce	Mature	>35 cm	1	0	10	0
Spruce	Regenerating	15–25 cm	16	4	6	0
Spruce	Regenerating	25–35 cm	5	1	5	2
Spruce	Regenerating	>35 cm	1	0	0	0
Mixedwood	Mature	15–25 cm	23	3	31	4
Mixedwood	Mature	25–35 cm	15	0	22	1
Mixedwood	Mature	>35 cm	0	0	10	0
Mixedwood	Regenerating	15–25 cm	3	1	7	1
Mixedwood	Regenerating	25–35 cm	3	1	0	0
Mixedwood	Regenerating	>35 cm	5	2	2	1
Pine	Regenerating	15–25 cm	35	0	25	3
Pine	Regenerating	25–35 cm	17	4	6	1
Pine	Regenerating	>35 cm	6	4	8	3

Table 14. Comparison of snag condition classes in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests.

Forest Type	Treatment Type	Snag Condition Class	All Snags	Snags with Cavities
Spruce	Mature	1	0	0
Spruce	Mature	2	16	0
Spruce	Mature	3	10	0
Spruce	Mature	4	11	3
Spruce	Mature	5	6	0
Spruce	Mature	6	5	0
Spruce	Regenerating	1	0	0
Spruce	Regenerating	2	3	2
Spruce	Regenerating	3	0	0
Spruce	Regenerating	4	7	0
Spruce	Regenerating	5	2	0
Spruce	Regenerating	6	0	0
Mixedwood	Mature	1	1	0
Mixedwood	Mature	2	9	0
Mixedwood	Mature	3	6	0
Mixedwood	Mature	4	13	2
Mixedwood	Mature	5	18	3
Mixedwood	Mature	6	16	0
Mixedwood	Regenerating	1	3	0
Mixedwood	Regenerating	2	2	0
Mixedwood	Regenerating	3	0	0
Mixedwood	Regenerating	4	1	0
Mixedwood	Regenerating	5	2	2
Mixedwood	Regenerating	6	1	0
Pine	Regenerating	1	7	0
Pine	Regenerating	2	9	0
Pine	Regenerating	3	3	1
Pine	Regenerating	4	14	3
Pine	Regenerating	5	3	1
Pine	Regenerating	6	3	2

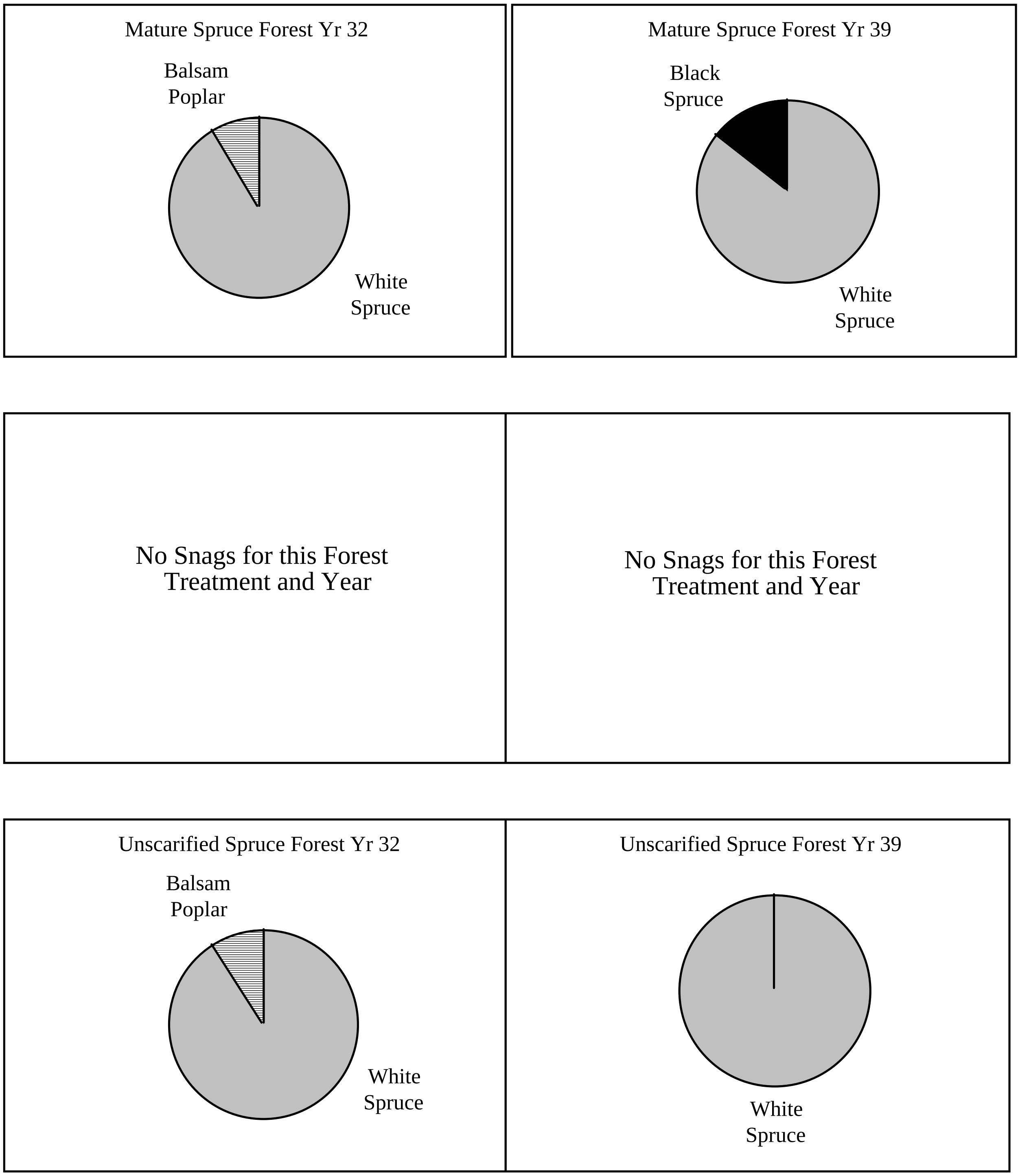


Figure 68. Species composition of snags in **SPRUCE** forests during Yrs 32 and 39 (1988–1995).

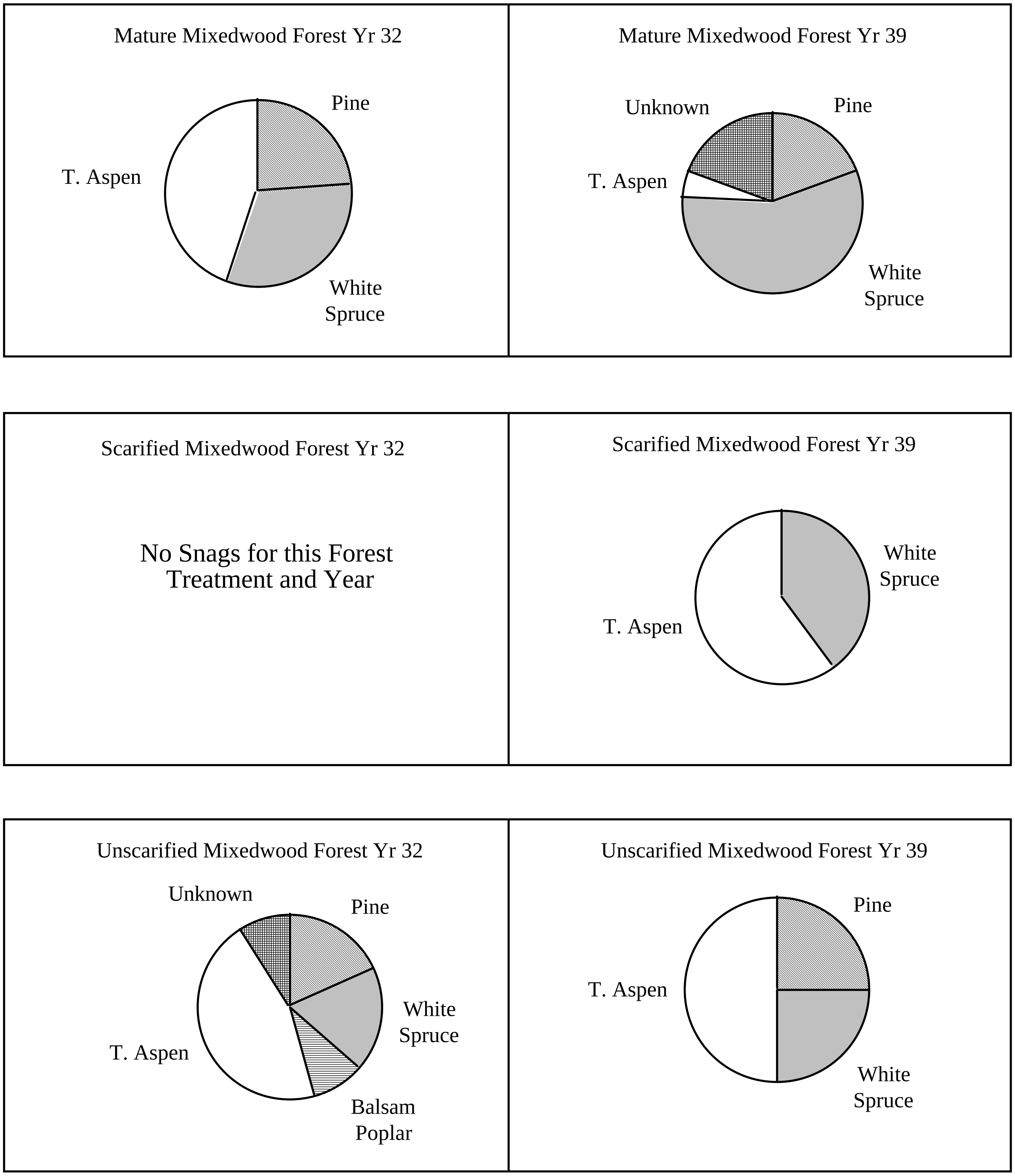


Figure 69. Species composition of snags in **MIXEDWOOD** forests during Yrs 32 and 39 (1988–1995).

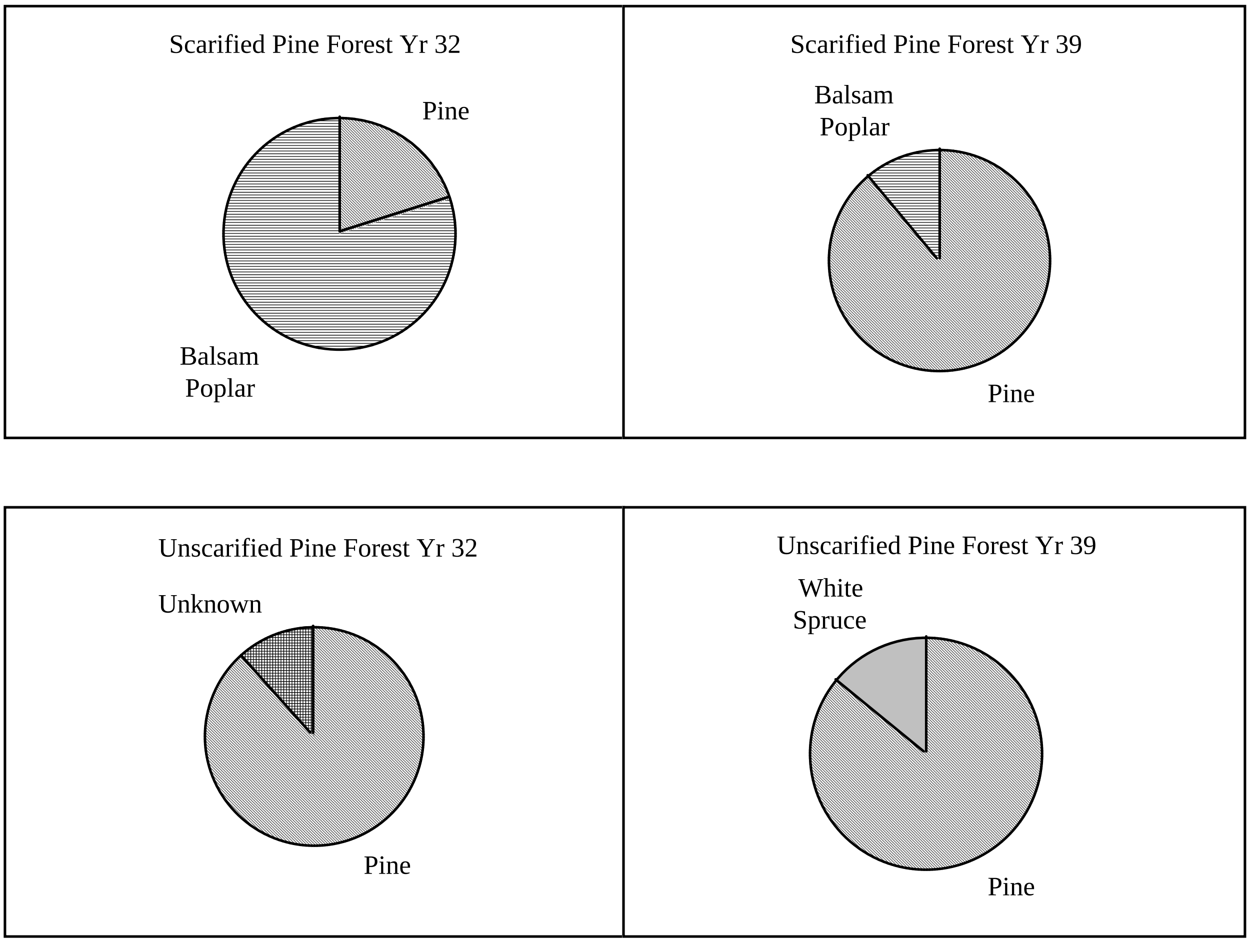


Figure 70. Species composition of snags in **PINE** forests during Yrs 32 and 39 (1988–1995).

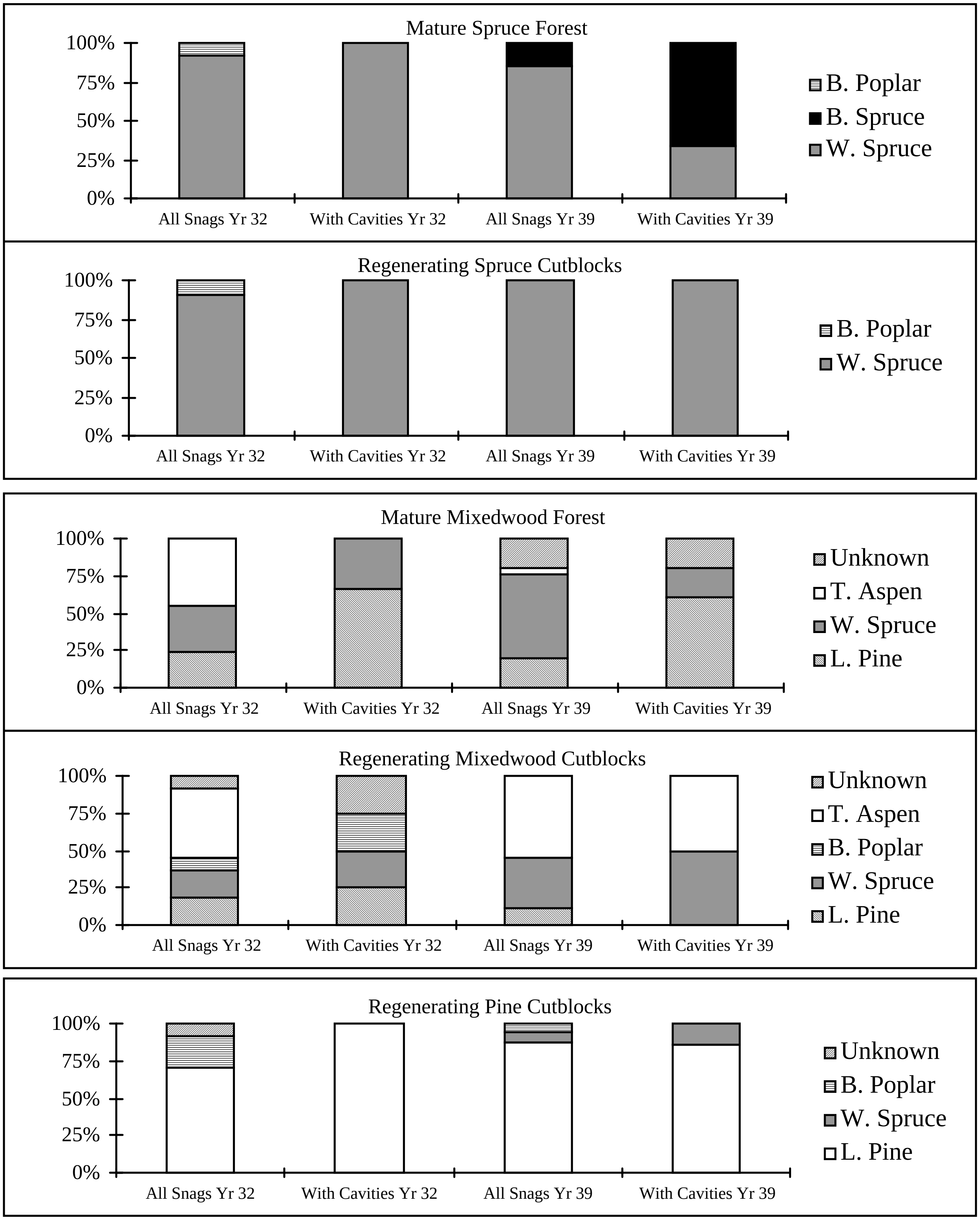


Figure 71. Snag species composition for total snags and those containing cavities; Yrs 32 and 39 (1988–1995).

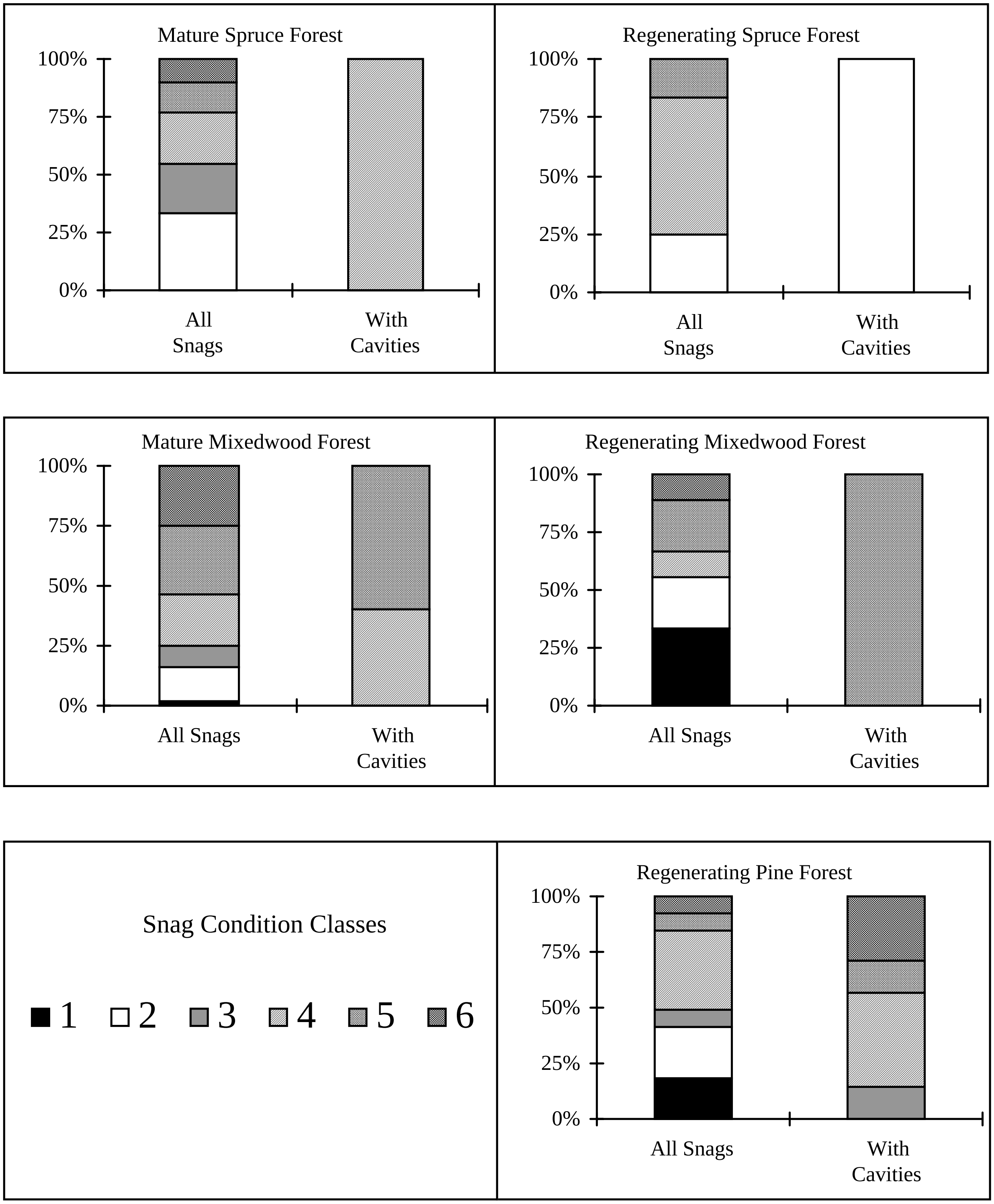


Figure 72. Comparison of snag condition in forest types and logging treatment in Yr 39 (1995).

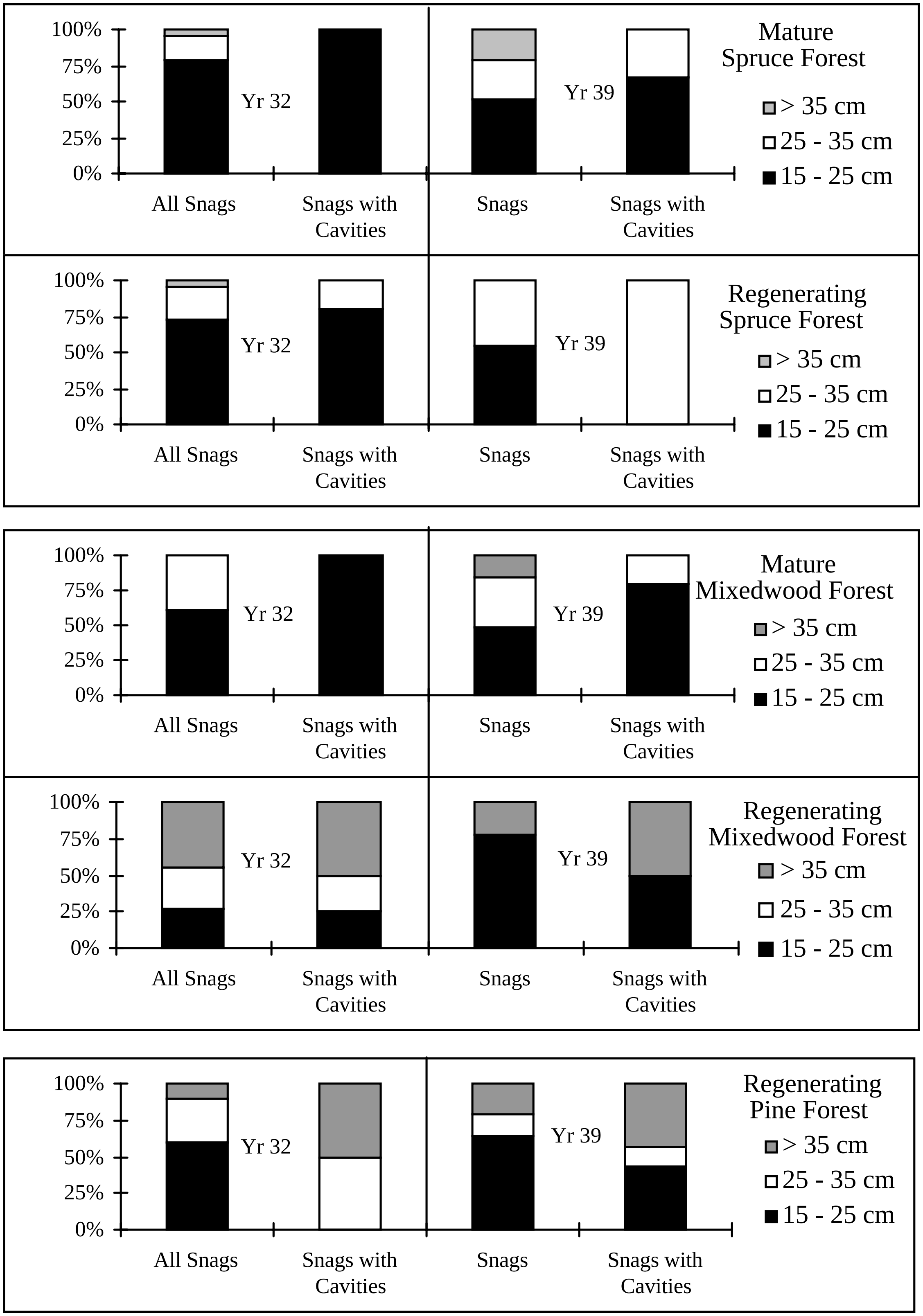
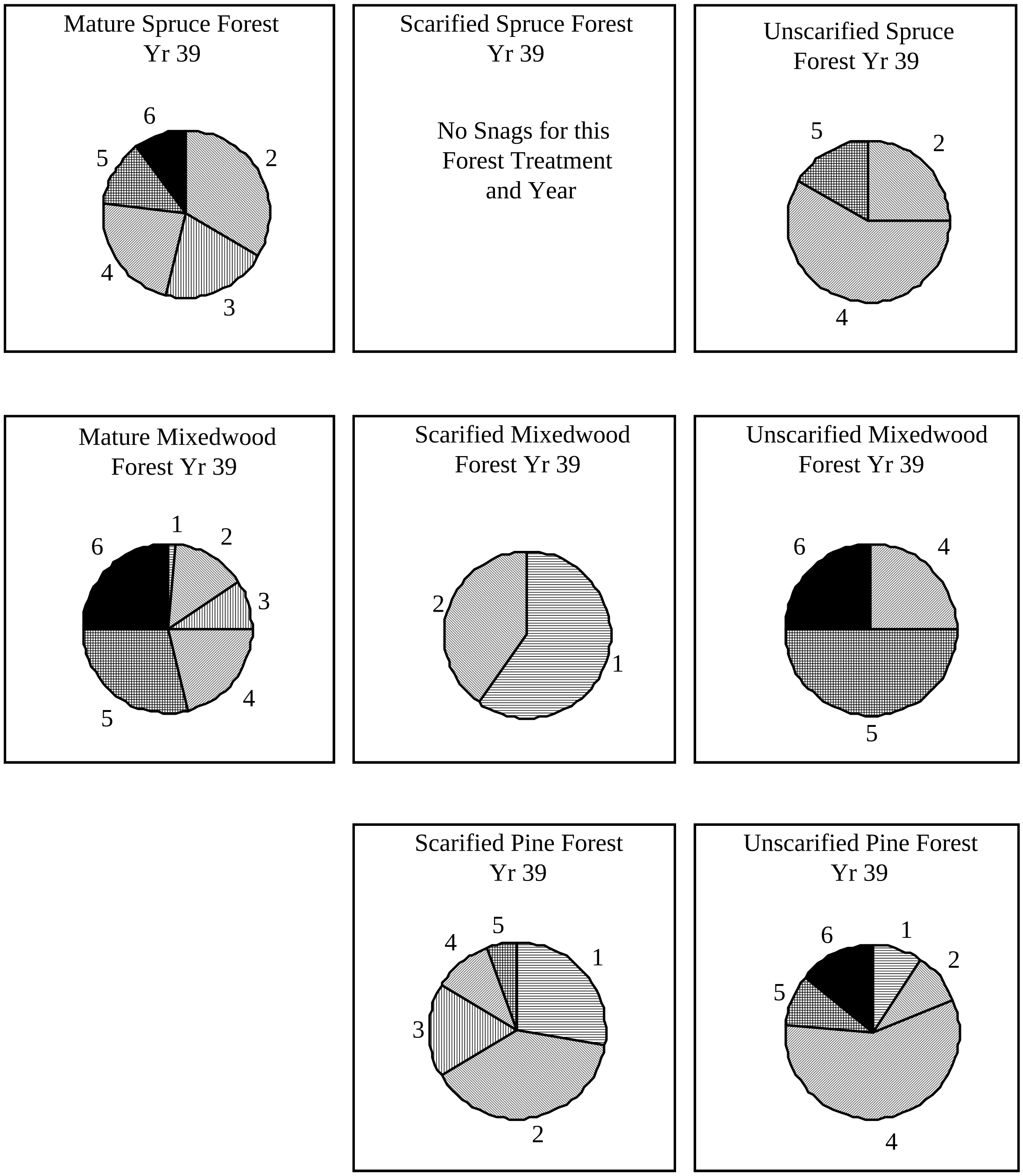


Figure 73. Comparison of snag and cavity-containing snag frequency relative to snag diameter (dbh) in **SPRUCE**, **MIXEDWOOD**, and **PINE** forests during Yrs 32 and 39 (1988–1995).



Codes	Description
1	recently dead tree; leaves still attached or bark still moist or green underneath
2	snag hard and dry, fine branches and bark mostly present
3	snag hard and dry - stem sound, bark variable, fine branches absent, large branches present
4	snag hard and dry although become soft in places; only main bole present, bark scattered or absent
5	snag moderately soft often with dry rot in bole; bark mostly absent
6	snag very soft with decomposed bole

Figure 74. Proportion of snags within different snag condition classes; Yr 39 (1995).

Down Wood

Mature **SPRUCE** and **MIXEDWOOD** forests had higher down wood cover than their respective regenerating 40 Yr old cutblocks (Table 15), while scarified and unscarified cutblocks did not differ in amount (Table 15, Figure 75). Mature **SPRUCE** and **MIXEDWOOD** forests had an average down wood cover of 4–5%, and regenerating scarified and unscarified forests of **SPRUCE**, **MIXEDWOOD**, and **PINE** cutblocks had down wood covers of 1–2% (Table 15, Figure 75).

Mature **SPRUCE** forests had higher average diameter of down wood than did the regenerating cutblocks (Table 16, Figure 76). No differences in average diameter of down wood occurred between cutblock treatment types for **SPRUCE**, **MIXEDWOOD** or **PINE** forests, suggesting that scarification had no affect on average diameter of down wood in regenerating cutblocks at Yr 40.

Frequency of down wood diameter declined exponentially on scarified and unscarified **SPRUCE** cutblocks, but was more broadly distributed across diameter classes in mature **SPRUCE** forests (Table 17, Figure 77). Lower recruitment levels for small diameter down wood occurred in regenerating **MIXEDWOOD** cutblocks than in the mature forest (Figure 78). No clear differences in frequency of down wood diameter occurred between scarified and unscarified **PINE** cutblocks.

For all forest types, the proportion of rotten to solid down wood increased with down wood diameter (Figure 77–Figure 79). This pattern suggests that much of the larger down wood was deposited at or prior to the logging event and has had considerable time to decompose. The amount of sound down wood was higher in mature forests than cutblocks for both **SPRUCE** and **MIXEDWOOD** forests (Table 18, Figure 80). Presumably the uneven age-class structure of mature forests provides for continuous recruitment of down wood. Cover of rotten wood >7.5 cm did not differ significantly among any of the three forest types or among cutblock treatments. Amount of rotten wood was higher than sound wood in all regenerating cutblocks.

An examination of sound wood frequencies may indicate how deadwood inputs are related to tree size and mortality in the cutblock treatments. In mature forests, sound wood input occurs in all size classes up to 40 cm dbh in both **SPRUCE** and **MIXEDWOOD** forests, whereas sound wood recruitment occurs at a maximum of 10 cm on scarified **SPRUCE** and **MIXEDWOOD** cutblocks, and up to 25 cm in the unscarified cutblocks. This comparison suggests that down wood input on unscarified cutblocks is more similar to that of a mature forest than to the pattern observed on scarified cutblocks. No difference in recruitment pattern of sound down wood was observed in **PINE** cutblocks.

Table 15. Ground cover (%) of down wood (>7.5 cm) in **SPRUCE**, **MIXEDWOOD** and **PINE** forests; Yr 40.

Forest	Mature		Scarified		Unscarified	
Type	Average	S.D.	Average	S.D.	Average	S.D.
SPRUCE	5.02	2.27	1.61	1.30	2.02	1.36
MIXEDWOOD	3.93	1.09	1.37	0.73	0.79	0.86
PINE	-	-	1.41	1.07	2.20	1.39

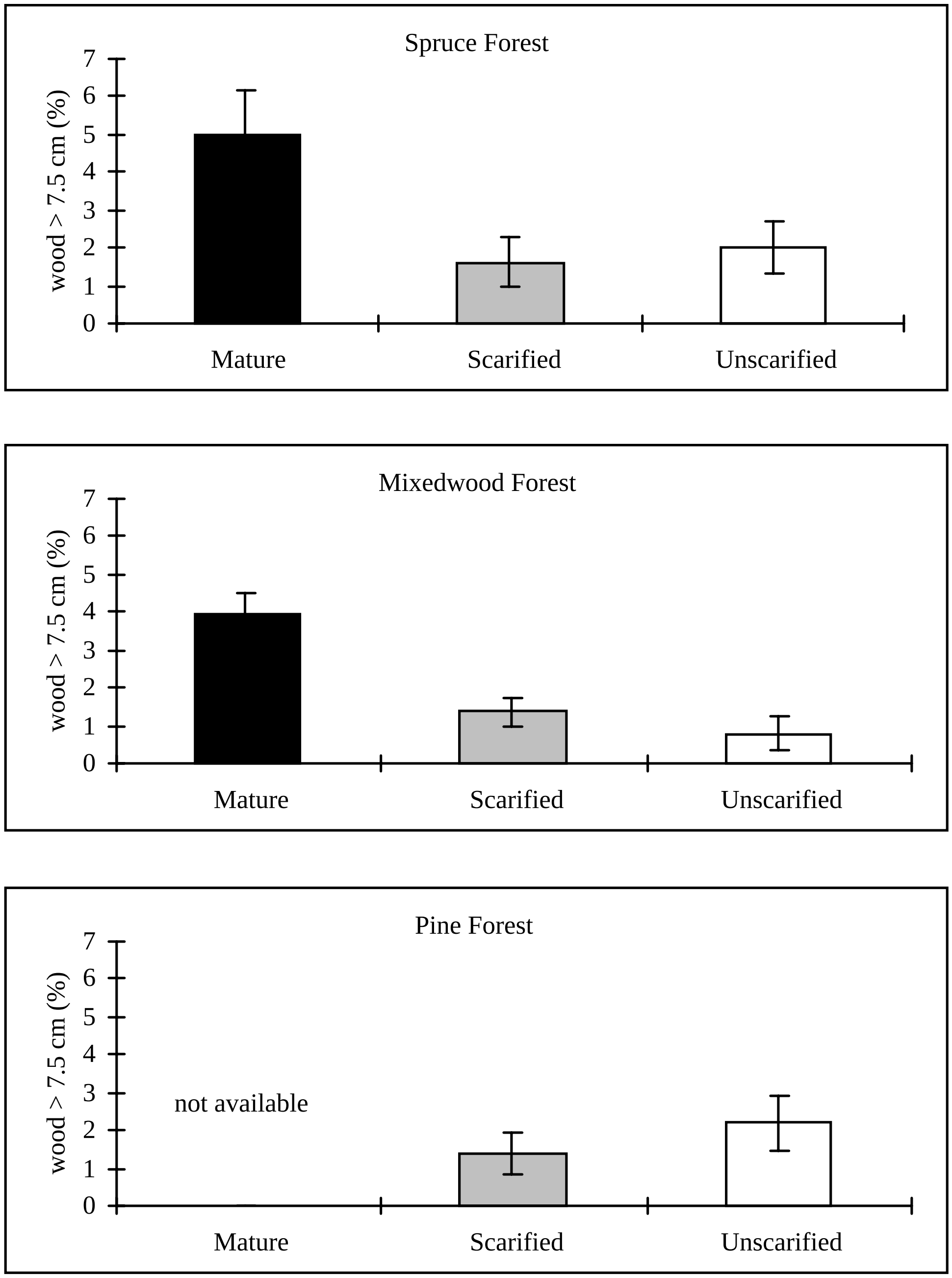


Figure 75. Average ground cover (%, ± 2. S.E.) of down wood (>7.5 cm) in **SPRUCE**, **MIXEDWOOD** and **PINE** forests in Yr 39.

Table 16. Mean diameter of down wood in **SPRUCE**, **MIXEDWOOD** and **PINE** forests (Yr 39).

Forest	Mature		Scarified		Unscarified	
Type	Average	S.D.	Average	S.D.	Average	S.D.
SPRUCE	18.5	1.19	13.6	0.98	14.9	0.99
MIXEDWOOD	17.9	1.03	19.8	2.56	18.5	2.76
PINE	-	-	15.2	1.32	17.4	1.18

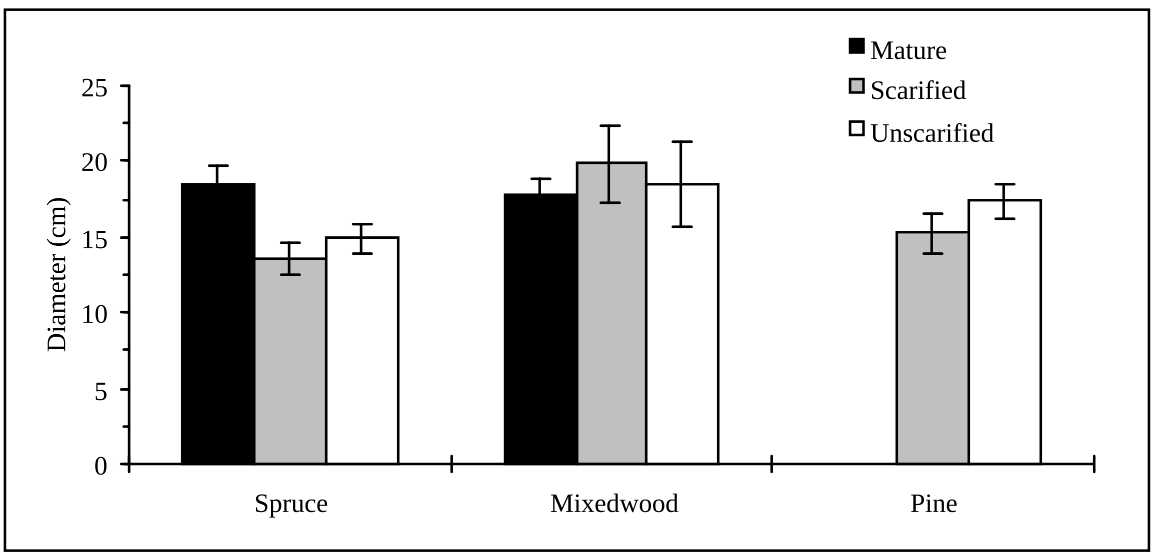


Figure 76. Mean diameter (cm, ± 2. S.E.) of down wood in **SPRUCE**, **MIXEDWOOD** and **PINE** forests; Yr 40.

Table 17. Down wood condition in different diameter classes in **SPRUCE**, **MIXEDWOOD** and **PINE** forests; Yr 40.

Forest Type	Mature			Scarified			Unscarified		
	Rotten	Sound	Total	Rotten	Sound	Total	Rotten	Sound	Total
SPRUCE									
10 cm	54	60	114	93	11	104	76	25	101
15 cm	40	64	104	38	0	38	37	7	44
20 cm	30	42	72	18	0	18	28	5	33
25 cm	18	32	50	10	0	10	10	2	12
30 cm	28	14	42	4	0	4	6	1	7
35 cm	10	6	16	1	0	1	2	0	2
40 cm	2	2	4	1	0	1	4	0	4
45 cm	0	0	0	2	0	2	0	0	0
50 cm	2	0	2	0	0	0	0	0	0
55 cm	0	2	2	0	0	0	0	0	0
60 cm	0	0	0	0	0	0	0	0	0
MIXEDWOOD									
10 cm	24	19	43	12	2	14	6	3	9
15 cm	24	17	41	10	0	10	7	0	7
20 cm	28	15	43	12	0	12	6	0	6
25 cm	15	9	24	10	0	10	6	1	7
30 cm	5	5	10	2	0	2	1	0	1
35 cm	1	2	3	0	0	0	2	0	2
40 cm	0	1	1	1	0	1	0	0	0
45 cm	0	0	0	3	0	3	0	0	0
50 cm	0	0	0	0	0	0	0	0	0
55 cm	0	0	0	0	0	0	0	0	0
60 cm	0	0	0	0	0	0	0	0	0
PINE									
10 cm	-	-	-	49	16	65	38	17	55
15 cm	-	-	-	49	10	59	50	7	57
20 cm	-	-	-	35	4	39	8	2	10
25 cm	-	-	-	20	0	20	6	0	6
30 cm	-	-	-	7	0	7	3	2	5
35 cm	-	-	-	3	0	3	4	0	4
40 cm	-	-	-	2	0	2	0	0	0
45 cm	-	-	-	1	0	1	0	0	0
50 cm	-	-	-	0	0	0	1	0	1
55 cm	-	-	-	0	0	0	1	0	1
60 cm	-	-	-	1	0	1	0	0	0

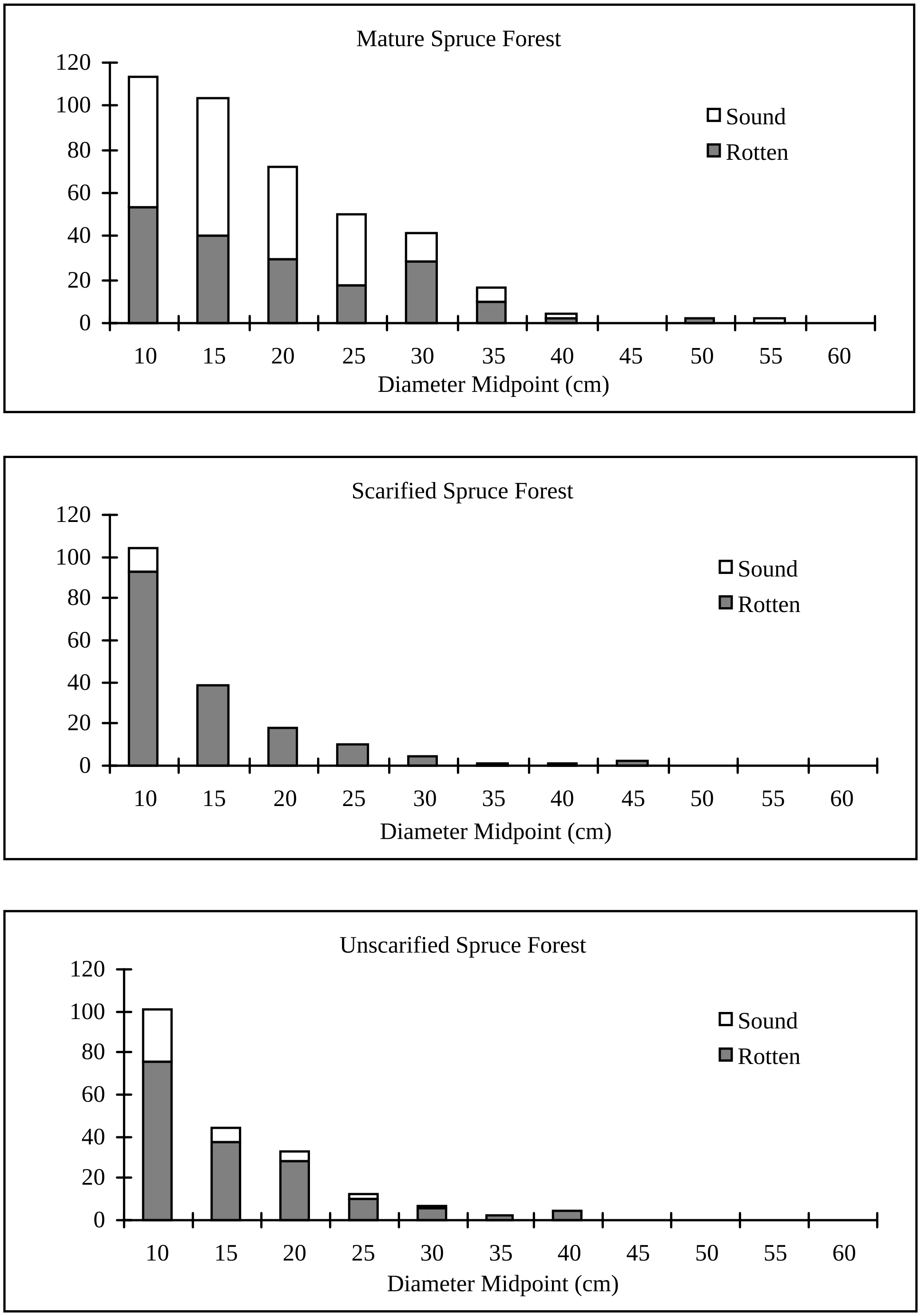


Figure 77. Diameter frequency distribution of sound and rotten down wood in SPRUCE forest as affected by site treatment; Yr 40.

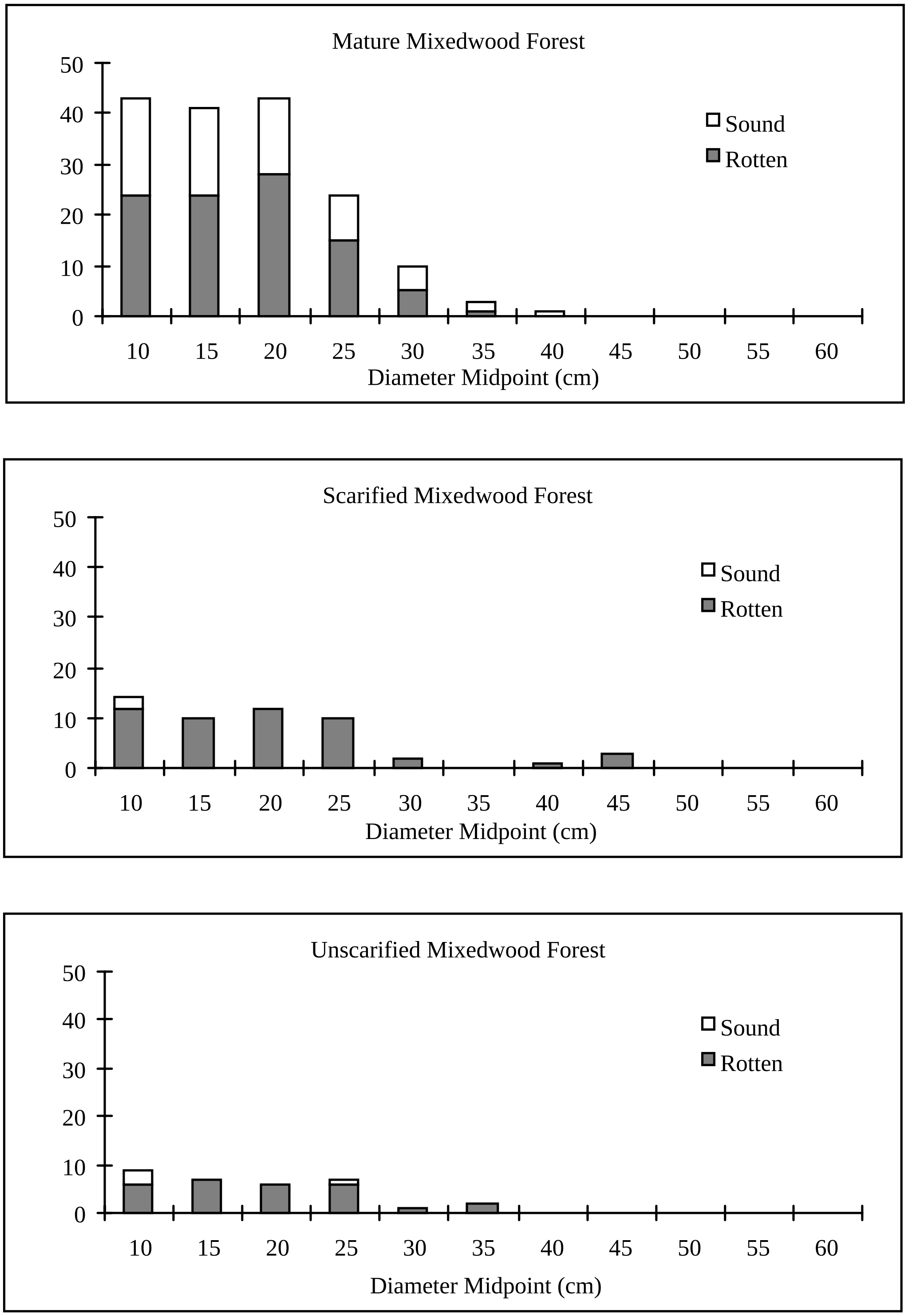
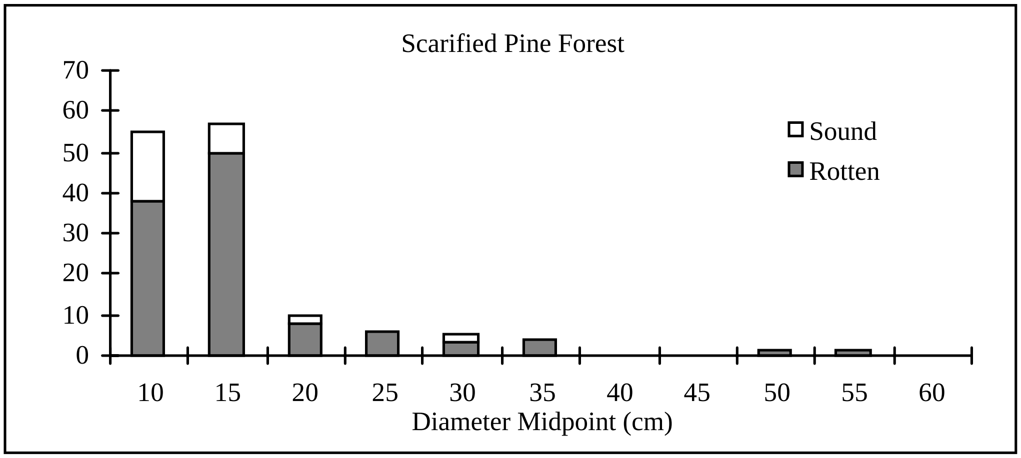


Figure 78. Diameter frequency distribution of sound and rotten down wood in **MIXEDWOOD** forests as affected by site treatment; Yr 40.



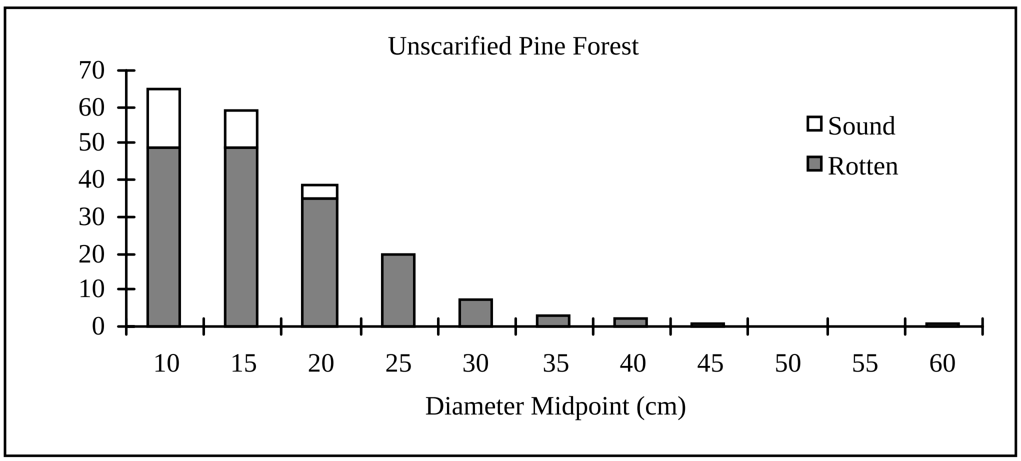


Figure 79. Diameter frequency distribution of sound and rotten down wood in **PINE** forests as affected by site treatment; Yr 40.

Table 18. Frequency of down wood condition (sound, rotten) in forest types and different site treatments; Yr 40.

Forest Type	Condition	Mature		Scarified		Unscarified	
		Average	SD	Average	SD	Average	SD
SPRUCE	Sound	2.67	1.45	0.25	0.09	0.56	0.32
	Rotten	2.35	1.16	1.71	1.09	1.67	1.19
MIXEDWOOD	Sound	1.64	0.80	0.22	0.01	0.25	0.16
	Rotten	2.29	1.06	1.35	0.76	0.99	0.84
PINE	Sound	n/a	n/a	0.51	0.51	0.42	0.28
	Rotten	n/a	n/a	1.41	0.86	2.07	1.22

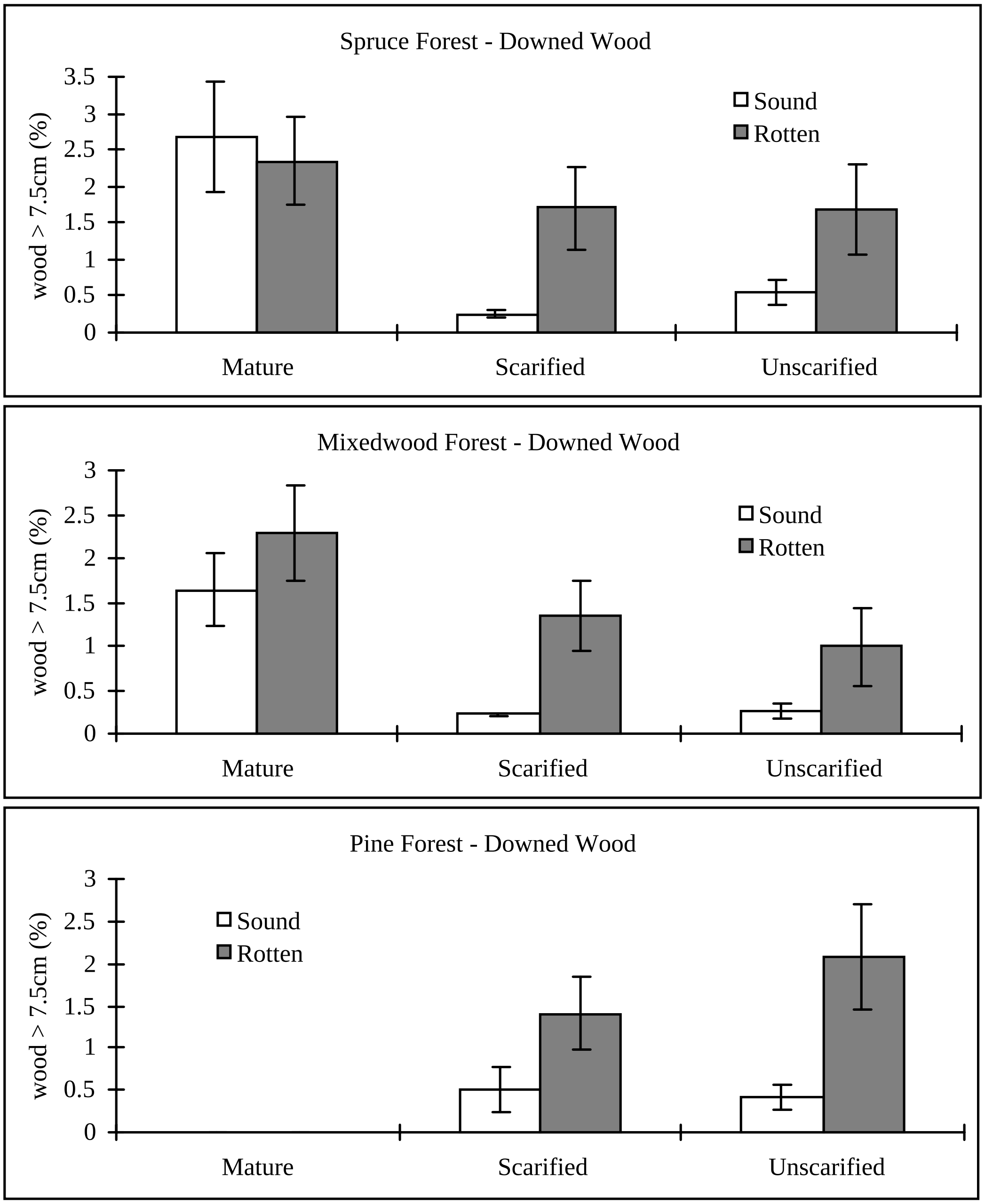


Figure 80. Cover (%, ± 2. S.E.) of sound and rotten down wood >7.5 cm in **SPRUCE**, **MIXEDWOOD** and **PINE** forests; Yr 40.

Understory Visibility

Visibility through the forest understory, at the conclusion of the study, increased with distance upward from the ground surface (Table 19, Figure 81), reflecting visual obstruction caused by the dense herbaceous and lower shrub strata. Generally, understory visibility was highest in the **MIXEDWOOD** forest, followed by the **SPRUCE** forests, and was lowest in the **PINE** forests. Low visibility in regenerating **PINE** cutblocks was largely caused by very high densities of green alder. Visibility did not differ between mature **SPRUCE** forests and regenerating cutblocks (Yrs 32, 39) but was higher on scarified mixedwood cutblocks than either mature forests or unscarified cutblocks. No differences in visibility between scarified and unscarified **PINE** cutblocks were observed.

Table 19. Mean understory visibility as affected by forest type and treatment; Yrs 32–39.

Forest Type	Yrs	Treatment	N	0–0.5 m		0.5–1.5 m		1.5–2.5 m	
				Mean	SD (x2)	Mean	SD (x2)	Mean	SD (x2)
SPRUCE	32	Mature	30	1.43	0.39	2.32	0.56	2.90	0.67
	32	Scarified	30	1.17	0.17	2.20	0.42	3.18	0.54
	32	Scarified	30	1.90	0.41	2.62	0.62	3.05	0.69
	32	Unscarified	30	1.33	0.20	1.93	0.34	2.45	0.48
	32	Unscarified	30	1.23	0.19	2.15	0.44	2.88	0.45
	39	Scarified	30	1.03	0.07	1.77	0.32	2.45	0.41
	39	Scarified	30	1.27	0.19	2.10	0.51	2.25	0.52
	39	Unscarified	30	1.30	0.22	2.18	0.31	2.60	0.47
	39	Unscarified	30	1.47	0.33	2.13	0.49	2.25	0.55
MIXEDWOOD	32	Mature	30	1.34	0.30	2.62	0.54	2.74	0.53
	32	Scarified	30	2.97	0.47	3.88	0.45	3.93	0.54
	32	Unscarified	30	1.43	0.29	1.93	0.52	1.98	0.54
	39	Scarified	30	2.53	0.54	2.92	0.56	3.10	0.63
	39	Unscarified	30	1.43	0.32	1.67	0.44	1.52	0.40
PINE	32	Scarified	30	1.03	0.07	1.82	0.37	2.08	0.52
	32	Scarified	30	1.03	0.07	1.52	0.33	1.80	0.52
	32	Unscarified	30	1.33	0.28	1.70	0.37	1.50	0.29
	32	Unscarified	30	1.17	0.22	1.62	0.41	1.65	0.41
	39	Scarified	30	1.23	0.19	1.77	0.38	1.75	0.43
	39	Scarified	30	1.20	0.25	1.67	0.34	1.80	0.42
	39	Unscarified	30	1.03	0.07	1.65	0.31	1.60	0.33
	39	Unscarified	30	1.10	0.15	1.83	0.37	1.92	0.42

Visibility Code	% of stratum visible
1	0–20% visibility
2	20–40% visibility
3	40–60% visibility
4	60–80% visibility
5	80–100 visibility

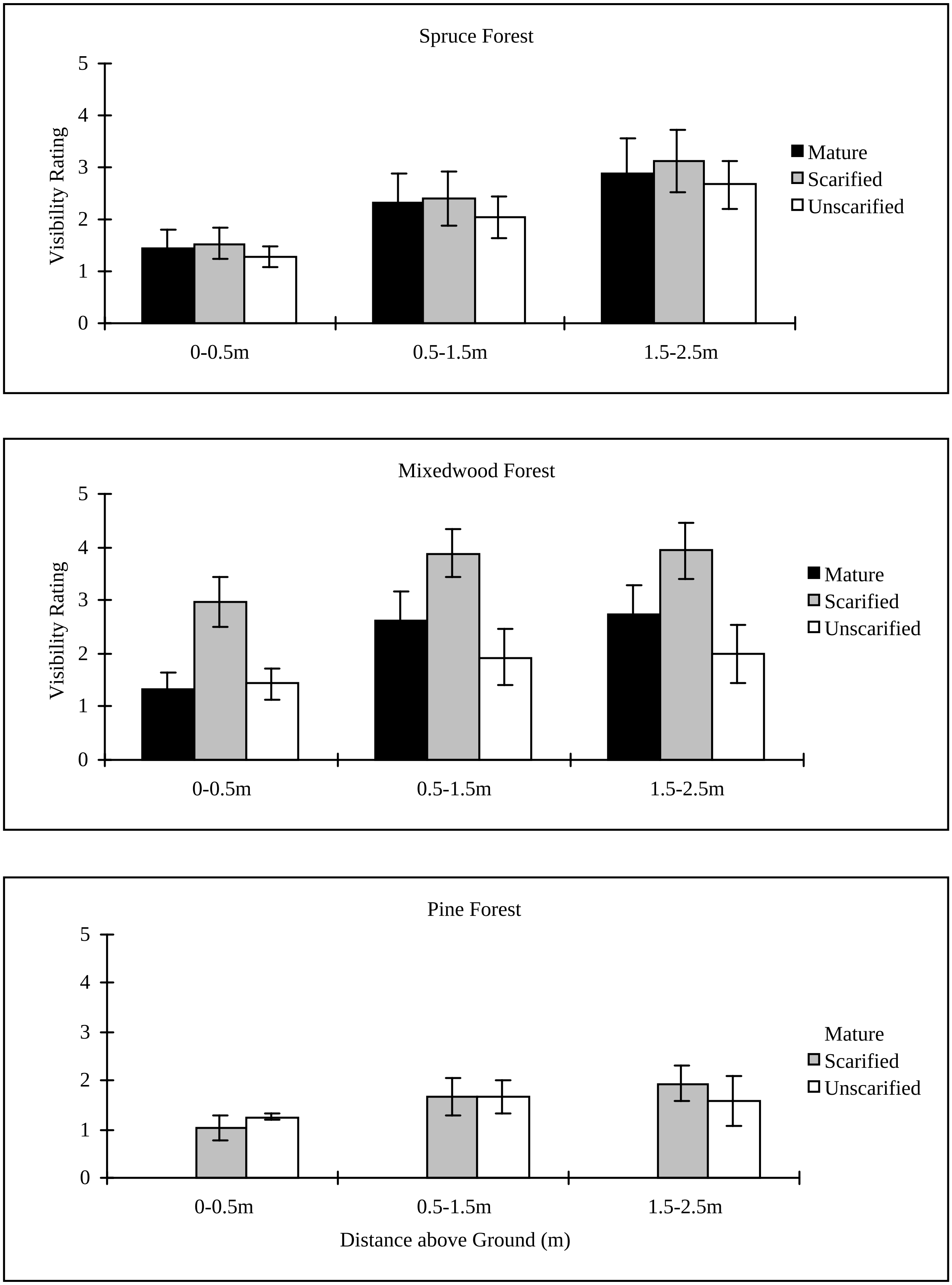


Figure 81. Visibility (± 2. S.E.) of the understory of **SPRUCE**, **MIXEDWOOD** and **PINE** forests (Yrs 32 and 39).

Wildlife Community Structure

Wildlife Pellet Surveys

Combined Ungulates

Based on scat density, abundance of deer, moose, and elk generally increased after Yr 1, though species achieved their highest densities at different seral stages in each forest type (Table 20, Figure 82, Figure 83). Combined ungulate abundance increased slowly on scarified **SPRUCE** cutblocks during Yrs 1–27 and did not change significantly thereafter. Unscarified cutblocks increased quickly during Yrs 9–17, peaking in Yr 17 following the removal of the 2nd pass residual conifer blocks (Yrs 12–15), then declined to levels similar to those on the scarified cutblocks.

Total ungulate abundance increased quickly on **MIXEDWOOD** cutblocks during Yrs 1–9, declined by Yr 27 after the 2nd pass logging removed the remaining mature forest blocks, and thereafter remained low. Ungulate abundance was generally higher on the scarified cutblocks during Yrs 1–9 and higher on unscarified cutblocks during Yrs 27–39.

Total ungulate abundance remained low to moderate on **PINE** cutblocks during Yrs 1–6 following single pass harvest, increased slowly during Yrs 6–32, and declined during Yrs 32–39. At all seral stages, scat density was higher on the unscarified than scarified cutblocks.

On **SPRUCE** cutblocks, deer scat was most abundant, followed by elk and moose. On **MIXEDWOOD** cutblocks, elk scat was most abundant, followed by deer and moose. On **PINE** cutblocks, deer scat was most abundant, followed by moose and elk. Whereas deer scat densities increased on **PINE** cutblocks with successional stage, highest moose scat densities occurred in young seral stages.

Comparisons of average scat density on site treatments (scarified, unscarified) indicated that ungulates were of higher abundances on unscarified **SPRUCE** cutblocks (196.1 groups/ha) than on scarified cutblocks (168.9 groups/ha). On **MIXEDWOOD** cutblocks, scat densities were higher on scarified cutblocks (127.0 groups/ha) than on unscarified cutblocks (103.9 groups/ha). On **PINE** cutblocks, scat densities were higher on unscarified cutblocks (87.3 groups/ha) than on scarified cutblocks (35.9 groups/ha).

Generally, cervid abundance remained below the carrying capacity of forage during the study. Factors that might explain low cervid abundance include inadequate security and shelter cover during Yrs 1–30 on scarified **SPRUCE** and **MIXEDWOOD** cutblocks, removal of 2nd pass residual blocks before adequate cover developed in the 1st pass cutblocks, and continued presence of human activities.

Deer

Deer abundance remained low in both scarified and unscarified **SPRUCE** cutblocks during Yrs 1–9 (Table 20, Figure 82, Figure 83). On unscarified cutblocks, abundance increased rapidly during Yrs 9–17, but dropped quickly once the 2nd pass residual forests were harvested. During the same period (Yrs 9–17) deer abundance on scarified cutblocks increased slowly and was significantly lower than on unscarified cutblocks. Deer abundance during Yrs 27–39 remained at moderate levels for both scarified and unscarified cutblocks. Relative abundance of deer on regenerating cutblocks surpassed densities on unharvested mature **SPRUCE** forests by Yr 6 for unscarified cutblocks and by Yr 9 for scarified cutblocks.

Deer abundance increased quickly following logging during Yrs 1–6 in both scarified and unscarified **MIXEDWOOD** cutblocks and then declined during Yrs 6–27. Deer abundance on unscarified cutblocks increased during Yrs 27–32 then declined during Yrs 32–39. On scarified cutblocks, deer abundance increased slowly during Yrs 27–39. Deer density on unscarified cutblocks generally exceeded or equaled densities on scarified cutblocks. Throughout the study, relative abundance of deer on regenerating cutblocks remained below densities found on unharvested mature **MIXEDWOOD** forests.

Deer remained absent from **PINE** unscarified cutblocks during Yrs 1–9, and from scarified cutblocks during Yrs 1–27. Deer pellet groups on unscarified **PINE** cutblocks increased from 0 to 138 /ha from Yrs 9–32, then declined to levels of 28 groups/ha by Yr 39. Deer arrived on scarified cutblocks between Yrs 27 and 32, increased and then decreased by Yr 39. Throughout the study, deer density on unscarified **PINE** cutblocks exceeded densities on scarified cutblocks.

Deer were more abundant on **SPRUCE** cutblocks than on **MIXEDWOOD** and **PINE** cutblocks (Table 20, Figure 82, Figure 83). Abundance of deer on **MIXEDWOOD** and **PINE** cutblocks was similar, though peak densities occurred early on **MIXEDWOOD** cutblocks and late in the study for **PINE** cutblocks.

Elk

Following logging, elk remained at low-moderate densities (~10–60 pellet groups/ha) on both scarified and unscarified **SPRUCE** cutblocks except for Yr 17 when densities were high (428 groups/ha) on unscarified cutblocks (Table 20, Figure 82, Figure 83). Elk densities decreased rapidly once the 2nd pass residual **SPRUCE** forests were harvested. Elk pellet groups were absent on the unharvested mature spruce forest.

Elk pellet groups on mature unharvested **MIXEDWOOD** forests were 8/ha. Immediately following logging (Yr 1), pellet groups were absent on scarified and unscarified cutblocks. Elk abundance increased quickly during Yrs 1–9, declined significantly during Yrs 9–32, and were absent by the conclusion of the study (Yr 39). Elk densities were higher on the scarified cutblocks during the early portions of the study (Yrs 6–9) and higher on the unscarified cutblocks during Yrs 27–32. Elk densities were higher on cutblocks than on unharvested mature **MIXEDWOOD** forest during Yrs 6 and 9 for scarified cutblocks and during Yrs 6–32 on unscarified cutblocks.

Elk scat densities on unscarified and scarified **PINE** cutblocks were generally low throughout the study. Highest densities on both unscarified and scarified cutblocks occurred during Yr 6. Of the five sampling periods where elk scat was counted, densities were higher on unscarified cutblocks four times and were higher on scarified cutblocks one time.

Elk were most abundant on **MIXEDWOOD** cutblocks, followed by **SPRUCE** cutblocks, and were of low density on **PINE** cutblocks. Elk achieved their highest densities during the herb-dominated young post-logging stages in **PINE** and **MIXEDWOOD** types and at the sapling stages for **SPRUCE** forests.

Moose

Moose increased in density on unscarified **SPRUCE** cutblocks immediately following logging at Yr 1, then were absent from these cutblocks during Yrs 6–32 (Table 20, Figure 82, Figure 83). Moose had re-established at low densities on unscarified cutblocks at the conclusion of the study (Yr 39). Immediately following logging, moose were absent on scarified cutblocks, then increased to moderate levels (30 pellet groups/ha) by Yr 9. Moose were absent from scarified cutblocks during Yrs 17–32, presumably in response to the removal of the residual blocks of mature forest. Thereafter, moose increased moderately to 16 pellet groups/ha by Yr 39. Relative abundance of moose on regenerating cutblocks exceeded the low densities on unharvested mature **SPRUCE** forests during Yrs 1 and 39 for unscarified cutblocks and during Yr 6, 9, and 39 for scarified cutblocks.

Moose were absent from scarified **MIXEDWOOD** cutblocks throughout the study with the exception of Yr 9, when 75 pellet groups/ha were measured. The rapid drop in moose abundance was associated with the removal of remaining residual blocks of mature **MIXEDWOOD** forest. Moose increased in abundance slowly following logging on unscarified cutblocks during Yrs 1–6, then slowly decreased and were absent during Yrs 27–39. No moose scat were measured on the unharvested mature **MIXEDWOOD** forests.

Moose scat densities on unscarified and scarified **PINE** cutblocks were moderate at Yr 1, declined to zero by Yr 6, then increased rapidly by Yr 9. Thereafter, moose densities remained at moderate levels during Yrs 9–39. At all stages of the study, densities of moose scat on unscarified cutblocks exceeded that of scarified cutblocks. Only in **PINE** cutblocks, where a 1-pass logging system was used, and where adequate winter habitat returned quickly, did moose abundance remain relatively constant during Yrs 9–32.

Moose were most abundant on **PINE** cutblocks and were of similar abundance on **MIXEDWOOD** and **SPRUCE** cutblocks.

<u>Hare</u>

Snowshoe hares were absent or of low abundance during Yrs 1–9 in all forest types (Table 20, Figure 84). Hare abundance on **SPRUCE** cutblocks remained low during Yrs 9–17, increased during Yrs 17–27, then declined to low levels during Yrs 27–39. During all years where hare scat were measured, densities were considerably higher on the unscarified **SPRUCE** cutblocks. Hare densities increased steadily during Yrs 9–32 on unscarified **MIXEDWOOD** cutblocks, then declined rapidly during Yrs 32–39, and were absent by the conclusion of the study. Hare scat were absent on scarified **MIXEDWOOD** cutblocks throughout the study. On **PINE** cutblocks, hare densities were 0 during Yrs 0–9, increased during Yrs 9–27, then declined quickly by Yr 32 and remained low. No significant difference in scat density between scarified and unscarified **PINE** cutblocks occurred.

<u>Grouse</u>

Based on scat counts, grouse species were absent during Yrs 1–9 for all forest types (Table 20, Figure 84). A few blue grouse were observed on scarified **SPRUCE** cutblocks and a few ruffed grouse were seen on unscarified **MIXEDWOOD** cutblocks during the summers of Yrs 1–9, but their densities were too low to provide measurable scat densities. On **SPRUCE** cutblocks, grouse abundance increased similarly for both scarified and unscarified cutblocks during Yrs 9–17 and thereafter declined. Declines in grouse abundance on unscarified cutblocks was more drastic and rapid than on scarified cutblocks. Whereas grouse scat were present in moderate densities on scarified cutblocks during Yrs 27–32, they were absent on unscarified cutblocks. Grouse densities on **MIXEDWOOD** cutblocks peaked at Yr 27 for scarified cutblocks and at Yr 32 for unscarified cutblocks. Grouse remained absent on **PINE** cutblocks during Yrs 1-27, then increased during Yrs 27–32, with densities being considerably higher on scarified than unscarified cutblocks. Grouse densities on **PINE** cutblocks declined during Yrs 32–39. By Yr 39, grouse were either absent or in low densities on all forest types and cutblock treatment types. In general, grouse scat was more abundant on scarified cutblocks than on unscarified cutblocks.

Table 20. Mean pellet group counts (#/ha) of deer, elk, moose, and hare in SPRUCE, MIXEDWOOD, and PINE forests; Yrs 1–39 (1955–1995).

	Deer		**Elk**		**Moose**		**Snowshoe Hare***		**Grouse**	
	Scarified	Unscarified	Scarified	Unscarified	Scarified	Unscarified	Scarified	Unscarified	Scarified	Unscarified
SPRUCE										
Yr 1	17	0	17	0	0	17	0	0	0	0
Yr 6	17	32	0	17	17	0	0	0	0	0
Yr 9	30	0	15	15	30	0	0	0	0	0
Yr 17	107	588	53	428	0	0	–	–	53	53
Yr 27	375	162	10	20	0	0	100	160	30	0
Yr 32	160	246	50	28	0	0	8	60	30	0
Yr 39	210	102	58	60	16	8	2	0	8	0
Average	130.9	161.4	29.0	31.1	9.0	3.6	18.3	36.6	17.3	7.6
Mature	24		0		4		0		0	
IXEDWOOD										
Yr 1	0	17	0	0	0	0	0	0	0	0
Yr 6	67	67	300	149	0	17	0	0	0	0
Yr 9	30	45	274	214	75	15	0	0	0	0
Yr 27	0	10	0	40	0	0	0	1,712	50	0
Yr 32	8	46	0	4	0	0	0	2,348	20	90
Yr 39	8	0	0	0	0	0	0	0	0	0
Average	18.8	30.8	95.7	67.8	12.5	5.3	0.0	676.7	11.7	15.0
Mature	92		8		0		0		56	
PINE										
Yr 1	0	0	0	17	17	32	0	0	0	0
Yr 6	0	0	17	32	0	0	0	0	0	0
Yr 9	0	0	0	0	45	75	0	0	0	0
Yr 27	0	80	0	10	40	50	9,683	8,774	0	0
Yr 32	48	138	4	0	18	30	1,172	412	264	82
Yr 39	18	28	4	12	4	20	8	4	12	6
Average	11.0	41.0	4.2	11.8	20.7	34.5	1,810.5	1,531.7	46.0	14.7
ll Forest Types (Averages)										
Yr 1	6	6	6	6	6	16	0	0	0	0
Yr 6	28	33	106	66	6	6	0	0	0	0
Yr 9	20	15	96	76	50	30	0	0	0	0
Yr 27	125	84	3	23	13	17	3,245	3,549	27	0
Yr 32	72	143	18	11	18	10	391	763	104	57
Yr 39	79	43	21	24	7	9	3	1	7	2
Average	55.0	54.0	41.7	34.3	16.7	14.7	606.5	718.8	23.0	9.8

* values for snowshoe hares are pellets/ha rather than pellet groups/ha.

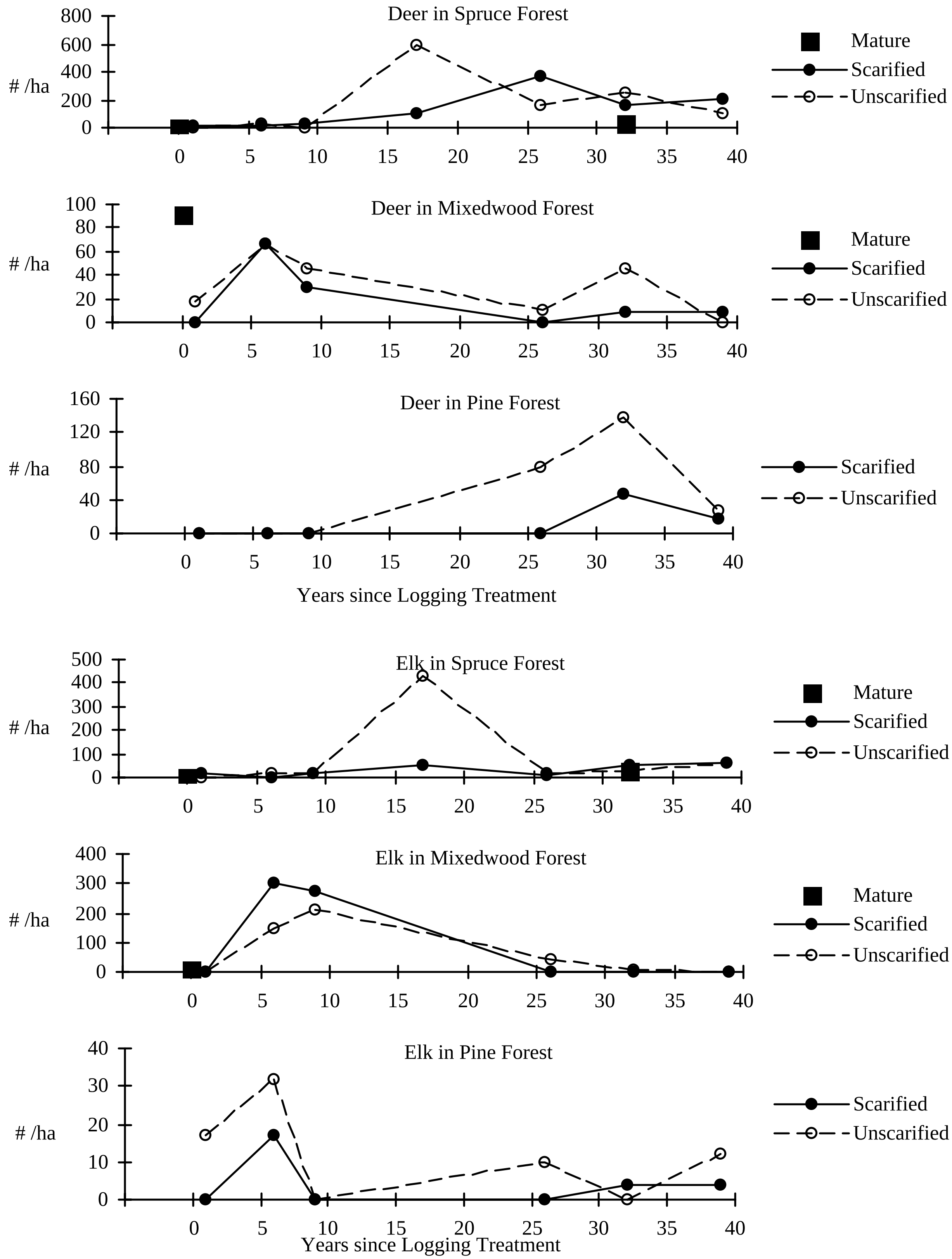


Figure 82. Abundance of deer (above) and elk (below) pellet groups during Yrs 1–39 (1955–1995).

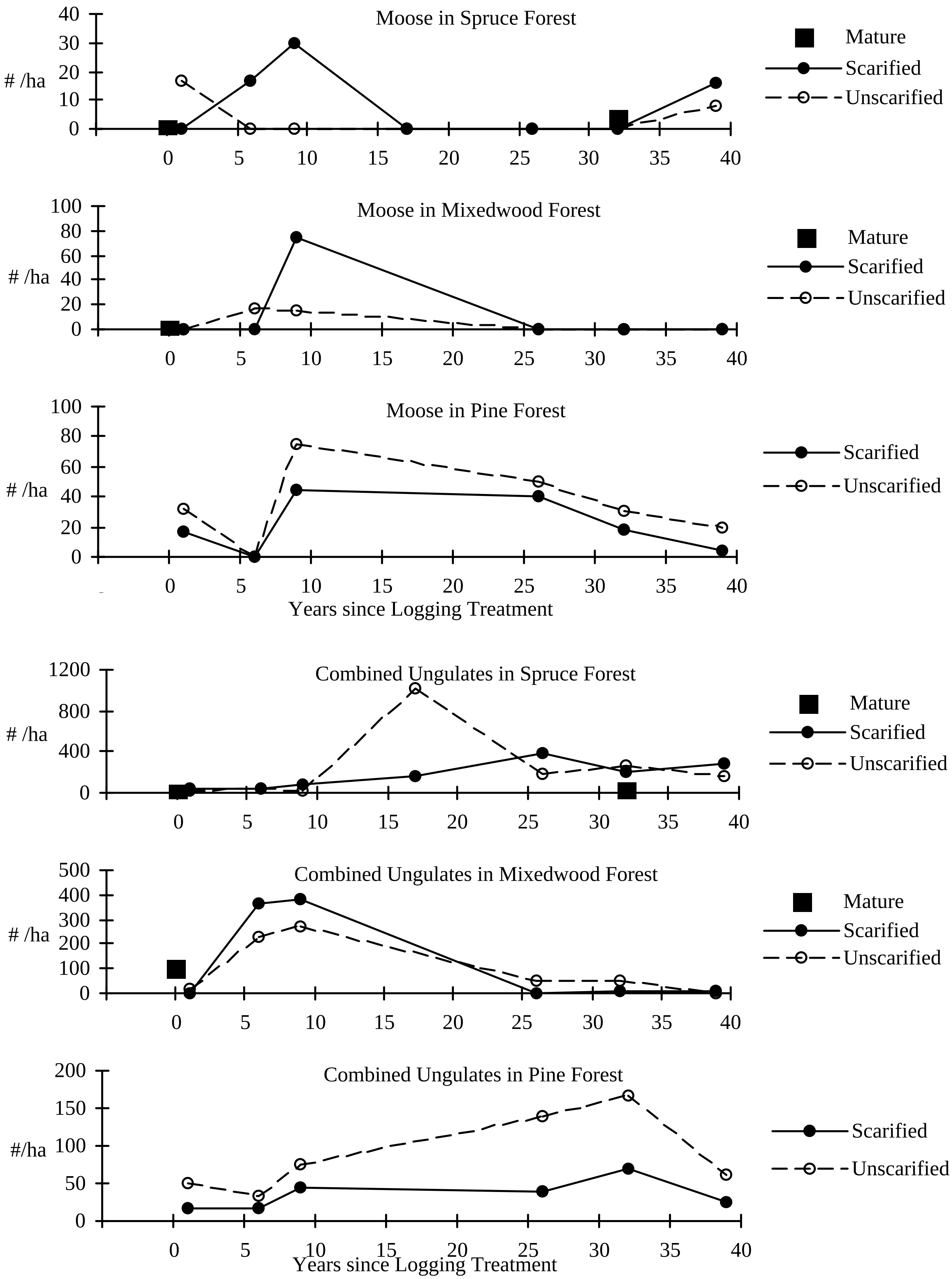


Figure 83. Abundance of moose (above) and combined ungulates (below) pellet groups during Yrs 1–39 (1955–1995).

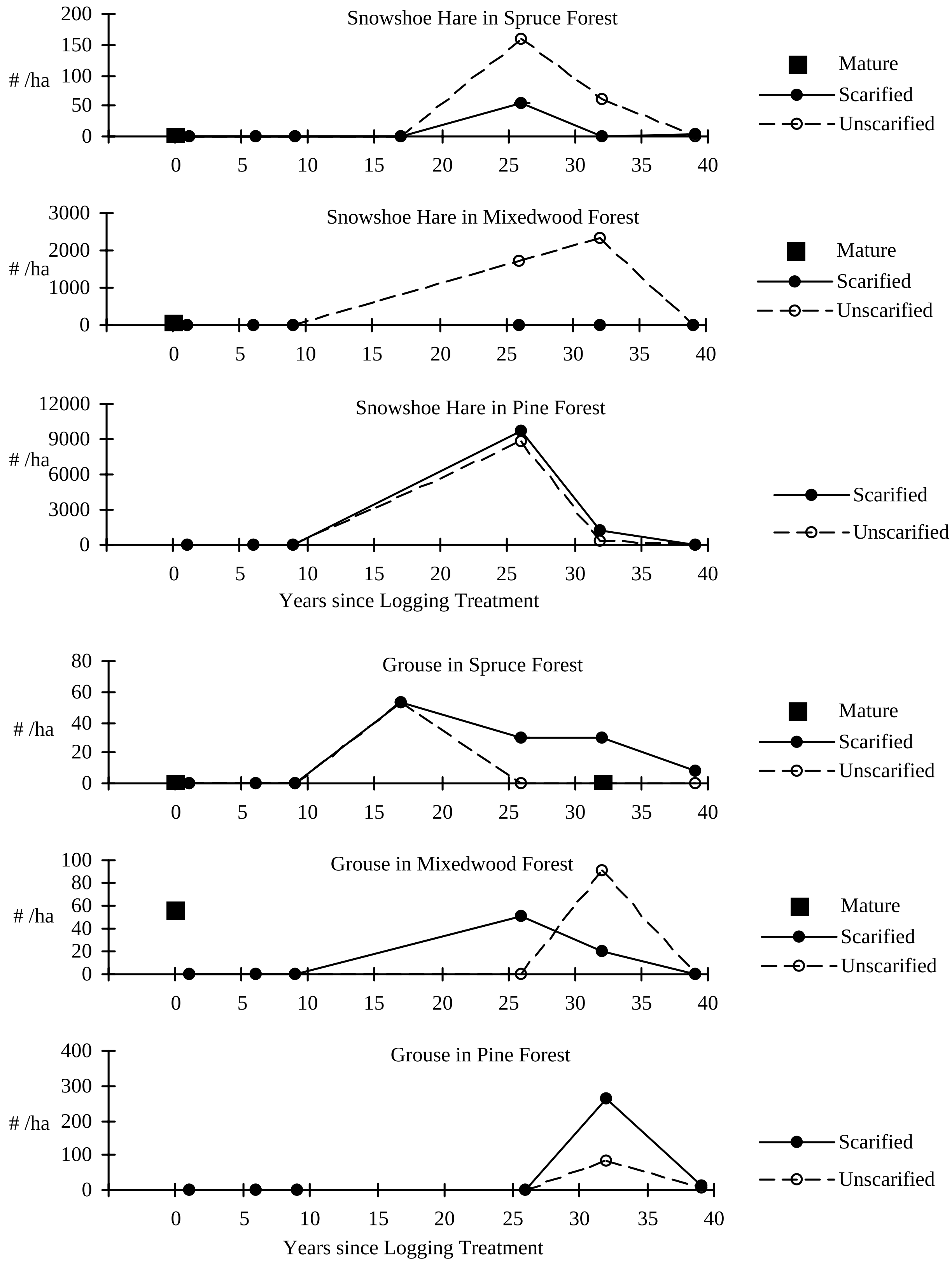


Figure 84. Abundance of snowshoe hare (above) and grouse (below) pellets in Yrs 1–39 (1955–1995).

Direct Observations of Wildlife

This report makes reference to different seral stages of regenerating forest communities. The "grass/forb/seedling" stage refers to data collected during Years 1–15 post-logging, the "pole/sapling" stage refers to Years 16–30 post-logging, and the "young forest" stage refers to Years 31–40 post-logging

<u>Temporal Trends in All Forest Types</u>

Cavity-dwelling birds. Observations of cavity-dwelling birds increased with successional stages, with 0 observations during the grass/forb/seedling stage, 56 observations during the pole/sapling stage, and 61 observations during the young forest stage (Table 21–Table 23). The dominant cavity-dwelling species were northern flicker, red-breasted nuthatch and chickadees.

Grouse. Observations of grouse increased from 18 in the grass/forb/seedling stage to 43 observations during the pole/sapling stage, and declined to 28 observations during the young forest stage (Table 21–Table 23). Ruffed grouse, blue grouse, and spruce grouse were more commonly seen than sharp-tailed grouse. Blue grouse and ruffed grouse were most commonly seen in the younger grass/forb/seedling and pole/sapling stages, whereas spruce grouse were more commonly observed in pole/sapling and the young forest stages.

Combined Birds. Observations of birds increased with successional stages, with 19 observations during the grass/forb/seedling stage, 201 observations during the pole/sapling stage, and 287 observations during the young forest stage (Table 21–Table 23). The most commonly observed species were the yellow-rumped warbler, cedar waxwing, spruce grouse, ruffed grouse, gray jay, dark-eyed junco, northern flicker, white-throated sparrow, black-capped and boreal chickadee.

Furbearers. In comparison to birds, furbearers were infrequently observed on cutblocks with 0 observations during the grass/forb/seedling stage, 7 observations during the pole/sapling stage, and 14 observations during the young forest stage (Table 21). The most commonly observed species was red squirrel; others observed included black bear, coyote and wolf.

<u>Temporal Trends in **SPRUCE** Forest</u>

Cavity-dwelling birds. Observations of cavity-dwelling birds increased with successional stages, with 0 observations during the grass/forb/seedling stage, 4 observations during the pole/sapling stage, and 23 observations during the young forest stage (Table 21). The dominant cavity-dwelling species were northern flicker, red-breasted nuthatch and chickadees.

Grouse. Observations of grouse increased from 7 in the grass/forb/seedling stage to 16 observations during the pole/sapling stage, and declined to 10 observations during the young forest stage (Table 21). Ruffed grouse and blue grouse were relatively commonly seen in comparison to spruce and sharp-tailed grouse. Blue grouse were more commonly observed in the youngest stage (Yrs 1–15), while ruffed grouse were more common during Yrs 16–40.

Combined Birds. Observations of birds increased with successional stages, with 7 observations during the grass/forb/seedling stage, 50 observations during the pole/sapling stage, and 107 observations during the young forest stage (Table 21). The most commonly observed species were white-throated sparrow, cedar waxwing, and yellow-rumped warbler.

Furbearers. Furbearers were seldom observed on the **SPRUCE** cutblocks with 0 observations during the grass/forb/seedling stage, 1 observation during the pole/sapling stage, and 4 observations during the young forest stage (Table 21). The most commonly observed species was red squirrel.

Temporal Trends in **MIXEDWOOD** Forest

Cavity-dwelling birds. Observations of cavity-dwelling birds was highest in the pole/sapling stage (50), followed by the young forest stage (33), and lowest in the grass/forb/seedling stage (0). The dominant cavity-dwelling species were northern flicker, chickadees, yellow-bellied sapsucker, and red-breasted nuthatch.

Grouse. Observations of grouse increased from 8 in the grass/forb/seedling stage to 25 observations during the pole/sapling stage, and declined to 7 observations during the young forest stage (Table 22). Ruffed grouse and spruce grouse were relatively commonly seen in comparison to blue and sharp-tailed grouse. Whereas ruffed grouse were observed in all successional stages of the cutblocks, spruce grouse were only observed in the later stages (Yrs 16–40).

Combined Birds. Observations of birds increased once the forest developed past the herbaceous stage, with 9 observations during the grass/forb/seedling stage, 111 observations during the pole/sapling stage, and 110 observations during the young forest stage (Table 22). The most commonly observed species were northern flicker, chickadees, ruffed grouse, dark-eyed junco, and yellow-rumped warbler.

Furbearers. Furbearers were seldom observed on the **MIXEDWOOD** cutblocks with 0 observations during the grass/forb/seedling stage, 5 observations during the pole/sapling stage, and 8 observations during the young forest stage (Table 22). The most commonly observed species was red squirrel.

Temporal Trends in **PINE** Forest

Cavity-dwelling birds. Observations of cavity-dwelling birds increased with successional stages, with 0 observations during the grass/forb/seedling stage, 2 observations during the pole/sapling stage, and 5 observations during the young forest stage (Table 23). The dominant cavity-dwelling species were chickadees.

Grouse. Observations of grouse varied from 3 in the grass/forb/seedling stage to 2 during the pole/sapling stage and 11 during the young forest stage (Table 23). Sharp-tailed grouse were only observed during Yrs 1–15, spruce grouse during Yrs 31–40, while ruffed grouse were observed during Yrs 16–40.

Combined Birds. Observations of birds increased with successional stages, with 3 observations during the grass/forb/seedling stage, 40 observations during the pole/sapling stage, and 70 observations during the young forest stage (Table 23). The most commonly observed species were spruce grouse, gray jay, dark-eyed junco, and yellow-rumped warbler.

Furbearers. Furbearers were seldom observed on the **PINE** cutblocks with 0 observations during the grass/forb/seedling stage, 1 observation during the pole/sapling stage, and 2 observations during the young forest stage (Table 23). The most commonly observed species was red squirrel.

Cutblock Treatment Effects in All Forest Types

Cavity-dwelling un higher on unscarified (81) than on scarified (36) cutblocks (Table 21–Table 23). *Grouse* observations were higher on scarified (62) than on unscarified cutblocks (27) (Table 21–Table 23). *Combined Bird* observations were higher on unscarified (283) than on scarified (224) cutblocks (Table 21–Table 23). *Furbearers* were observed 6 times on scarified and 15 times on unscarified cutblocks (Table 21–Table 23).

Cutblock Treatment Effects in Spruce Forest

Cavity-dwelling bird observations were higher on unscarified (19) than on scarified (8) cutblocks (Table 21–Table 23). *Grouse* observations were higher on scarified (25) than on unscarified cutblocks (8) (Table 21–Table 23). *Combined Bird* observations were higher on scarified (95) than unscarified (69) cutblocks (Table 21–Table 23). *Furbearers* were observed rarely on unscarified (2) and scarified (3) cutblocks (Table 21–Table 23).

Cutblock Treatment Effects in Mixedwood Forest

Cavity-dwelling bird observations were higher on unscarified (62) than on scarified (21) cutblocks (Table 21–Table 23). *Grouse* observations were similar on scarified (21) and unscarified cutblocks (19) (Table 21–Table 23). *Combined Bird* observations were higher on unscarified (159) than on unscarified (71) cutblocks (Table 21–Table 23). *Furbearers* were observed two times on scarified and 11 times on unscarified cutblocks (Table 21–Table 23).

Cutblock Treatment Effects in Pine Forest

Cavity-dwelling bird observations were higher on scarified (7) than on unscarified (0) cutblocks (Table 21–Table 23). *Grouse* observations were higher on scarified (16) than on unscarified cutblocks (0) (Table 21–Table 23). *Combined Bird* observations were similar on scarified (58) and unscarified (55) cutblocks (Table 21–Table 23). *Furbearers* were observed 0 times on scarified and 1 time on unscarified cutblocks (Table 21–Table 23).

Comparison of Mature Forests and Cutblock Treatment at Yr 32

Comparison of observations and taxonomic richness of birds in Yr 32 on scarified and unscarified cutblocks and in unharvested mature forests indicates that regenerating **SPRUCE** and **MIXEDWOOD** cutblocks had greater numbers of birds and greater taxonomic diversity than did unharvested mature forests (Table 24). Cutblock treatment did not appear to have a major influence on taxonomic richness on **SPRUCE**, **MIXEDWOOD**, or **PINE** regenerating cutblocks, while bird observations were more frequent on unscarified than scarified **MIXEDWOOD** cutblocks and higher on scarified than unscarified **PINE** cutblocks.

Table 21. Observations (# /standardized time unit) of selected wildlife species following clearcut logging of SPRUCE forests; Yrs 1–39 (1955–1995). Higher abundances on scarified (S) or unscarified (U) forests noted where observations >0 and the difference >20%.

	SPRUCE Scarified				**SPRUCE Unscarified**		
	Grass/Forb/ Seedling Stage (Yr 1–15)	Pole/Sapling Stage (Yr 16–30)	Young Forest Stage (Yr 31–40)	comparison of scarified and unscarified cutblocks	Grass/Forb/ Seedling Stage (Yr 1–15)	Pole/Sapling Stage (Yr 16–30)	Young Forest Stage (Yr 31–40)
Tree cavity-dwelling birds							
northern flicker	0	1	2	U	0	0	9
yellow-bellied sapsucker	0	0	0		0	0	0
pileated woodpecker	0	0	0		0	0	0
kestrel	0	0	0		0	0	0
hawk owl	0	0	0	U	0	0	1
black-capped/boreal chickadee	0	2	1	U	0	0	4
red-breasted nuthatch	0	1	1	U	0	0	3
mountain bluebird	0	0	0	U	0	0	2
starling	0	0	0		0	0	0
subtotal	0	4	4		0	0	19
Grouse							
ruffed grouse	0	9	3	S	0	2	5
spruce grouse	0	1	0		0	1	0
blue grouse	7	3	0	S	0	0	0
sharp-tailed grouse	0	0	2	S	0	0	0
subtotal	7	13	5		0	3	5
Other Birds							
merlin hawk	0	0	0		0	0	0
sharp-shinned hawk	0	0	0		0	0	0
northern goshawk	0	0	0		0	0	0
common snipe	0	0	0		0	1	0
upland sandpiper	0	0	0	U	0	2	0
cedar waxwing	0	0	16	S	0	4	0
red crossbill	0	0	0		0	0	0
common nighthawk	0	2	0	S	0	0	0
gray jay	0	0	2	U	0	2	2
dark-eyed junco	0	6	9		0	8	8
yellow-rumped warbler	0	1	0	U	0	1	12
white-throated sparrow	0	0	24	S	0	0	1
white-crowned sparrow	0	2	0	S	0	1	0
subtotal	0	11	51		0	19	23
Furbearers							
red squirrel	0	0	1	U	0	1	2
lynx	0	0	0		0	0	0
marten	0	0	0		0	0	0
bear (black/grizzly)	0	0	0		0	0	0
coyote/fox	0	0	0		0	0	0
wolf	0	0	1		0	0	0
subtotal	0	0	2		0	1	2
Cumulative Count	**7**	**28**	**62**		**0**	**23**	**49**

Table 22. Observations of selected wildlife species following clearcut logging of **MIXEDWOOD** forests; Yrs 1–39 (1955–1995). Higher abundances on scarified (S) or unscarified (U) forests are noted where observations >0 and the difference >20%.

	MIXEDWOOD Scarified				**MIXEDWOOD Unscarified**		
	Grass/Forb/ Seedling Stage (Yr 1–15)	Pole/Sapling Stage (Yr 16–30)	Young Forest Stage (Yr 31–40)	comparison of scarified and unscarified cutblocks	Grass/Forb/ Seedling Stage (Yr 1–15)	Pole/Sapling Stage (Yr 16–30)	Young Forest Stage (Yr 31–40)
Tree cavity-dwelling birds							
northern flicker	0	0	5	U	0	9	2
yellow-bellied sapsucker	0	0	0	U	0	7	0
pileated woodpecker	0	0	1	U	0	0	3
kestrel	0	6	0		0	4	1
hawk owl	0	0	0		0	0	0
black-capped/boreal chickadee	0	2	1	U	0	22	8
red-breasted nuthatch	0	0	1	U	0	0	5
white-breasted nuthatch	0	0	0		0	0	1
mountain bluebird	0	0	2	S	0	0	0
starling	0	0	3	S	0	0	0
subtotal	0	8	13		0	42	20
Grouse							
ruffed grouse	0	20	0	S	8	0	2
spruce grouse	0	0	0	U	0	4	2
blue grouse	0	0	0		0	0	0
sharp-tailed grouse	0	0	1	U	0	1	2
subtotal	0	20	1		8	5	6
Other Birds							
merlin hawk	0	0	0	U	0	6	2
sharp-shinned hawk	0	0	0		0	1	0
northern goshawk	0	0	0	U	0	3	0
common snipe	0	0	0		0	0	0
upland sandpiper	0	0	0		0	0	0
cedar waxwing	0	0	0	U	0	2	0
red crossbill	0	0	1	U	0	0	2
common nighthawk	0	3	1	S	1	1	0
gray jay	0	0	0	U	0	4	4
dark-eyed junco	0	5	15		0	4	18
yellow-rumped warbler	0	0	1	U	0	7	19
white-throated sparrow	0	0	3	U	0	0	4
white-crowned sparrow	0	0	0		0	0	0
subtotal	0	8	21		1	28	49
Furbearers							
red squirrel	0	1	0	U	0	4	7
lynx	0	0	0		0	0	0
marten	0	0	0		0	0	0
bear (black/grizzly)	0	0	1		0	0	0
coyote/fox	0	0	0		0	0	0
wolf	0	0	0		0	0	0
subtotal	0	1	1		0	4	7
Cumulative Count	**0**	**37**	**36**		**9**	**79**	**82**

Table 23. Observations of selected wildlife species following clearcut logging of PINE forests; Yrs 1–39 (1955–1995). Higher abundances on scarified (S) or unscarified (U) forests are noted where observations >0 and the difference >20%.

	PINE Scarified				PINE Unscarified		
	Grass/Forb/ Seedling Stage (Yr 1–15)	Pole/Sapling Stage (Yr 16–30)	Young Forest Stage (Yr 31–40)	comparison of scarified and unscarified cutblocks	Grass/Forb/ Seedling Stage (Yr 1–15)	Pole/Sapling Stage (Yr 16–30)	Young Forest Stage (Yr 31–40)
Tree cavity-dwelling birds							
northern flicker	0	0	0		0	0	0
yellow-bellied sapsucker	0	0	0		0	0	0
pileated woodpecker	0	0	1		0	0	0
kestrel	0	0	1		0	0	0
hawk owl	0	0	0		0	0	0
black-capped/boreal chickadee	0	2	2	S	0	0	0
red-breasted nuthatch	0	0	1		0	0	0
mountain bluebird	0	0	0		0	0	0
starling	0	0	0		0	0	0
subtotal	0	2	5		0	0	0
Grouse							
ruffed grouse	0	2	1	S	0	0	0
spruce grouse	0	0	10	S	0	0	0
blue grouse	0	0	0		0	0	0
sharp-tailed grouse	3	0	0	S	0	0	0
subtotal	3	2	11		0	0	0
Other Birds							
merlin hawk	0	0	0		0	0	0
sharp-shinned hawk	0	0	0		0	0	0
northern goshawk	0	0	1		0	0	0
common snipe	0	0	0		0	1	0
upland sandpiper	0	0	0		0	0	0
cedar waxwing	0	0	0		0	0	0
red crossbill	0	0	0		0	0	0
common nighthawk	0	0	0		0	0	0
gray jay	0	4	4	U	0	2	26
dark-eyed junco	0	6	10	U	0	16	6
yellow-rumped warbler	0	7	3	S	0	1	4
white-throated sparrow	0	0	0		0	0	0
white-crowned sparrow	0	0	0		0	0	0
subtotal	0	17	18		0	19	36
Furbearers							
red squirrel	0	0	1		0	0	1
lynx	0	0	0		0	0	0
marten	0	0	0		0	0	0
bear (black/grizzly)	0	1	0		0	0	0
coyote/fox	0	0	0		0	0	0
wolf	0	0	0		0	0	0
subtotal	0	1	1		0	0	1
Cumulative Count	**3**	**22**	**34**		**0**	**19**	**37**

Table 24. Comparison of bird observations in mature forests and cutblocks that are 32 years old.

	SPRUCE Forest			**MIXEDWOOD Forest**			**PINE Forest**	
Taxal Groups	Mature	Scarified	nscarified	Mature	Scarified	nscarified	Scarified	nscarified
Flycatchers	0	6	2	0	3	0	5	0
Chickadees	0	0	4	0	1	8	2	12
Thrushes	0	34	16	1	29	25	18	30
Bluebirds	0	0	0	0	2	0	0	0
Warblers	1	4	12	3	2	20	9	20
Vireos	0	1	0	0	0	0	6	4
Waxwings	0	12	0	0	0	0	0	0
Corvids	6	2	5	0	0	1	2	20
Sparrows	0	9	7	2	9	43	1	4
Finches, Siskins	0	5	0	2	5	27	0	4
Juncos	1	6	7	1	5	16	5	6
Nuthatches	2	1	2	5	1	5	4	1
Kinglets	0	1	1	0	0	2	3	8
Woodpeckers	0	1	3	3	6	14	0	6
Grouse	0	8	0	1	0	8	9	23
Hawks	0	0	0	1	1	0	2	2
Other Birds Species	0	4	22	0	2	7	9	10
Total Observations	10	94	81	19	66	176	261	150
# Taxal Groups Seen	4	13	10	9	12	11	15	13

Table 25. Comparison of attributes following cutblock treatment in each forest type at the conclusion of the study; Yr 40. + or – denote difference greater than or equal to 20%. For ungulate, hare, and grouse abundance both Yr 32 and Yr 39 data were used to increase sample size.

Attribute	SPRUCE		MIXEDWOOD		PINE	
	Scarified	Unscarified	Scarified	Unscarified	Scarified	Unscarified
Plant Species Richness						
Total Spp.	=	=	+	–	+	–
Forbs	=	=	+	–	+	–
Graminoids	=	=	+	–	=	=
Non-Woody Spp.	=	=	+	–	+	–
Shrubs	=	=	=	=	=	=
Woody Spp.	=	=	=	=	=	=
Ground Cover						
Graminoid Cover	=	=	+	–	+	–
Forb Cover	=	=	+	–	=	=
Dwarf Shrub Cover	=	=	+	–	+	–
Moss Cover	=	=	–	+	=	=
Total Ground Cover	=	=	=	=	=	=
Spruce density						
Total	+	–	–	+	–	+
Seedling	+	–	–	+	–	+
Sapling	+	–	–	+	–	+
Subcanopy	–	+	–	+	–	+
Canopy	–	+	–	+	–	+
Aspen density						
Total	+	–	+	–	=	=
Seedling	+	–	+	–	–	+
Sapling	+	–	+	–	–	+
Subcanopy	=	=	+	–	+	–
Canopy	=	=	=	=	+	–
Pine density						
Total	=	=	=	=	=	=
Seedling	=	=	+	–	–	+
Sapling	=	=	+	–	–	+
Subcanopy	=	=	+	–	=	=
Canopy	=	=	–	+	–	+
Snag density	–	+	=	=	–	+
Snag Cavities	–	+	–	+	–	+
Understory Visibility						
low stratum	=	=	+	–	=	=
medium stratum	=	=	+	–	=	=
high stratum	=	=	+	–	=	=
Cavity-dependent Birds	–	+	–	+	+	–
Grouse	=	=	–	+	+	–
Moose	+	–	=	=	–	+
Deer	+	–	+	–	–	+
Elk	=	=	–	+	–	+
Hare	–	+	–	+	+	–
Browse Availability	–	+	+	–	+	–
Browse Use	=	=	–	+	=	=

DISCUSSION

Successional Patterns in Forest Structure

Several similar temporal trends in plant community structure were exhibited in each forest type (**SPRUCE, MIXEDWOOD**, **PINE**) during the 1st four decades following logging treatment. These patterns reflect the mechanisms by which forest communities respond to disturbance events that re-initiate succession.

The most acute change caused by clearcut logging was the complete, or near complete, removal of the forest canopy and the significant changes its removal caused to physical and meteorological conditions on the forest floor. The loss of the overstory trees would have lead to significant changes in levels of incoming solar radiation, precipitation and wind at the forest floor (Oke 1987). In general, graminoid plants (primarily grasses) responded with sexual and asexual reproduction and rapidly increased their ground cover from ~5-10% to 50–70% during Yrs 0–6. Forbs responded similarly, though lagging behind graminoids by 5 years and achieved cover levels of 20–50%. Dwarf shrubs and shrub species responded more slowly than did herbaceous species and gradually increased during Yrs 1–26. As shrubs and tree saplings became a more conspicuous feature of regenerating cutblocks, graminoid and forb cover decreased during Yrs 6–26, presumably in response to competition for space, light, and nutrients. Graminoid cover levels did not change appreciably during Yrs 26–39 and remained at moderate levels of 20–40%. In contrast to graminoids, forb cover values recovered upwards during Yrs 26–39 to levels of ~30–60%. Mosses were first observed in measurable abundances in Yr 26 and thereafter increased in all forest types. This plant group is apparently poorly suited to young cutblocks whose canopy is open and whose forest floor is dominated by graminoids and forbs. An alternative hypothesis is that moss species await down wood to achieve advanced rot classes which in turn provide suitable substrate for these species (Maser and Trappe 1984).

When all ground cover species (grasses, forbs, rushes, sedges, dwarf shrubs) were combined, a clear and similar temporal pattern was observed in each forest type. Ground cover increased rapidly during Yrs 1–6, declined during Yrs 6–26, then increased during Yrs 26–39. It is likely that the initial pulse was caused by a resource-rich environment with minimal competition, the declining phase was likely in response to competition with overtopping shrubs and saplings, and the recovery phase (Yrs 26–39) related to the formation of a forest canopy whose trees belonged to a different height strata than those of herbaceous ground plants.

Roberts and Gilliam (1995), in reviewing a model of species diversity proposed by Peet and Christensen (1988), suggested that plant species richness starts low following a disturbance event, builds quickly during the establishment phase of forests, remains stable, then declines as emerging trees experience the thinning phase. In the transition between developing and mature forests, species richness would rise again. Finally, the model proposes two possible outcomes: either total richness increases to an equilibrium value, or peaks and then declines back to the equilibrium level.

In this study, plant species richness increased with seral stage in the **SPRUCE** cutblocks (Yrs 4–39) and in all **MIXEDWOOD** and **PINE** cutblocks during Yrs 26–39 except unscarified **MIXEDWOOD** cutblocks whose species richness remained stable. Species richness (average of the total per sample) increased slowly over Yrs 0–6, increased to much higher levels by Yrs 26-32, and then leveled off or decreased. This result applies to both the

SPRUCE and **MIXEDWOOD** forest stands. In contrast, the **PINE** forest was still showing steady increases in species richness during Yrs 26-39.

In all forest types, forbs contained the highest species richness, generally followed by graminoids, shrubs, trees and dwarf shrubs. In **SPRUCE** cutblocks, where the re-sampling interval was shortest, species richness on cutblocks exceeded that of mature (~135 yrs old) unharvested forests by Yr 6. In general, patterns in diversity indices (Shannon, Simpson) exhibited similar temporal patterns reflecting the arrival of new species following harvest and a progressive change to a more equitable distribution of individual plants among species.

Trends in diversity and species richness demonstrated in this study are generally consistent with a study in the Pacific Northwest Region of the United States. Halpern and Spies (1995) present data on species richness on two sites in Oregon measured prior to cutting (~120 year old forest), and remeasured annually during the next 25 years. They showed that richness following logging was initially low; then either declined slightly or did not increase immediately following disturbance; then increased during Yrs 5–20 in an inconsistent manner, until richness was double initial levels, then stabilized. Although part of the increase in species richness was attributed to the arrival of exotic species, these did not account for a significant proportion of the new species. The largest contributing component of new species richness was attributed to native invading species. Species present in the forest prior to logging remained relatively constant over time. The invading species, though important for overall sample richness, began to decline in cover contribution and plot richness at ~Yr 15. Their results suggests that the post-logged forest was beginning to revert to its pre-harvest richness level as early as 15 years post disturbance. Ehnes and Shay (1995) also showed increases in plant species richness between Yrs 13–37 in both pyrogenic and logged boreal forest communities in Manitoba.

Important differences in the observed patterns of species richness occurred between non-woody and woody species in this study. Non-woody species appeared to be dominating the overall trend in species richness, particularly graminoids, and secondarily, forbs. Tree species remained relatively constant over time, and shrubs fluctuated by ~ 2 species except in **SPRUCE** cutblocks where they increased by 4–5 species since the first measurement period.

Several prominent species that initially invaded cutblocks were exotic grasses and forbs such as timothy, smooth brome, and white clover. These species, however, seemed to be minor in comparison to the increase in native species, which is similar to the results of Halpern and Spies (1995). If the model of Peet and Christensen applies to our cutblocks, species richness should decline as the forest canopy “fills in” during the next 10–30 years and assume values similar to that of the mature forest.

The mature unharvested forest increased in plant species richness as it advanced from 135 years to 170 years, following a trend similar to that documented by Lee *et al.* (1995) in aspen/spruce mixedwoods in east-central Alberta. Most of this increase was due to new arrivals of forb species. The arrival of these species might be related to an increase in the regional floristic composition of the forest landscape caused by logging events in the 1950’s–1980’s. Whereas the pre-logging era landscape was relatively homogenous and dominated by mature conifer communities, logging created a more heterogeneous landscape in terms of stand age and composition. Since the onset of the logging era in the Hinton region, the forest landscape has become highly fragmented, leaving mature forest patches surrounded by younger disturbed areas from which invading plant species are likely to invade. An alternative explanation for the increase in species richness of the unharvested **SPRUCE** mature forest between Yrs 5 (135 year-old forest) and Yr 40 (170 year-old forest) involves the role of gap dynamics and the resulting increase in structural complexity of the stand as it undergoes “break-up” (Lee *et al.* 1995). Increasing frequency of canopy gaps in the 170-old mature forest would be associated with an increasing number of invading herbaceous and shrub species associated with the small meadows predictively found beneath canopy gaps. Some of the change in species richness may reflect better identification as the study proceeded, but this would likely be a minor component since forbs are driving the change and are easily identified.

Does Cutblock Scarification Improve Conifer Regeneration?

The primary motivation behind scarifying cutblocks is to enhance the probability of establishment and subsequent growth of conifers (either spruce or pine). Without successful regeneration of harvested cutblocks by conifers, the outcomes of growth and yield models based on minimal regeneration lags will over-estimate volume growth and not accurately predict when individual stands acquire sufficient conifer volume to warrant the next harvest event. The study described in this report allows the objective evaluation of whether scarification offers a conifer response advantage in comparison to similar cutblocks that were not scarified.

Regenerating SPRUCE Cutblocks

The potential for scarified **SPRUCE** cutblocks to regenerate conifers should have been enhanced by aerial seeding of white spruce during Yr 3. Unlike scarified cutblocks, unscarified cutblocks were not given any site preparation or treated with aerial seeding. The general response of white spruce during the 1^{st} four decades following logging on scarified cutblocks was favorable in terms of density (Figure 20), but most of these conifers had, by the study conclusion, developed only to sapling height. At Yr 26, the percent of 0.89 m^2 plots that had at least one spruce was 24% for scarified and 27% for unscarified cutblocks (Stelfox 1988). Height growth rates, in contrast, were higher on the unscarified cutblocks. By the conclusion of the study, densities of white spruce of canopy or subcanopy height were higher on the unscarified cutblocks, although the difference was narrowing. The relative inability of the young white spruce on scarified cutblocks to establish good height growth is likely related to competition for light, moisture, and space associated with higher densities of suckering *Populus* spp. and possible loss of topsoil associated with blading of the ground. Establishment and survival of spruce seedlings on the unscarified cutblocks was likely assisted by availability of down wood of suitable rot classes for germination substrate and by those seedlings left undisturbed by the absence of a site treatment event. During later stages of post-harvest development (Yrs 32–39), young white spruce seedlings were becoming abundant in the understory of the scarified cutblocks, and many of these seedlings were establishing on down woody material of advanced rot class (John Stelfox, personal communication).

Given current tree demographic profiles seen on **SPRUCE** cutblocks, scarified cutblocks are lagging in volume growth in comparison to unscarified cutblocks. Whereas densities of seedling and sapling spruce are reasonable on scarified cutblocks, there is poor recruitment of sapling trees into the subcanopy height class. Even if recruitment levels from sapling to subcanopy strata were to improve immediately on scarified cutblocks, it is likely that rotation ages of scarified cutblocks will be a decade or longer than required on unscarified cutblocks.

From a forest management perspective, the costs of site preparation and aerial seeding made the scarified cutblocks an expensive alternative to the unscarified cutblocks. By the end of four decades following logging, there was no evidence of improved conifer regeneration on scarified cutblocks. Rather, unscarified cutblocks possessed higher densities of both canopy and subcanopy trees. These patterns suggest that clearcut logging followed by scarification may not be a favorable forest management strategy for conifer production of **SPRUCE** sites of similar physiography and structure.

Regenerating MIXEDWOOD Cutblocks

The potential for scarified **MIXEDWOOD** cutblocks to regenerate conifers should have been enhanced by repeated planting of white spruce container seedlings, and periodic plantings of pine seedlings during the 1st decade following the logging treatment. Unlike scarified cutblocks, unscarified cutblocks were not given any site preparation or planted with seedlings. In comparisons to unscarified cutblocks, the establishment and growth rate of white spruce during the 1st four decades following logging on scarified cutblocks was strikingly inferior. At Yr 26, the percent of 0.89 m^2 plots on scarified and unscarified cutblocks that had at least one spruce was 8% and 25%, respectively (Stelfox 1988). An examination of temporal patterns in density of different height classes of white spruce on scarified **MIXEDWOOD** cutblocks between Yrs 32 and 39 indicated that high levels of mortality were occurring for trees of subcanopy and sapling height and that recruitment into the taller strata was minimal. In contrast, survivorship of canopy, subcanopy, sapling and seedling spruce on unscarified cutblocks was comparatively high. By the conclusion of the study, unscarified cutblocks exhibited higher cover and densities of canopy, subcanopy, sapling, and seedling spruce than found on scarified cutblocks. The poor performance and higher mortality rates of white spruce seedlings on scarified **MIXEDWOOD** cutblocks was partially attributed to frost damage associated with cutblocks with no residual trees (Des Crosley, Chief Forester, Northwest Pulp and Power, personal communication). Relative to the unscarified cutblocks, the low volume of vegetation in the form of shrubs and trees in the scarified cutblocks would have concentrated incoming solar radiation at or near the ground surface during the day, and these scarified cutblocks would have experienced a faster rate of longwave radiation loss at night. Collectively, these processes would have lead to hotter daytime and colder nighttime ambient temperatures on scarified cutblocks, which could have lead to higher incidences of frost-related or heat-related mortality. Another factor that might have contributed to higher mortality of spruce seedlings on scarified cutblocks was higher levels of competition for space, nutrients, and light associated with higher densities of trembling aspen.

Unlike the planted white spruce seedlings, the planted pine seedlings exhibited reasonable survivorship and had advanced into the sapling and subcanopy strata by the conclusion of the study. Pine densities were expectedly lower on the unscarified cutblock, as these blocks had sparse unharvested residual pine trees and had not received plantings of pine seedlings.

From a forest management perspective, the costs of site preparation and container planting made the scarified cutblocks an expensive alternative to the unscarified cutblocks. By the end of four decades following logging, there was clear evidence of inferior conifer regeneration on scarified cutblocks in comparison to unscarified cutblocks. Relatively low densities and high mortality rates of spruce of seedling, sapling, subcanopy and canopy height strata on scarified cutblocks demonstrate a clear need by forest managers to place these stands on an extended rotation. Given current tree demographic profiles seen on **MIXEDWOOD** cutblocks, scarified cutblocks are lagging significantly in volume growth in comparison to unscarified cutblocks, and are therefore likely to have a functional rotation that is two decades or longer than required on unscarified cutblocks.

The patterns described above suggest that clearcut logging followed by scarification may not be a favorable forest management strategy for conifer production of **MIXEDWOOD** sites of similar physiography, composition, and structure.

Regenerating PINE Cutblocks

The potential for scarified and unscarified **PINE** cutblocks to regenerate conifers should have been enhanced by planting of pine seedlings following the logging treatment. Density and height growth rate of pine on scarified cutblocks during the two decades following logging on scarified cutblocks was higher than on unscarified cutblocks. At the conclusion of the study (Yr 39), however, densities of canopy (~900/ha) and subcanopy (~350/ha) pine were similar on both cutblock treatment groups. The convergence in response of the two cutblock treatments occurred during Yrs 26–32 when mortality rates of pine on scarified cutblocks were significantly higher than those on unscarified cutblocks. Higher pine mortality on scarified cutblocks was attributed to debarking caused by snowshoe hare, whose higher density on scarified cutblocks was associated with abundant forage and concealment cover in the form of dense willow and alder. An examination of temporal patterns in density of different height classes of pine on scarified and unscarified **PINE** cutblocks between Yrs 32 and 39 indicated that survivorship levels of subcanopy trees were high and that most had advanced into the canopy height class.

In contrast to the similar abundance of pine trees on scarified and unscarified **PINE** cutblocks at the conclusion of the study, the pattern for white spruce illustrated an advantage of unscarified cutblocks. During Yrs 32 and 39, densities of white spruce of seedling, sapling, subcanopy and canopy height were greater in the unscarified than scarified cutblocks. This difference might be attributed to the retention of spruce trees of seed-bearing age on the unscarified cutblocks, and the improved growth environment for spruce seedlings beneath the incomplete canopy left standing after logging.

From a forest management perspective, the costs of site preparation made scarified cutblocks an expensive alternative to unscarified cutblocks. By the end of four decades following logging, there was no evidence of superior pine regeneration on scarified cutblocks in comparison to unscarified cutblocks. Rather, densities of canopy and subcanopy trees were similar and the unscarified cutblocks possessed higher densities of young pine trees. In addition, the unscarified **PINE** cutblocks supported significantly higher volumes of white spruce than did the scarified sites. These patterns suggest that clearcut logging followed by scarification may not be a favorable forest management strategy for conifer production of **PINE** sites of similar physiography and structure.

Does Cutblock Scarification Alter Plant Community Structure and Wildlife Habitat?

As society becomes more aware of the importance of appropriate plant community structure to maintaining ecological function and populations of biota in forest ecosystems, so does the need by forest managers to evaluate the consequences of different harvest and regeneration strategies on variables other than fiber growth and tree canopy composition. This section compares forest structure during four decades of post-harvest succession on scarified and unscarified cutblocks with specific attention to availability of forest elements (winter thermal shelter, security cover, forage) known to be important to wildlife habitat.

Mammals and birds occupying temperate latitudes during winter months must minimize heat loss from their bodies if they are to survive (Gates and Hudson 1979, Stalmaster and Gessman 1984). For wildlife species that remain supranivean during winter months, conifers frequently provide an important shield to heat loss by absorbing and reradiating longwave radiation emanating from the bodies of animals bedded beneath or within (Keay and Peek, 1980; Mooty et al. 1987). By blocking winds with their boughs and stems, conifers can reduce wind speed at or near the forest floor, and can thereby reduce convective heat loss from the body surface of animals. For example, a study by Thomas *et al.* (1979) in the Blue Mountains of Oregon and Washington showed that crown closures of 75% of pole-size conifers (2 m+) are minimal requirements for overwinter thermal protection for deer and elk.

Security (or hiding) cover offers animals an opportunity to remain concealed from predators while foraging, moving, or bedding, or affords concealment to predators that are seeking prey. Numerous studies have shown that wildlife species are unable to use habitats that possess reasonable forage and climate if security cover is inadequate (Telfer 1970, Kearney and Gilbert 1976).

Quantity and quality of forage is a critical factor influencing distribution and behaviour of wildlife (for review see Renecker and Hudson 1993). In many forest communities, forage may be more of a limiting factor than thermal or security cover, since common forage groups (forbs, grasses, shrubs) are constrained in quantity by the competitive influences that a forest canopy creates in terms of competition for space, light, moisture and nutrients. Disturbance events such as fire or logging reset the successional clock and allow for a flush of herbaceous vegetation during early seral stages. The intensity, timing, and spatial pattern of the perturbation can vary, however, and the interactions of these variables will, in large part, determine the availability, quality, and persistence of forage available to herbivores.

Regenerating SPRUCE Cutblocks

During the early stages of post-logging succession (Yrs 1–32), conifer height and density on regenerating cutblocks were inadequate to provide suitable thermal protection for many wildlife species. During Yrs 1–12, however, the intervening unharvested mature **SPRUCE** blocks provided proximal thermal protection. By the conclusion of the study (Yr 39), mature unharvested spruce forests had conifer covers at heights of 2+, 6+ and 10+ m of 59, 49 and 34%, respectively. In contrast, conifer covers on regenerating cutblocks at similar heights were 27, 18 and 10% on unscarified cutblocks and 12, 5, and 0.8% on scarified cutblocks. Accordingly, thermal cover was highest on mature unharvested spruce forest, followed by unscarified cutblocks, and lowest on scarified cutblocks. These results indicate that 4 decades of post-logging succession does not enable clearcut cutblocks to regenerate thermal cover equal to that found in unharvested mature **SPRUCE** forests. The higher conifer cover values found in unharvested mature **SPRUCE** forests presumably afforded higher levels of thermal protection against cold weather than that found on regenerating cutblocks. Within **SPRUCE** cutblocks, thermal protection available on unscarified cutblocks was considerably higher than that found on scarified cutblocks. During Yrs 1–12, scarified and unscarified cutblocks were adjacent to unharvested **SPRUCE** residual blocks and were observed (Stelfox, personal observation) to be used extensively by selected wildlife (cervids, furbearers) because of their high thermal and security cover values. These residual conifer blocks were removed during the 2^{nd} pass logging event (Yrs 12–13), and this event removed the favorable juxtaposition of browse (cutblock) and protection (residual block) habitat.

The amount of structural complexity (herbaceous vegetation, shrubs, down wood, tree boles) in the understory of the regenerating cutblock is an important component of security cover and for providing appropriate substrate for such purposes as nesting, resting, and foraging. At the conclusion of the study (Yrs 32–39), understory visibility was similar in mature forests and cutblocks (both scarified and unscarified) at the height strata of 0–0.5, 0.5–1.5 and 1.5—2.5 m. Presumably, any differences in wildlife abundance between these three forest types would not be explained readily by this general index of security cover.

The process of transforming a mature spruce forest into a young regenerating cutblock precipitated a rapid flush in browse biomass production. Production levels peaked earlier on unscarified cutblocks (Yr 17) than on scarified cutblocks (Yr 26), presumably because the regenerating tree cohort was advanced and taller on unscarified cutblocks and was therefore competing for resources with the browse species below. During Yrs 32–39, browse production was declining quickly on both cutblock treatments, and this trend is attributed to the inability of shrubs to compete with a forest canopy that was "filling in" and to the loss of "browse" trees as they grew beyond the upper browse height (2.5 m). During the early years of the study (Yrs 1–17), browse production was consistently higher on the unscarified than on the scarified cutblocks. It is unclear why this difference existed, but it is likely that the process of site scarification damaged or destroyed some of the below-ground root systems of shrubs and they were unable to respond as quickly as those on the unscarified site. One might have expected browse biomass to actually be lower on the unscarified cutblocks because of their higher level of browse use (see discussion below), but such was not the case. It is possible that some level of browsing intensity might stimulate subsequent browse production. During the later stages of the study (Yrs 26–39) no obvious difference in browse production was observed between cutblock treatments, indicating that convergence had occurred and that the differences caused by the initial site preparation event were transitional.

Snags are an important physical component of forests as they offer substrate for various cryptogram plants, provide cavities for numerous biota and are the recruitment source for down wood and ultimately ground litter and soil organics (Maser and Trappe 1984). By the conclusion of the study (Yrs 32–39), snag densities on regenerating cutblocks had not recovered to levels found in the unharvested mature spruce forest. Snag densities were significantly greater on unscarified than scarified cutblocks and this difference is attributed to persistence of some original pre-logging snags and the ongoing mortality of residual green trees retained at the time of logging on unscarified cutblocks. As no green trees were retained on scarified cutblocks, these blocks will not acquire snags until the post-logged green tree cohorts age sufficiently to create a new cohort of snags. Although snag densities were higher on mature forests than unscarified cutblocks, they did not differ in the density of snags with visible cavities. This pattern suggests that cavity-dwelling wildlife on mature forests may be limited by factors other than snag density.

Regenerating MIXEDWOOD Cutblocks

During the early stages of post-logging succession (Yrs 1–32), conifer height and densities on the regenerating cutblocks were inadequate to provide suitable thermal protection for many of the measured wildlife species. During Yrs 1–12, however, the intervening unharvested mature **MIXEDWOOD** blocks provided proximal thermal protection and they were observed (Stelfox, personal observation) to be used extensively by selected wildlife because of their high thermal and security cover values. These residual **MIXEDWOOD** blocks were removed during the 2nd pass logging event (Yrs 12–13), and this event removed the favorable juxtaposition of browse (cutblock) and protection (residual block) habitat. By the conclusion of the study (Yr 39), mature unharvested **MIXEDWOOD** forests had conifer covers at heights of 2+, 6+ and 10+ m of 76, 49 and 25%, respectively. Conifer covers on regenerating cutblocks at similar heights were 144, 117 and 84% on unscarified cutblocks and 15, 11, and 7% on scarified cutblocks. Accordingly, thermal cover was highest on unscarified **MIXEDWOOD** cutblocks, intermediate on the unharvested mature **MIXEDWOOD** forest, and lowest on scarified cutblocks. The transformation of an unharvested mature aspen/spruce **MIXEDWOOD** stand to a spruce-dominated regenerating unscarified cutblock was apparent and this change expressed itself in high conifer, and hence thermal cover values. Scarified cutblocks continued to have low conifer covers, and hence thermal protection values, throughout the study.

At the conclusion of the study (Yrs 32–39), understory visibility was uniformly higher in **MIXEDWOOD** scarified cutblocks than on either mature forests or unscarified cutblocks at the height strata of 0–0.5, 0.5–1.5 and 1.5—2.5 m. In comparison to scarified cutblocks, unscarified cutblocks and mature forests had a dense understory characterized by higher levels of young conifers and willow. Accordingly, security cover was highest in mature **MIXEDWOOD** blocks and regenerating unscarified cutblocks and lowest on scarified **MIXEDWOOD** cutblocks.

Less browse data exists for the **MIXEDWOOD** cutblocks than was available in the **SPRUCE** cutblocks, but the general observed temporal patterns of shrub and tree density patterns were not dissimilar. Shrubs and hardwood trees of browse height generally increased following logging, peaked during Yrs 17–26, then declined. In contrast to the patterns observed in the **SPRUCE** cutblocks, browse production levels were consistently higher on the scarified than unscarified **MIXEDWOOD** cutblocks. This difference was clearly related to the high densities of competing sapling conifers on unscarified cutblocks and to the high densities of aspen, poplar, and willow on scarified cutblocks. The regeneration of conifers of the unscarified **MIXEDWOOD** cutblocks was sufficiently rapid that hardwood trees could not compete favorably and the shrub component was less abundant. During Yrs 26–39, browse production was declining on both cutblock treatments, and this trend is attributed to the inability of shrubs to compete with a forest canopy that was “filling in” and to the loss of “browse” trees as they grew beyond the upper browse height (2.5 m).

At Yr 32, snag densities on regenerating cutblocks had not recovered to levels found in the unharvested mature **MIXEDWOOD** forest. Snag densities were significantly greater at Yr 32 on unscarified than scarified cutblocks and this difference is attributed to the ongoing mortality of residual green trees retained and snags left standing at the time of logging on unscarified cutblocks. By Yr 39, a substantial proportion of the snags on unscarified cutblocks had fallen to the forest floor, and snags had now appeared on the scarified cutblocks. Unlike the unscarified cutblocks whose snags were largely residual trees unharvested during the logging event, snags on scarified cutblocks were of the post-log cohort and were younger. Although snag densities were higher on mature **MIXEDWOOD** forests than unscarified cutblocks, they did not differ in the density of snags with visible cavities. Snags on scarified cutblocks were comparatively young (and of an early rot class) and did not contain any cavities. This pattern illustrates the importance of forests possessing appropriate numbers and sequencing of green tree mortalities so that snags with cavities occur throughout the successional pathway of **MIXEDWOOD** forests.

Regenerating PINE Cutblocks

Conifer covers on regenerating **PINE** cutblocks at heights of 2+, 6+ and 10+ m were 110, 108 and 99% on unscarified cutblocks and 114, 113, and 104% on scarified cutblocks. Accordingly, thermal cover was similar on both cutblock treatments. As no intervening unharvested mature pine blocks occurred, its interaction effect with cutblock treatments was absent.

At the conclusion of the study (Yrs 32–39), understory visibility was similar on scarified and unscarified **PINE** cutblocks at the height strata of 0–0.5, 0.5–1.5 and 1.5—2.5 m. Presumably, any differences in wildlife abundance between these cutblock treatment types would not be explained readily by this general index of security cover. In comparison to **SPRUCE** and **MIXEDWOOD** cutblocks, visibility was low in **PINE** cutblocks because of relatively high conifer and alder densities.

Less browse data were collected for the **PINE** cutblocks than were collected in the **SPRUCE** cutblocks, but the general observed temporal patterns of shrub and tree density patterns were not dissimilar. Shrubs and hardwood trees of browse height generally increased following logging, peaked during Yrs 17–26, then declined. During Yrs 26–32, browse production was higher on the unscarified cutblocks, and this was attributed to higher densities of aspen/poplar and honeysuckle. During Yrs 32–39, browse production decreased rapidly on unscarified cutblocks because of the loss of hardwood browse plants as they grew beyond browse height and because conifers were overtopping shrubs and forming a closed canopy. It is interesting to note that browse production did not similarly decline in the scarified cutblocks during Yrs 32–39. Browse production levels on scarified cutblocks were maintained because of high mortality rates to seedling and sapling pine trees caused by high levels of debarking by snowshoe hare.

At Yr 32, snag densities were higher on unscarified than scarified **PINE** cutblocks but this difference had disappeared by Yr 39 due to a high fall-down rate on old snags on unscarified cutblocks. Unlike the unscarified cutblocks whose snags were largely residual trees unharvested during the logging event, snags on scarified cutblocks were of the post-log cohort and were younger. Snags on scarified cutblocks were comparatively young (and of an early rot class) and few contained cavities.

Does Cutblock Scarification Alter Wildlife Abundance and Diversity?

Indices of wildlife abundance indicated several major differences between scarified and unscarified cutblocks, between cutblocks and unlogged mature forests, and among the three forest types during the first 40 years following logging. Major differences in each forest type, cutblock treatment, and stand age are examined by faunal groups.

Ungulates

Temporal and spatial patterns of ungulate abundance could be readily interpreted in context of three factors, namely forage availability, thermal cover, and human harassment. Appropriate management of these physical and anthropogenic variables in space and time are the primary challenge to resource managers seeking to maintain ungulate populations on the boreal forest landscape.

SPRUCE Forest

Deer abundance was initially low in the mature unharvested forest and remained low in both scarified and unscarified cutblocks during Yrs 1–9 despite a significant flush in grasses, forbs, and low shrubs. The absence of a fast numerical response by deer may reflect the time required for higher reproductive rates to express themselves in higher deer densities. Alternatively, deer densities may have been limited on cutblocks during this period because of the absence of supra-nivean winter shrub browse, absence of adequate thermal protection provided by conifers, and the deeper snowpacks that characterized open cutblocks. The observations that all deer and deer pellets counted were of summer use on cutblocks (Stelfox 1976) suggests that adequate thermal and concealment habitat structures were not available during this stage and may have been the primary limiting factors. By Yr 17, deer abundance had increased dramatically on unscarified cutblocks and grown moderately on scarified cutblocks. At this stage, forage was abundant in both summer (forbs, grasses) and during winter (tall shrubs above the snowpack). Whereas use of scarified cutblocks remained summer use only, deer were now occupying unscarified cutblocks year-long (Stelfox 1976). Deer appeared to be responding numerically to the improved forage conditions on cutblocks, but responded less favorably on scarified cutblocks because of limited thermal and security cover. The loss of unharvested residual blocks during Yrs 12–15 appeared to have a greater effect on deer densities on scarified than unscarified cutblocks because of the developing cover structures available on unscarified cutblocks. During Yrs 27–39, deer densities on cutblocks remained generally stable in association with reasonable forage values (shrubs declining and grass/forbs increasing) and improving security and thermal cover. The increasing popularity of Wildhorse Lake Campground in the 1980’s and increasing off-road use by recreationalists during this period may have significantly limited deer densities below that which forage and cover levels were capable of supporting. It is also possible that deer mortality caused by recreational hunting was also limiting deer below carrying capacity.

Moose densities were low in the mature spruce forest and increased following logging during Yrs 1–9 on cutblocks in general and on scarified cutblocks specifically. Although browse forage conditions were generally preferable on the unscarified cutblocks, moose densities were higher on scarified cutblocks. During this period, moose use of cutblocks was confined to the summer season (Stelfox 1976) during which moose used unharvested mature forests for security cover and to minimize heat stress during daylight hours. Preference for moose during Yrs 6–9 for scarified cutblocks may have reflected better opportunities for convective cooling (higher wind speeds on cutblocks without residual trees) during summer browsing events. Following the removal of the mature residual blocks during

Yrs 12–15, the local moose population disappeared and remained absent until following Yr 32. Their absence is likely related to the loss of security and thermal (cooling) cover provided by the residual conifer blocks, and the lack of such features on the young regenerating cutblocks. Moose did not re-establish populations on the cutblocks until following Yr 32 when densities and heights of hardwood and conifer trees were sufficient to provide concealment and thermal protection. The temporal pattern in moose abundance on cutblocks emphasizes the critical importance of security and thermal cover, without which abundant browse biomass has limited practical value to moose. Forest harvest strategies designed to maintain mature conifer forests interspersed among young regenerating cutblocks are likely critical to maintaining high regional moose densities.

Elk abundance was initially low in the mature unharvested forest and remained low (summer use only) in both scarified and unscarified cutblocks during Yrs 1–9 despite a significant flush in grasses, forbs, and low shrubs. Elk densities may have been limited on cutblocks during this period because of the absence of adequate security and thermal protection provided by conifers, absence of supra-nivean winter shrub browse, and the deeper snowpacks that characterized open cutblocks. By Yr 17, summer elk abundance had increased dramatically on unscarified cutblocks and grown moderately on scarified cutblocks. Although forage was abundant in both summer (forbs, grasses) and winter (tall shrubs above the snowpack), use of cutblocks remained limited to the non-winter seasons (Stelfox 1976). Elk appeared to be responding numerically to the improved forage conditions on cutblocks, but responded less favorably on scarified cutblocks because of limited thermal and security cover. Conifer heights, for example, were nearly twice as high on unscarified than scarified cutblocks, and would have been preferable in terms of security cover. The unharvested residual blocks were used extensively as daytime cover for elk during Yrs 1–9 (Stelfox 1976), and their harvest during Yrs 12–15 lead to a rapid decline of elk on both cutblock treatments. Elk densities on cutblocks increased slowly during Yrs 27–39 in association with increasing security and thermal cover and now involved yearlong use. During Yr 32–39, grass and forb cover increased in response to declining shrub densities as the tree canopy matured. The increasing cover of herbaceous vegetation, in combination with improving security cover, may have been the major factors leading to the recovery of the regional elk population. As with other cervid species, the increasing popularity of Wildhorse Lake Campground in the 1980's and increasing off-road use by recreationalists during this period may have significantly limited elk densities below that which forage and cover levels were capable of supporting. Elk were observed to be highly responsive to hunting pressure and would predictively abandon the Spruce cutblock region and retreat into Jasper National Park for the remainder of the hunting season.

MIXEDWOOD Forest

The high densities of deer recorded in the mature unharvested forest presumably reflected favorable availability of both forage and protective cover that appears typical of stands with both a hardwood and softwood element in the canopy (Roy and Stelfox 1995). Although deer densities declined to low levels immediately following logging (Yr 1), they increased on both cutblock treatments during the summers of Yrs 1–6 in response to improving forage (grass/forb) availability. The observations that all deer and deer pellets counted were of summer use on cutblocks (Stelfox 1976) suggests that adequate thermal and concealment habitat structures were not available during this stage and may have been the primary limiting factors. Densities of deer remained moderate to high during Yrs 6–9, but had declined to low levels following the removal of the mature residual blocks during Yrs 12–15. The general increase in deer densities on cutblocks during Yrs 27–39 is likely in response to the improving thermal and security cover provided by an emerging conifer cohort and increasing cover of forbs, grasses and shrubs in association with a taller tree canopy. Although the temporal response of deer on scarified and unscarified cutblocks was similar, densities were generally higher on unscarified cutblocks. This difference is attributed to generally more favorable levels of thermal protection and security cover. As discussed earlier, the general temporal response in deer density appears to be driven by temporal patterns in protective cover, namely its initial presence (unharvested mature residual blocks), loss (2nd pass harvest of residual blocks), and redevelopment of protective cover (development of conifers on regenerating cutblocks).

Moose were of low density in mature unharvested forests and absent immediately (Yr 1) following logging. Thereafter, moose populations increased gradually on unscarified cutblocks (Yr 1-9) and abruptly on scarified cutblocks (Yrs 6–9). Higher densities of moose on scarified than unscarified cutblocks at Yr 9 was thought to be related to higher browse biomass and densities of aspen saplings on the scarified cutblocks (Stelfox and Cormack 1962). Following the removal of the residual mature forest blocks the moose population disappeared and had not re-established by the conclusion of the study. The complete absence of a moose population, despite an abundance of moose browse, indicates the importance of adequate thermal cover and security cover against human harassment. Although conifer height and densities were greater on unscarified than scarified cutblocks, their densities were apparently inadequate as minimal security or thermal cover for moose. The appropriate extent and spatial distribution of mature unharvested forests should be a primary consideration of resource managers trying to maintain regional moose populations on a commercial forest landscape.

Elk were of low density in mature mixedwood forests and in Yr 1 cutblocks, but responded rapidly and had achieved high densities in both scarified and unscarified cutblocks during Yrs 6–9. The higher densities of elk observed on the scarified cutblocks during summer months of Yrs 6–9 is associated with higher levels of browse. Following the removal of the residual mature forest blocks (Yrs 12–15) the elk population disappeared on scarified cutblocks and remained of very low densities on unscarified cutblocks throughout the remainder of the study. In general, the temporal response of elk was similar between cutblock treatments and mostly driven by the timing of the loss of the mature residual blocks at Yrs 12–15. As with deer and moose, retention of residual mature forest blocks is a critical element of elk habitat on a commercial forest landscape.

For all ungulate species, though particularly elk and deer, the development of a large gravel pit operation, and continuous activities related to off-road vehicles are believed to have caused substantial harassment to local ungulate populations and to have limited their ability to fully use available forage and thermal cover during Yrs 27–39.

PINE Forest

The **PINE** cutblocks, when harvested, were located within a large tract of continuous mature pine that had very low densities of deer prior to the onset of logging (Stelfox and Cormack 1962). The extended absence of deer from scarified (Yrs 1–27) and on unscarified (Yrs 1–9) cutblocks suggests that their was a lag between the arrival of reasonable deer habitat and a detectable deer population. Alternatively, the very high densities of pine seedlings in scarified cutblocks (512 seedlings/ha, Yr 6) compared to unscarified cutblocks (100/ha, Yr 6) (Stelfox and Cormack 1962) might have discouraged deer from using the cutblocks. The arrival of deer on the **PINE** cutblocks during the later stages of the study (Yrs 26–39) was associated with an emerging and "self-thinned" pine forest that had reasonable levels of forbs, grasses, and shrubs, Higher levels of both deer and deer browse were found on unscarified cutblocks in comparison to scarified cutblocks, indicating the importance of forage once tree cover levels were satisfactory.

Moose were absent from mature **PINE** forests (Stelfox and Cormack 1962) then increased immediately in numbers following logging in response to increasing densities of shrubs, willow in particular, and aspen saplings. Moose populations were significantly reduced by Yr 6 and this was thought to be caused by heavy hunting pressure associated with increased road access. Moose populations recovered by Yr 9 as pine seedlings became established and attained heights that provided reasonable security cover. Although forage biomass and density continued to remain high, moose densities declined monotonically in both scarified and unscarified cutblocks during Yrs 9–39. Although moose typically decline in density as forest succession advances (Krefting 1974; Cairns and Telfer 1980) this is generally attributed to declines in browse biomass and such a trend was not observed in this study. It is interesting to note that the declining moose trend observed in this study was consistent with a provincial decline in moose populations between 1970 and 1990 that was attributed to increasing wolf populations, increasing recreational hunting, and increased use of all-terrain vehicles (Stelfox and Stelfox 1995). Higher densities of moose on unscarified than scarified cutblocks throughout the study was associated with higher densities of aspen saplings and lower densities of willow on unscarified cutblocks, suggesting that aspen saplings may be more important than willow as moose browse.

Elk densities increased immediately (Yr 1) following logging on unscarified cutblocks and were moderate to high on both scarified and unscarified cutblocks during Yr 6. At this stage, the study cutblocks were the first areas in the region to be opened up by logging and therefore would have attracted elk preferring early seral stages. This increase was associated with a dramatic increase in grass and forb cover in both scarified and unscarified cutblocks. The higher densities on unscarified cutblocks may have been related to better protective cover (thermal and security) provided by residual aspen and conifer retained at logging. Populations were low to absent in Yr 9 and this was attributed to the high mortality associated with an exceptionally deep and prolonged snowpack during the winter of 1964-1965. Elk densities thereafter increased slowly in both scarified and unscarified cutblocks and were generally higher on unscarified cutblocks. The higher densities of elk on unscarified cutblocks were associated with higher levels of grass cover. The absence of a strong numerical response of elk on **PINE** cutblocks during Yrs 9–39 may be related to a landscape effect caused by regional logging during Yrs 1–15 that ensured an abundance of young stands throughout the region and not just on the study area.

General Observations

The findings of this study that moose abundance was highest in young forest communities is similar to observations elsewhere in Alberta (Cairns and Telfer 1980, Rolley and Keith 1980; Roy and Stelfox 1995) and across North America (Krefting 1974; Peek et al 1974; Telfer 1984; Cederlund and Okarma 1988). The most important factors encouraging high moose densities in early seral stages, and declining densities in later forest stages, are availability of shrub, sapling and willow browse (Dorn 1970; Philips et al. 1973; Crete 1977; McNichol and Gilbert 1980; Van Ballenberghe et al. 1989; Westworth and Associates 1991).

Although browse biomass increased significantly during Yrs 1–10, browse utilization by cervids generally remained low (<10%) and significantly below carrying capacity (Stelfox 1984). On young regenerating cutblocks during winter months, browse forage was frequently covered by a deep snowpack, and the open nature of the young cutblocks provided minimal security and thermal cover. Ungulate abundance during winter months was higher on cutblocks when woody browse exceeded 2 m in height, suggesting that availability of supranivean forage may be an important factor affecting distribution of ungulates. In Michigan, Ozaga (1968) observed that white-tailed deer in winter preferentially used conifer-dominated habitat with shallow snowpack in comparison to hardwood forests where snowpacks were comparatively deep.

This study emphasizes the importance of appropriate amounts and distribution of cover and forage on cutblocks in determining winter distribution and abundance of ungulates. Other studies in Alberta (Tomm *et al.* 1981; Holroyd and Van Tighem 1983; Westworth *et al.* 1984; Stelfox *et al.* 1995) and in Saskatchewan (Hunt 1976) have shown the importance of cover and forage to distribution and abundance of cervids during winter.

The low utilization of forage-rich cutblocks by ungulates when protective cover is minimal is not unique to this study. Other studies have shown that forage generally increases in quantity and quality following logging but that ungulates fail to fully use cutblocks when inadequate thermal and security (hiding) cover exists (Lyon and Jensen 1980; McNichol and Gilbert 1980). The lack of adequate winter thermal cover during Yrs 1–32 for **PINE** and unscarified **MIXEDWOOD** cutblocks and throughout the study for scarified **MIXEDWOOD** and both **SPRUCE** cutblocks was apparently a major reason for ungulate abundance remaining well below the forage carrying capacity during the first 40 years post-logging.

Higher abundance of moose in **PINE** than in **SPRUCE** and **MIXEDWOOD** cutblocks during Yrs 9–27 was associated with higher canopy closure, security cover, alder density, and lower levels of industrial activity (gravel extraction, road and vehicle densities) and recreational activities (off-road vehicles, camping). The abundance of alder in **PINE** cutblocks may have also increased protein content of browse forage (Virtanen 1962; Becking 1970).

Negative relationships between winter wind chill measurements and ungulate density noted in this study (Stelfox 1984) and elsewhere in North America (Telfer 1970, Huegel et al 1986, Roy and Stelfox 1995) suggests that ungulates species are sensitive to low winter temperatures and therefore dependent on habitat structures (e.g., conifers) that reduce wind speed or minimize body heat loss. In this study, a positive correlation was observed between conifer crown closure and ungulate abundance in cutblocks of all forest types, though most pronounced in **SPRUCE**. In Idaho, Keay and Peek (1980) also found that deer preferred winter sites that were proximal to conifer thermal cover. A positive correlation between understory security values and ungulate abundance was also observed. Security and conifer canopy cover values of 50% appeared to be minimal levels required for yearlong use of cutblocks by ungulates (Stelfox 1984).

Although conifer cover and density increased with cutblock age, minimum deer and elk winter thermal cover ("dense pole-sapling stage conifers (2+ m) with a canopy closure of 75%"; Thomas 1979) had not developed by Yr 32 (pole-sapling stage) on **SPRUCE** and **MIXEDWOOD** cutblocks. Security cover was below minimal requirements ("vegetation capable of hiding 90% of a standing adult deer or elk at a distance of 60 m"; Thomas 1979) at Yr 32, particularly on those cutblocks those that were scarified.

It was not until Yr 39 that minimum winter thermal cover (definition of Thomas 1979) was observed and then only on scarified and unscarified **PINE** cutblocks and on unscarified **MIXEDWOOD** cutblocks. At that time, comparable canopy closure values on scarified **SPRUCE** and **MIXEDWOOD** were only 12 and 15% with ungulate visibility values still high (19 and 38%) during summer. The development of minimum winter thermal cover for deer appeared to be delayed by ~10 years by scarification of **SPRUCE** and **MIXEDWOOD** cutblocks.

The prudent selection of biophysical features of the forest landscape by ungulates is critical to maintaining a positive energy balance, to ensuring reproductive fitness (Moen 1973; Renecker and Hudson 1993) and is the basis for observed optimal foraging and resource use strategies (Pulliam 1974; Belovsky 1978).

Snowshoe Hare

Snowshoe hares were most abundant on cutblocks with dense shrubs and high densities of sapling trees. These features were most pronounced during Yrs 25–32 for **PINE** cutblocks and on unscarified **SPRUCE** cutblocks. Hares were less abundant in the more open scarified **SPRUCE** and **MIXEDWOOD** cutblocks and in mature forests. The preference of hares for dense shrub and high sapling cover and avoidance of open habitats noted in this study concurs with findings elsewhere in Alberta (Westworth *et al.* 1984, Radvanyi 1987, Roy *et al.* 1995). The higher snowshoe hare abundance recorded in young forest seral stages with abundant cover is likely related to their need for protective cover from predators and for abundant forage provided by high densities of shrubs and saplings (Wolfe et al. 1982, Carreker 1985, Litvaitis et al. 1985; Radvanyi 1987). Hare abundance and hare-caused girdling of conifers was positively correlated with deciduous shrub/tree density and height of conifers, poplar and willow. By creating a uniform and preferred hare habitat of dense alder and willow, scarification of **PINE** cutblocks made regenerating conifer trees more susceptible to mortality caused by hare barking.

Grouse

Four different grouse species (ruffed, spruce, blue, sharp-tailed) were observed in this study. Blue grouse were only observed in the scarified **SPRUCE** cutblocks and preferred early seral stages (Yrs 1–27) during the summer months. These young open cutblocks with abundant down wood, berry-producing shrubs and minimal tree cover are consistent with preferred blue grouse nesting habitat. Ruffed grouse were the most flexible of the grouse species and found in each forest type and each cutblock seral stage. In general, observations of ruffed grouse were more common on scarified than unscarified cutblocks, a pattern that might indicate avoidance of cutblocks with roosting snags that could be used by avian predators. Few sharp-tailed grouse were observed during the study and it was not possible to derive any patterns of preference or avoidance. Spruce grouse did not occur on young cutblocks, returning only when conifer height and density provided adequate forest canopy (Yr 17). By the latter part of the pole-sapling and young forest stages, spruce grouse were again abundant, particularly in aspen/spruce forest associations.

Bear

Based on general observations of black bear sign by the senior author, black bear abundance generally increased with cutblock age and with specific cutblock structures (rotting logs, fruit-bearing shrubs (e.g., buffalo-berry, hedysarum tubers, developing conifer and mixedwood canopy). Their absence on cutblocks younger than Yr 17 was likely related to inadequate hiding and thermal cover, scarcity of rotten stumps and logs for arthropod forage, and low abundance of edible berries and tubers. No obvious difference in use by bears of scarified and unscarified cutblocks was noted.

Other studies (Lindsey and Meslow 1977) have also shown that black bears require a combination of cover and food which includes an abundance of insects in rotting wood and berry-producing shrubs. Studies in northern California by Kelleyhouse (1977) and in spruce-fir associations of Montana (Jonkel and Cowan 1971) showed that recently logged areas with either avoided or minimally used by black bears.

Birds

Abundance of snag-dependent birds was positively associated with the presence of large live trees, in particular aspen and balsam poplar, and snags (dead and partially dead trees). Although less than in mature stands, unscarified cutblocks contained a significantly higher density of snags than did scarified cutblocks. Consequently, at least 75% of cavity-dwelling bird sightings were on unscarified and 25% on scarified cutblocks. Most of those in **MIXEDWOOD** cutblocks were on, or near, mature/old aspen or balsam poplar snags that contained cavities. Four species (hairy woodpecker, yellow-bellied sapsucker, starling and hawk owl) were positively associated with unscarified cutblocks whereas the northern flicker, black-capped and boreal chickadees seemed more ubiquitous in their associated with scarified and unscarified cutblocks.

The diversity of cavity-dwelling species (n=12) was also apparent in the range of snag diameter sizes used as well as snag condition classes and species composition. Although a higher percentage of large snags with DBH 35+ cm contained cavities, intermediate sized snags of 25–35 cm dbh had 12% with cavities, while even the smaller snags of 15–25 cm had 18% with cavities.

The importance of mixedwood forests (both mature forests and unscarified cutblocks) for snag-dwelling birds was evident by the greater density of snags and those with cavities compared with **SPRUCE** and **PINE** forests. This superior habitat in **MIXEDWOOD** was correlated with significantly higher total observations of snag-dependent birds as well as species diversity than in **SPRUCE** or **PINE** forests. Dickson *et al.* (1983) found bird species richness, abundance and diversity were significantly higher in plots with snags than in snagless plots. A study in Oregon and Washington found a direct relationship between the number of snags and the number of snag-dwelling wildlife species (Thomas *et al.* 1979).

Unscarified cutblocks were able to sustain most of the common bird guilds observed in the mature stands; e.g., nuthatches, jays, warblers, and woodpeckers, although scarified cutblocks significantly depleted those guilds during the first 40 years post-logging.

Avifauna abundance was greater in **MIXEDWOOD** than in **SPRUCE** or **PINE** cutblocks. The results were consistent with findings by Welsh (1981) that revealed population density and diversity of bird populations was greater within boreal **MIXEDWOOD** than within **PINE** or **SPRUCE** forests.

SUMMARY

The issue of post-logging establishment and survival of commercial trees is most critical to this study, for its presumed performance is the rationale behind clearcut logging and scarification as the dominant harvest and regeneration strategy adopted in the region. From a silvicultural view, the ultimate gauge of performance must wait for the forest stand to attain merchantable volumes, for only then can one properly calculate meaningful harvest and regeneration costs ($\$/m^3$/yr). Since softwood forest stands in the Hinton region generally achieve harvestable volumes and piece sizes by 90-100 years, the forest stands examined in this study are approximately half-way to merchantable age. As such, any conclusions of this study regarding the economic wisdom of scarification and planting following clearcutting are preliminary. The reader is also reminded that the **SPRUCE** and **MIXEDWOOD** sites examined in this study are located in the Athabasca River Valley bottomlands, a region that receives frequent winter chinooks, strong winds, windblow loess, and frost pocket events, and therefore patterns observed there may not be representative of upland sites. Given these caveats, the findings of this study over four decades do not ascribe any fiber growth advantage to scarification and subsequent plantings (or aerially seeding) in comparison to strategies where non-merchantable trees are retained, and natural regeneration occurs. This conclusion is best illustrated with white spruce regeneration on the **SPRUCE** and **MIXEDWOOD** cutblocks 40 years after logging. For white spruce trees in both the canopy and the subcanopy strata, densities were significantly higher in unscarified than scarified cutblocks. One must remember that the scarified **SPRUCE** and **MIXEDWOOD** cutblocks also received single or multiple plantings or aerial seedings of white spruce following scarification. The primary explanations for this discrepancy in white spruce response between scarification/planting and unscarified/natural regeneration appear to lie in two related plant community dynamics phenomena. The first focuses on the non-merchantable trees left on the site at the time of logging. These trees were of moderate density, were established, and displayed reasonable growth in response to the removal of a competing overstory. From an optimal capital investment perspective, their retention at the time of logging represented maintenance of existing natural equity, and the subsequent stand performance benefited from established trees accruing new growth on existing phytomass. In addition, these residual green trees appeared to provide a favorable emerging overstorey for development of seedling and sapling conifers, trees that contributed to the uneven age structure of the regenerating cutblock and would provide future residual trees for subsequent logging events.

Although seedling and sapling densities of white spruce in the scarified cutblocks were moderate (**MIXEDWOOD** cutblocks) to high (**SPRUCE** cutblocks) by Year 40 (reflecting the manual planting episodes), they did not demonstrate high levels of survival, nor favorable recruitment into the subcanopy or canopy strata. The causal mechanisms for this poor recruitment in scarified cutblocks is unclear, but may reflect unfavorable microclimates associated with an absent overstory or disruptions to the ground surface (and associated microbes) caused by the scarification event. If current stand development trends continue, it is logical to expect that the **SPRUCE** and **MIXEDWOOD** cutblocks created by natural regeneration on unscarified cutblocks will be ready to receive their second harvest event 1 to 2 decades sooner than those receiving scarification and planting events. The wisdom of scarification and planting strategies becomes even more dubious when one considers the significant costs of site preparation (scarification), and subsequent hand-planting or aerial seeding of conifers. A survey of several forest

companies in Alberta revealed 1999 cutblock scarification and planting costs for white spruce at (~$100–200/ha) and (~$1000/ha), respectively.

As stated earlier, the SPRUCE and MIXEDWOOD cutblocks are found along the Athabasca River valley bottomlands and therefore may not reflect patterns in upland sites. Accordingly, examining tree growth response patterns in the upland PINE cutblocks might reveal a different pattern. The fiber growth trajectory of lodgepole pine on scarified and unscarified PINE cutblocks is somewhat different from the SPRUCE and MIXEDWOOD cutblocks. In this forest trajectory, young pine established equally well on both treatment types, recruitment into higher strata was favorable, yielding canopy strata densities of ~800–1000 stems/ha by the end of the 4th decade. The major differences between scarified and unscarified PINE cutblocks was not in the canopy strata, but the structure and composition beneath. For each of lodgepole pine, white spruce, black spruce and balsam fir, understorey densities were higher on the unscarified cutblocks. This difference in understory tree density was most pronounced for white spruce. Although the site preparation strategy had generated similar volumes of lodgepole pine in the canopy by Yr 40, it came at a cost of reduced volume and tree species composition offered by white spruce, trembling aspen, black spruce, and balsam fir. Although there was no direct seeding or planting cost associated with the scarified PINE cutblocks, there were significant costs associated with scarification following the logging event. It would therefore appear that a management objective of an even-age pine monoculture can be accommodated with a clearcut/scarification strategy. In contrast, the unscarified PINE cutblocks had similar lodgepole pine volumes, but had greater structural diversity and volumes of secondary tree species (white spruce, trembling aspen, black spruce, balsam poplar).

Albertan's appreciate the environmental, societal, and economic services provided by forest ecosystems to society (Alberta Forest Conservation Strategy 1997), As such, societal demands of forest companies are increasing, requiring forestry practices that ensure reasonable tree regeneration, ecological function, and biodiversity on regenerating forest cutblocks. For these reasons it is imperative that longterm studies such as the one described in this report examine the response of plant community structure and wildlife to different harvest and regeneration strategies.

A significant and predictable change in plant community dynamics occurred following clearcut logging, largely in response to physical changes in plant community structure caused by the logging event. The most pronounced meteorological changes involved temperature and light regimes associated with the removal of all merchantable trees in the forest canopy. From a plant community dynamics perspective, the physical removal of trees also created a large and immediate increase in ground space available to non-tree flora for establishment or expansion. Graminoid cover increased rapidly during the early post-logging years, but declined as cover of forbs and shrubs increased. Shrubs did not respond numerically to logging as quickly as did herbaceous species, but maintained consistent increases in cover throughout the study. As expected, moss cover remained very low or absent during the first 3 decades following logging in all forest types, but had increased considerably by decade 4.

Temporal patterns in understory plants were generally similar between scarified and unscarified cutblocks. Herbaceous cover was marginally higher in unscarified than scarified cutblocks during Yrs 1–10, but this difference generally disappeared during later stages of the study. There was some evidence that forbs were advantaged by scarification and their cover levels were higher on scarified than unscarified cutblocks in MIXEDWOOD and PINE forests. Dwarf shrub cover was generally higher during Yrs 1–27 on unscarified than scarified cutblocks. Although no clear difference in moss cover was detected following treatment types in SPRUCE and PINE forests, moss cover was significantly higher in unscarified MIXEDWOOD cutblocks.

Plant species richness generally increased with spruce cutblock age throughout post-harvest succession and also in mature unharvested forest as it progressed through post-rotational seral stages. Plant species richness achieved maximum levels at or near the end of the study in both scarified and unscarified cutblocks; both at values higher than recorded in the mature unharvested forest. Forb species were the highest contributor to species richness, generally followed by shrubs, graminoids (grasses, sedges, rushes), dwarf shrubs, trees, and fern/allies. Increased post-harvest species richness occurred primarily through the addition of forb species. Whereas no major differences in species richness of plant groupings was observed between scarified and unscarified SPRUCE cutblocks, species richness was generally higher on scarified than unscarified cutblocks in PINE and MIXEDWOOD cutblocks.

For the SPRUCE cutblocks on which browse data was most consistently collected, browse biomass was low immediately following logging and then increased sharply during Yrs 1–9. Maximum browse biomass levels occurred at Yr 17 for unscarified (1,068 kg/ha) and Yr 26 for scarified (934 kg/ha) cutblocks. Browse biomass levels were higher on unscarified than scarified cutblocks during Yrs 1–17 and did not differ appreciably during Yrs 26–39. In general, unscarified cutblocks had higher browse stem densities than did scarified cutblocks.

Snag densities were significantly higher in mature forests than in regenerating cutblocks. At Yrs 32 and 39 for all forest types, snags were more common on unscarified cutblocks than in ones subjected to scarification; this difference in snag density, however, had largely disappeared by Yr 39 for MIXEDWOOD and PINE cutblocks. Generally, snag densities declined between Yrs 32 and 39, suggesting that snag recruitment rates had dropped or that fall-over rates of snags had increased. Snags containing cavities were equally common in mature forests and unscarified cutblocks for SPRUCE and MIXEDWOOD forests, but were absent (SPRUCE, MIXEDWOOD) or of low densities (PINE) on scarified cutblocks.

Mature SPRUCE and MIXEDWOOD forests had higher down wood cover than their respective regenerating 40 Yr old cutblocks (Table 15), while scarified and unscarified cutblocks did not differ in amount of down wood. Mature SPRUCE and MIXEDWOOD forests had an average down wood cover of 4–5%, while regenerating scarified and unscarified forests of SPRUCE, MIXEDWOOD, and PINE cutblocks had down wood covers of 1–2%.

Mature SPRUCE forests had higher average diameter of down wood than did the regenerating cutblocks (Table 16, Figure 76). No differences in average diameter of down wood occurred between cutblock treatment types for SPRUCE, MIXEDWOOD or PINE forests, suggesting that scarification had no affect on average diameter of down wood in regenerating cutblocks at Yr 40.

Horizontal visibility through the forest understory, at the conclusion of the study, increased with distance upward from the ground surface, reflecting visual obstruction caused by the dense herbaceous and lower shrub strata. Visibility did not differ between mature SPRUCE forests and regenerating cutblocks (Yrs 32, 39) but was higher on scarified MIXEDWOOD cutblocks than either mature forests or unscarified cutblocks. No differences in visibility between scarified and unscarified PINE cutblocks were observed.

Security cover and thermal shelter for cervid (deer, elk, moose) species was lower on scarified cutblocks than unscarified cutblocks because of the removal of overstory vegetation and the leveling of understory woody vegetation associated with clearcut logging and subsequent site preparation. Conifer densities for trees greater than 2 m, and hence thermal protection to cervids, was greater on unscarified cutblocks than scarified **SPRUCE** and **MIXEDWOOD** cutblocks at Yrs 32 and 39. The extent that scarified and unscarified cutblocks were used by cervids was significantly reduced when the intervening unharvested forests were harvested at Yr 13, indicating the importance of juxtaposition of young regenerating cutblocks and mature forests.

The loss of residual green trees and snags and the lowered structural diversity of scarified cutblocks were associated with lower cavity-dwelling bird richness and abundance in comparison to unscarified cutblocks.

FOREST HARVEST RECOMMENDATIONS RELEVANT TO WILDLIFE HABITAT MANAGEMENT

The following recommendations are relevant to forest sites similar to those studied and described in this report.

1. Where maintenance of structural diversity of forest stands and a diversity of habitat structures is a management objective, the maintenance of residual trees (i.e., partial cutting) and reliance on natural regeneration is a preferred strategy.
2. Where yearlong resident populations of deer, elk, and moose are a dominant management objective, young-mature conifer blocks of widths exceeding 100 m and interspersed at distances less than 200 m throughout the cutblocks should be retained until regenerating cutblocks provide adequate winter thermal cover. Managers should consider a 3-pass system (with entries at ~0, 30, and 60 years) for **SPRUCE** and **MIXEDWOOD** forests, where a minimum of one-third of the area would exist in a forest structure that provides thermal protection.
3. Decadent green trees or snags (25+/ha) should be retained to maintain viable populations of cavity-dwelling wildlife on cutblocks.
4. To enhance movement of wildlife populations that require mature forest elements across a fragmented logged landscape, residual blocks at least 100 m wide bordering lakes and major streams may help to maintain viable populations of tree cavity-dwelling species, as well as cervids, grouse, furbearers, and insectivorous birds.
5. Retaining small patches of wildlife cover on cutblocks can help maintain populations of wildlife during the early post-logging seral stages. When using large equipment such as feller-bunchers to clearcut forests, it is more practical to retain patches of residual trees than scattered individual trees. Patches of mature aspen found within conifer forests appear to be important to many wildlife species.
6. Conversion of large tracts of mature conifer forests to a mosaic of age classes by clearcut logging can increase abundance and diversity of wildlife. However, several wildlife species such as elk have a low tolerance to human activities and abandon otherwise favorable habitat if subjected to harassment. Minimizing human activities on cutblocks should be a forest management objective, especially during the winter season.
7. Where understory spruce occur beneath mature spruce and **MIXEDWOOD** canopies, harvest strategies should attempt to retain seedlings and saplings during logging. This study indicated that conifer regeneration on unscarified **SPRUCE** and **MIXEDWOOD** cutblocks was advanced by 5–10 years over that on scarified cutblocks. By not scarifying cutblocks, benefits occur to both wood fiber production and wildlife.
8. Growth rates of pine, poplar, and willow appeared to be associated with density of nitrogen-fixing green alder and perhaps other nitrogen-fixing plant species. Information on the importance of native nitrogen-fixing plants for enhancing both wood fiber growth and wildlife habitat should be determined before definitive forest management guidelines are developed for suppressing deciduous plant species. Species that should be evaluated are green alder, buffalo-berry, vetch, peavine, hedysarum, locoweed, and milk vetch.

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APPENDIX 1. LOCATION OF PHOTOPOINTS

SPRUCE FOREST

Photopoint 1. Located on a mound in a pile of logs 20 m east of the Camp 1 road running south from Wildhorse campground.

Photopoint 2. Located near the SE corner of the scarified cutblock and 15 m north of the East-West Road. It is 33 m north of Photopoint 3.

Photopoint 3. Located on a bank at the south side of the East–West road near the southeast corner of the scarified cutblock and 33 m south of Photopoint 2.

Photopoint 4. Located 33 m north of the East-West road within the scarified cutblock and halfway between the southeast and southwest corners of this cutblock.

Photopoint 5. Located near the southeast corner of the unscarified cutblock and 3 m south of the south side of the East-West road.

Photopoint 6. Located 33 m west of Photopoint 5 on south bank of E-W road.

Photopoint 7. Located at north edge of mature spruce on south side of Highway 16, 400 m west of Truck Weigh Station.

Photopoint 8. Located on grid line 4, Replicate 5, Sample 1 of mature spruce south of Highway 16.

MIXEDWOOD FOREST

Photopoint 1. Located on a hill due south of the boundary between the scarified and unscarified cutblocks. The photopoint was moved about 30 m east in 1981 because the initial view was obscured by foreground trees. The location is marked by a red-flagged wooden stake.

Photopoint 2. Located on a high point above old Highway 16 on the south side and 1.0 km east of the junction of old Highway 16 and the new CNR gravel road between Pedley siding and Camp 9 gravel pit. The photopoint is in the middle of a conspicuous clump of spruce at the top of a steep gravel cut. This photopoint looks over the unscarified cutblock. It was marked by a wood stake with blue flagging in 1995.

Photopoint 3. Located ~300 m east of photopoint 1 at the top of a bank above the scarified cutblock. It is situated about 45 m north of the old railway bed. The view is directed down on a scarified area about 200 m east of the border between the scarified and unscarified cutblock. No stake was erected here in 1981 because the scarified areas were being cleared for gravel mining.

PINE FOREST

Photopoint 1. Located at the bend in the Camp 5 road, 3.5 km in from the Hinton–Robb road. From this point the view is north down the Camp 5 road looking towards both the unscarified and scarified cutblocks. It is marked by a 1.5 m metal stake.

Photopoint 2. Located 18.2 m NW of a round, metal culvert at the intersection of the main Camp 5 road and a haul-road running NW from the Camp 5 road. This junction is 0.5 km north of Photopoint 1 and 4.3 km from the Robb road. This photopoint is located at the south end of the unscarified block and about 250 m northeast of the Quigley Creek bridge. This photopoint looks north onto the unscarified cutblock. A new 0.5 m metal stake was placed in 1988.

Photopoint 3. Located 0.5 km east of Photopoint 2, on the south side of the road at a location 33 m east of the old exclosure plot. A compass bearing of 316° (NW) from the photopoint to the point where the photos were centered was used. A 0.5 m metal stake identifies the location.

APPENDIX 2. DATA SHEET HEADERS

Appendix Table 2.1. Form 1, Vegetation cover data sheet header.

Hinton Forest Wildlife Study						**Vegetation Cover Data**						
Forest		Sample			Date (d/m/yr)		Observers					
Block												
Repl.	Grid	Plot	Spec.	Cover	Spec.	Cover	Spec.	Cover	Spec.	Cover	Spec.	Cover

Appendix Table 2.2. Form 2, Shrub stem density and use data sheet header.

Hinton Forest Wildlife Study								**Shrub Stem Density and Use Data**										
Forest		Sample					Date (d/m/yr)		Observers									
Block						0-.2mm	.2-.4	.4-.6	.6-.8	.8-1	1-2	2-3	4-6	6-8	6-8	8-10	>10	
Repl.	Grid	Plot	Spec.	Use-S	Use-W	Ht 1	Ht 2	Ht 3	Ht 4	Ht 5	Ht 6	Ht 7	Ht 8	Ht 9	Ht10	Ht11	Ht12	Total

Appendix Table 2.3. Form 3, Tree stem density and use data sheet header.

Hinton Forest Wildlife Study								**Tree Stem Density and Use Data**										
Forest		Sample					Date (d/m/yr)		Observers									
Block						0-.2mm	.2-.4	.4-.6	.6-.8	.8-1	1-2	2-3	4-6	6-8	6-8	8-10	>10	
Repl.	Grid	Plot	Spec.	Use-S	Use-W	Ht 1	Ht 2	Ht 3	Ht 4	Ht 5	Ht 6	Ht 7	Ht 8	Ht 9	Ht10	Ht11	Ht12	Total

Appendix Table 2.4. Form 4, Tree dimension and snag data sheet header.

Hinton Forest Wildlife Study							**Tree Dimension and Snag Data**							
Forest		Sample			Date (d/m/yr)		Observers							
Block			Conifer Tree Dimension					Snag Measurements						
Replicate	Grid	Plot	Tree #	Species	Width	DBH	Ht. Cl.	Snag #	Spec.	Cond.	DBH	Ht. Cl.	Cavities	In Use?

Appendix Table 2.5. Form 5, Visibility board data sheet header.

Hinton Forest Wildlife Study				**Visibility Board Data**			
Forest	Sample			Date (d/m/yr)	Observers		
Block							
Replicate	Grid	Plot	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5

Appendix Table 2.6. Form 6, Browse production data sheet header.

Hinton Forest Wildlife Study						**Browse Production Data**				
Forest		Sample			Date (d/m/yr)		Observers			
Block							all weights include bag except final weight			
Replicate	Grid	Plot	Species	Green Wt.	Wt. #2	Wt. #3	Dry Wt.	Bag Wt.	Final Wt.	% Use

Appendix Table 2.7. Form 7, Down wood cover data sheet header.

Hinton Forest Wildlife Study						**Down wood Cover Data**				
Forest		Sample			Date (d/m/yr)		Observers			
Block										
Replicate	Grid	Down Wood Diameter (cm)								

APPENDIX 3. LIST OF ABBREVIATIONS

Units

cm	centimetre
m	metre
km	kilometre
s	second
h	hour
d	day
g	gram
kg	kilogram
m a.s.l.	metres above sea level
$m\ s^{-1}$	metres per second
m^2	square metre
m^3	cubic metre
m/s	metres/second
kph	kilometre per hour
ha	hectare
ha^{-1} or /ha	per hectare
km^2	square kilometer
°C	degrees Celsius

Acronyms

α	alpha
ANOVA	analysis of variance
DBH	diameter at breast height
df	degrees of freedom
ISR	Incoming solar radiation
N	number of samples
NA	not analyzed
NS	not significant
P	Probability of significance level
R^2	Correlation of determination
S	significant
SD	standard deviation
SE	standard error
SEM	standard error of the means
χ^2	Chi-Square Value

APPENDIX 4. SPECIES LIST

Appendix Table 4.1. Vascular plant species observed in each forest type.

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Apocynaceae	*Apocynum sp.*	dogbane			*
Araliaceae	*Aralia nudicaulis*	wild sarsaparilla			*
Asteraceae	*Achillea millefolium*	common yarrow	*	*	*
	Agoseris glauca	false dandelion	*	*	*
	Anaphalis margaritacea	pearly everlasting	*	*	
	Antennaria pulcherrima	showy everlasting	*		
	Arnica spp.	arnica	*	*	*
	Aster ciliolatus	lindley’s aster	*	*	*
	Aster conspicuus	showy aster	*	*	*
	Aster sibiricus	low aster	*	*	
	Aster spp.	aster species	*	*	*
	Erigeron caespitosus	tufted fleabane	*	*	
	Erigeron glabellus	smooth fleabane	*	*	*
	Erigeron ochroleucus	fleabane	*	*	
	Erigeron philadelphicus	fleabane	*	*	
	Hieraceum triste	alpine hawkweed	*		
	Hieraceum umbellatum	narrow-leaved	*	*	
	Matricaria matricarioides	pineapple weed	*	*	
	Petasites palmatus	palmate-leaved coltsfoot	*		*
	Petasites sagittatus	coltsfoot			*
	Petasites spp.	coltsfoot	*	*	*
	Solidago gigantea	tall smooth goldenrod	*	*	*
	Solidago decumbens	goldenrod	*	*	*
	Sonchus arvensis	sow thistle	*		
	Taraxacum officinale	dandelion	*	*	*
	Tragopogon dubius	goatsbeard		*	
Betulaceae	*Alnus crispa*	green alder			*
	Betula glandulosa	bog birch	*		
	Betula occidentalis	black birch	*		
	Betula papyrifera	paper birch	*		
Boraginaceae	*Mertensia paniculata*	tall mertensia	*	*	*
Brassicaceae	*Braya spp.*	braya	*		
	Draba spp.	draba	*		
	Sisymbrium spp.	mustard	*	*	
Campanulaceae	*Campanula rotundifolia*	harebell	*	*	*
Caprifoliaceae	*Linnaea borealis*	twin-flower	*	*	*
	Lonicera dioica	twining honeysuckle	*		
	Lonicera involucrata	bracted honeysuckle	*		*
	Sambucus racemosa	elderberry			*
	Symphoricarpos albus	snowberry	*	*	
	Viburnum edule	low-bush cranberry	*		*
Caryophyllaceae	*Arenaria stricta*	sandwort		*	
	Cerastium spp.	mouse-eared chickweed	*	*	
	Stellaria longifolia	long-leaved chickweed		*	
	Stellaria longipes	long-stocked chickweed	*	*	
Chenopodiaceae	*Chenopodium album*	lamb’s quarter	*		
Cornaceae	*Cornus canadensis*	bunchberry	*	*	*
	Cornus stolonifera	dogwood	*		
Cruciferae	*Alyssum murale*	alyssum	*		

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Cupressaceae	*Juniperus communis*	ground juniper	*	*	
	Juniperus horizontalis	creeping juniper	*		
Cyperaceae	*Carex aurea*	golden sedge	*	*	*
	Carex aquatilis	water sedge	*		
	Carex backii	sedge		*	
	Carex capillaris	hairlike sedge	*		
	Carex eburnea	sedge	*		
	Carex flava	sedge	*		
	Carex interior	inland sedge	*		
	Carex lacustris	sedge	*		
	Carex siccata	sedge		*	
	Carex tenuifolia	sedge		*	
	Carex spp.		*	*	*
Elaeagnaceae	*Shepherdia canadensis*	Canadian buffalo-berry	*	*	
Equisetaceae	*Equisetum arvense*	common horsetail	*	*	*
	Equisetum pratense	horsetail			*
	Equisetum scirpoides	horsetail	*		*
	Equisetum sylvaticum	woodland horsetail			*
	Equisetum spp.	unidentified horsetail	*	*	*
Ericaceae	*Arctostaphylos uva-ursi*	common bearberry	*	*	*
	Ledum groenlandicum	Labrador tea		*	
	Oxycoccus microcarpus	small bog cranberry		*	
	Vaccinium caespitosum	dwarf bilberry		*	
	Vaccinium vitis idaea	lingonberry		*	
Fabaceae	*Astragalus striatus*	milk vetch	*		
	Astragalus alpinus	alpine milk vetch	*	*	
	Astragalus frigidus	american milk vetch	*	*	
	Astragalus drummondii	drummond's vetch	*	*	
	Astragalus eucosmus	elegant milk-vetch	*		
	Hedysarum sulphurescens	yellow hedysarum		*	
	Hedysarum boreale	indian potatoe	*	*	*
	Lathyrus ochroleucus	pea vine	*	*	*
	Oxytropis monticola	late yellow loco-weed	*		
	Oxytropis splendens	showy loco-weed	*	*	*
	Trifolium pratense	common red clover	*	*	*
	Trifolium repens	white dutch clover	*	*	*
	Vicia americana	wild vetch	*	*	*
Gentianaceae	*Gentianella amarella*	felwort	*	*	*
	Gentianella crinata	fringed gentian	*	*	*
Geranianaceae	*Geranium bicknellii*	crane's bill	*		*
Grossulariaceae	*Ribes oxyacanthoides*	wild gooseberry			*
	Ribes triste	wild red currant		*	
	Ribes lacustre	black gooseberry	*		
Iridaceae	*Sisyrinchium montanum*	blue-eyed grass	*	*	
Juncaceae	*Juncus balticus*	wire rush	*		*
	Juncus nodosus		*		
	Juncus parryi		*		
	Luzula parviflora	wood rush	*		
Liliaceae	*Disporum trachycarpum*	fairy-bells			*
	Lilium philadelphicum	western wood lily	*	*	*
	Maianthemum canadense	wild lily-of-the-valley	*		*

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
	Smilacina racemosa	false solomon's-seal	*	*	*
	Smilacina stellata	star-flow. solomon's-seal	*	*	*
	Streptopus amplexifolius	twisted-stalk		*	*
	Tofieldia glutinosa	sticky asphodel	*		
	Zygadenus elegans	smooth camas	*		*
Loranthaceae	*Arceuthobium americanum*	dwarf mistletoe			*
Onagraceae	*Circaea alpina*	enchanter's nightshade	*		
	Epilobium angustifolium	fireweed	*	*	*
	Epilobium latifolium	willow herb	*		
Ophioglossaceae	*Botrichium boreale*	moonwort	*	*	*
	Botrichium lunaria				
Orchidaceae	*Cypripedium passerinum*	sparrow's egg lady's slip.	*		*
	Cypripedium calceolus	yellow lady's slipper	*		
	Goodyera repens	rattling plantain	*		
	Habenaria hyperborea	northern green bog	*		*
	Habenaria obtusata	blunt-leaved orchid	*		
	Habenaria viridus	bracted orchid	*	*	*
	Malaxis paludosa	adder's mouth			*
	Orchis rotundifolia	round-leaved orchid	*		
	Spiranthes romanzoffiana	ladies' tresses			*
Parnassiacea	*Parnassia fimbriata*	grass of parnassus	*		*
Pinaceae	*Abies lasiocarpa*	subalpine fir			*
	Picea glauca	white spruce	*	*	*
	Picea mariana	black spruce			*
	Pinus contorta	lodgepole pine		*	*
Plantaginaceae	*Plantago major*	common plantain	*	*	
Poaceae	*Agropyron spicatum*	bluebunch wheat grass	*	*	
	Agropyron trachy./subsec.	slender wheat grass	*	*	*
	Agrostis alba	red top	*	*	
	Agrostis scabra	hair grass	*		*
	Bromus inermis	awnless brome	*	*	*
	Bromus sp	bromegrass	*	*	*
	Calamagrostis canadensis	bluejoint	*		*
	Calamagrostis inexpansa	northern reed grass	*		
	Calamagrostis purpurasc.	purple reed grass	*	*	
	Cinna latifolia	drooping wood reed			*
	Deschampsia caespitosa	tufted hairgrass	*	*	
	Elymus canadensis	Canada wild rye			
	Elymus glaucus	smooth wild rye	*	*	*
	Elymus innovatus	hairy wild rye	*	*	*
	Festuca ovina	sheeps fescue	*		
	Festuca rubra	red fescue	*	*	*
	Festuca saximontana	rocky mountain fescue	*		
	Festuca spp	unidentified fescue	*	*	*
	Glyceria striata	fowl manna grass	*		
	Oryzopsis asperifolia	rice grass	*		
	Phleum alpinum	mountain timothy	*		
	Phleum pratense	timothy	*	*	*
	Poa alpinum	alpine bluegrass		*	
	Poa palustris	fowl meadow grass	*	*	*
	Poa pratense	Kentucky blue grass	*	*	*
	Poa secunda	Sandberg blue grass			
Polygonaceae	*Polygonum viviparum*	bistort	*		

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Polypodiaceae	*Dryopteris carthusiana*	narrow spin. shield fern			*
	Gymnocarpium dryopteris	oak fern			*
Primulaceae	*Androsace spp.*	fairy candelabra	*		
	Androsace chamaejasme	sweet-scented androsace	*		
	Dodecatheon radicatum	shooting star		*	*
Pyrolaceae	*Moneses uniflora*	one-flowered	*	*	
	Orthilia secunda	one-sided wintergreen	*	*	*
	Pyrola asarifolia	common pink wintergreen	*	*	*
	Pyrola minor	lesser wintergreen	*	*	
	Pyrola spp.	unidentified wintergreen	*	*	*
Ranunculaceae	*Actaea rubra*	red and white baneberry			*
	Anemone multifida	cut-leaved anemone	*	*	*
	Anemone parviflora	northern anemone	*	*	*
	Aquilegia brevistyla	blue columbine	*	*	
	Clematis occidentalis	purple clematis			*
	Delphinium glaucum	tall larkspur		*	*
	Anemone occidentalis	chalice-flower	*		*
	Anemone spp.	unidentified anemone		*	
	Ranunculus acris	tall buttercup	*		*
	Ranunculus pedatifidus	northern buttercup	*		
	Thalictrum venulosum	veiny meadow rue	*		*
Rosaceae	*Amelanchier alnifolia*	saskatoon	*		
	Fragaria spp.	wild strawberry	*	*	*
	Geum rivale	purple avens	*		*
	Geum triflorum	prairie smoke	*		
	Potentilla anserina	silverweed	*		
	Potentilla fruticosa	shrubby cinquefoil	*	*	
	Potentilla norvegica	rough cinquefoil		*	*
	Prunus pennsylvanica	pin cherry	*		
	Prunus virginiana	choke cherry	*		
	Rosa acicularis / woodsii	wild rose	*	*	*
	Rubus idaeus	wild red raspberry			*
	Rubus pubescens	dewberry	*	*	*
	Rubus acaulis	dwarf raspberry	*		*
	Senecio palustris	marsh ragwort	*	*	
	Senecio pseudaureus	thin-leaved ragwort	*	*	*
	Senecio pauperculus	canadian butterweed	*	*	
	Senecio streptanthifolius	ragwort		*	
	Senecio spp.	unidentified groundsels	*	*	*
	Sorbus scopulina	western mountain ash			*
	Spiraea betulifolia/lucida	white meadowsweet	*	*	*
Rubiaceae	*Galium boreale*	northern bedstraw	*	*	*
	Galium triflorum	sweet-scented bedstraw		*	*
Salicaceae	*Salix arbusculoides*	little tree willow	*		
	Salix barclayi	barclay’s willow	*		
	Salix bebbriana	bebb’s willow	*		
	Salix boothii		*		
	Salix farriae		*		
	Salix glauca	grey-leaved willow	*		
	Salix myrtillifolia	blueberry willow	*		
	Salix planifolia	tea-leaved willow	*		
	Salix pseudomonticola	mountain willow	*		
	Salix pyrifolia	balsam willow	*		
	Populus balsamifera	balsam poplar	*	*	*
	Populus tremuloides	trembling aspen	*	*	*

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Santalaceae	*Comandra pallida*	comandra	*	*	
	Geocaulon lividum	bastard toad-flax	*	*	
Saxifragaceae	*Heuchera flabellifolia*	alum-root	*		*
	Mitella nuda	bishop’s-cap			*
Scrophulariaceae	*Castilleja miniata*	red paint-brush	*	*	*
	Orthocarpus luteus	owl-clover	*		
	Pedicularis bracteosa	bracted lousewort			*
	Pedicularis labradorica	Labrador lousewort			*
	Veronica spp.	unident. speedwell spp.			*
Umbelliferae	*Heracleum lanatum*	cow parsnip			*
	Osmorhiza chilensis	sweet cicely			*
	Zizia aptera	meadow parsnip	*	*	
Urticaceae	*Urtica dioica*	common nettle			*
Violaceae	*Viola renifolia*	kidney-leaved violet			*
	Viola adunca	early blue violet		*	
	Viola spp.	unidentified violet		*	*

Vascular plant systematics based on:

Moss, E.H. 1983. Flora of Alberta. A manual of flowering plants, conifers, ferns and fern allies found growing without cultivation in the province of Alberta, Canada. 2nd edition. Revised by Packer, J.G. University of Toronto Press, Toronto, ON.

Appendix Table 4.2. Bird species observed in each forest type.[*]

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Anatidae	*Bucephala clangula*	common goldeneye	*	*	
	Bucephala albeola	bufflehead	*		
	Lophodytes cucullatus	hooded merganser	*		
Accipitridae	*Falco columbarius*	merlin		*	
	Falco striatus	sharp-shinned hawk		*	
	Buteo swainsoni	Swainson's hawk	*		
	Accipiter gentilis	northern goshawk		*	
	Haliaeetus leucocephalus	bald eagle		*	
	Aquila chrysaetos	golden eagle	*		
	Buteo jamaicensis	red-tailed hawk	*		
Falconidae	*Falco sparverius*	American kestrel		*	
Phasianidae	*Bonasa umbellus*	ruffed grouse	*	*	*
	Dengragapus obscurus	blue grouse	*		
	Dendragapus canadensis	spruce grouse	*	*	*
	Tympanuchus phasianellus	sharp-tailed grouse	*	*	*
Scolopacidae	*Bartramia longicauda*	upland sandpiper	*		
	Gallinago gallinago	common snipe	*	*	*
Strigidae	*Surnia ulula*	hawk owl	*		
Caprimulgidae	*Chordeiles minor*	common nighthawk	*	*	
Trochilidae	*Selasphorus rufus*	rufous hummingbird	*		
Alcedinidae	*Ceryle alcyon*	belted kingfisher	*	*	
Picidae	*Sphyrapicus varius*	yellow-bellied sapsucker		*	
	Picoides villosus	hairy woodpecker		*	
	Colaptes auratus	northern flicker	*	*	*
	Dryocopus pileatus	pileated woodpecker		*	
Tyrannidae	*Empidonax alnorum*	alder flycatcher	*		
	Empidonax traillii	willow flycatcher	*		
	Contopus sordidulus	western wood peewee	*		
Hirundinidae	*Riparia riparia*	bank swallow		*	
Corvidae	*Perisoreus canadensis*	gray jay	*	*	*
	Pica pica	black-billed magpie	*	*	*
	Corvus brachyrhynchos	American crow	*	*	*
	Corvus corax	common raven	*	*	*
Paridae	*Parus atricapillus*	black-capped chickadee	*	*	*
Sittidae	*Sitta canadensis*	red-breasted nuthatch	*		*
	Sitta carolinensis	white-breasted nuthatch		*	
Muscicapidae	*Regulus calendula*	ruby-crowned kinglet		*	
	Catharus ustulatus	Swainson's thrush	*	*	
	Catharus guttatus	hermit thrush	*	*	*
	Turdus migratorius	American robin	*	*	*
	Sialia currucoides	mountain bluebird	*		
	Ixoreus naevius	varied thrush		*	
	Catharus fuscescens	veery		*	*

Appendix Table 4.2 (cont'd). List of birds found in each forest type [*].

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Bombycillidae	*Bombycilla cedrorum*	cedar waxwing	*	*	
Vireonidae	*Vireo gilvus*	warbling vireo	*		*
	Vireo olivaceus	red-eyed vireo			*
Emberizidae	*Dendroica coronata*	yellow-rumped warbler	*	*	
	Spizella passerina	chipping sparrow		*	
	Melospiza melodia	song sparrow	*		
	Zonotrichia albicollis	white-throated sparrow	*	*	
	Zontrichia leucophrys	white-crowned sparrow	*		
	Junco hyemalis	dark-eyed junco	*	*	*
	Euphagus cyanocephalus	Brewer's blackbird		*	
	Agelaius phoeniceus	red-winged blackbird		*	
Fringillidae	*Carduelis pinus*	pine siskin		*	*

[*]Bird systematics based on *The Atlas of Breeding Birds of Alberta*; Edited by Glen P. Semenchuk, Federation of Alberta Naturalists 1992:

Appendix Table 4. 3. Mammal species observed in each forest type.*

Family	Scientific Name	Common Name	Spruce	Mixedwood	Pine
Leporidae	*Lepus americanus*	snowshoe hare	*	*	*
Sciuridae	*Tamias minimus*	least chipmunk	*	*	*
	Tamiasciurus hudsonicus	red squirrel	*	*	*
Cricetidae	*Peromyscus maniculatus*	deer mouse	*	*	
	Clethrionomys gapperi	southern red-backed vole	*		
	Microtus pennsylvanicus	meadow vole	*		
Erethizontidae	*Erethizon dorsatum*	porcupine			*
Canidae	*Canis latrans*	coyote	*	*	*
	Canis lupus	gray wolf	*		*
	Vulpes vulpes	red fox			
Ursidae	*Ursus americanus*	black bear	*	*	*
	Ursus arctos	grizzly bear	*		
Mustelidae	*Mustela erminea*	ermine	*	*	*
	Mustela nivalis	least weasel			
	Martes americana	marten	*		*
	Martes pennanti	fisher			
Felidae	*Lynx canadensis*	Canada lynx	*		*
	Felis concolor	cougar	*		
Cervidae	*Odocoileus virginianus*	white-tailed deer	*	*	*
	Odocoileus hemionus	mule deer	*	*	*
	Cervus elaphus	elk	*	*	*
	Alces alces	moose	*	*	*

*Mammal systematics based on:
MacDonald C.; Roberts W.E.; Ealey, D.M. 1993. The vertebrate species of Alberta. Alberta Naturalist 23:1–15.

APPENDIX 5. DATA SUMMARY TABLES

Appendix Table 5.1. Relative abundance (% cover) of plant species in mature SPRUCE forests and scarified cutblocks. Values >0 and <0.1 are represented by +.

Form Class and Species	Spruce Forest															
	Mature				Scarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Dwarf Shrubs																
Arctostaphylos uva-ursi	-	-	0.7	0.8	-	-	-	-	-	-	7.2	2.9	11.6	4.1	18.5	5.5
Clematis occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus communis	2.6	1.1	-	-	-	-	-	-	-	-	0.1	0.1	0.3	0.3	0.8	1.0
Juniperus horizontalis	0.8	0.5	-	-	0.1	0.1	+	+	+	+	0.6	0.5	1.4	1.0	2.8	1.5
Spiraea betulifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium caespitosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium vitis-idaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dwarf Shrub Total	3.4		0.7		0.1		+		+		7.9		13.3		22.0	
Forbs																
Achillea millifolium	-	-	-	-	0.1	0.1	-	-	-	-	0.1	+	+	+	0.1	0.1
Actaea rubra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agoseris glauca	-	-	-	-	+	+	+	+	+	+	+	+	+	+	0.1	0.1
Alyssum murale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anaphalis margaritacea	-	-	-	-	-	-	-	-	-	-	0.2	0.1	-	-	0.1	0.1
Androsace chamaejasme	-	-	+	+	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.3	0.4
Anemone multifida	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Anemone parviflora	-	-	0.2	0.1	-	-	-	-	-	-	+	+	+	+	0.1	0.1
Antennaria pulcherrima	+	+	+	+	0.1	0.2	0.1	0.1	0.3	0.4	-	-	0.2	0.1	0.2	0.2
Apocynum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aquilegia brevistyla	+	+	-	-	0.1	0.1	+	0.1	0.1	0.1	0.1	+	+	+	0.1	0.1
Aralia nudicaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arceuthobium pusillum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arnica cordifolia	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Aster ciliolatus	-	-	0.2	0.1	-	-	-	-	-	-	-	-	1.1	0.3	2.5	0.6
Aster conspicuus	+	+	-	-	0.4	0.4	-	-	0.2	0.4	-	-	+	+	-	-
Aster sibiricus	0.1	+	-	-	-	-	-	-	-	-	+	+	0.1	0.1	0.4	0.3
Aster spp.	-	-	-	-	-	-	0.4	0.3	1.1	0.7	0.2	0.1	-	-	-	-
Astragalus alpinus	-	-	-	-	-	-	-	-	-	-	0.2	0.2	+	+	0.6	0.5
Astragalus drummondii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus frigidus	-	-	+	+	-	-	-	-	-	-	0.3	0.2	0.5	0.3	1.7	0.7
Astragalus striatus	-	-	-	-	-	-	-	-	-	-	+	+	0.2	0.2	-	-
Braya richardsonii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	+	+	+	+	+	+	0.1	0.1	0.1	0.1	0.2	0.1	0.1	+	0.2	0.1
Castilleja miniata	-	-	-	-	+	+	-	-	-	-	+	+	+	+	0.1	0.1
Cerastium arvense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium album	-	-	-	-	+	+	-	-	+	+	-	-	-	-	-	-
Comandra pallida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cornus canadensis	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Cypripedium calceolus	-	-	0.1	0.1	-	-	-	-	-	-	+	+	0.1	0.1	+	+
Cypripedium passerinum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Delphinium glaucum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disporum trachycarpum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dodecatheon radicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epilobium angustifolium	-	-	-	-	+	+	0.1	0.1	0.1	0.1	0.3	0.1	0.3	0.2	0.2	0.1
Epilobium latifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron caespitosus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Erigeron glabellus	-	-	-	-	-	-	-	-	-	-	0.1	0.1	+	+	0.1	0.1
Erigeron ochroleucus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron philadelphicus	-	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-

Appendix Table 5.1 (cont'd). Relative abundance (% cover) of plant species in mature SPRUCE forests and scarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				Scarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Erigeron spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Fragaria virginiana	-	-	+	+	0.2	0.2	-	-	-	-	0.4	0.2	0.6	0.3	1.1	0.5
Galium boreale	-	-	0.1	0.1	+	0.1	-	-	-	-	1.2	0.4	1.0	0.3	3.0	0.6
Galium triflorum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gentianella amarella	-	-	+	+	-	-	-	-	-	-	-	-	0.1	+	+	+
Gentianella crinata	0.1	+	-	-	0.2	0.1	+	+	+	+	0.3	0.1	+	+	0.1	+
Geocalon lividum	-	-	1.6	0.6	-	-	-	-	-	-	0.1	0.1	0.3	0.2	1.0	0.5
Geranium bicknellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geum rivale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geum triflorum	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Goodyera repens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria hyperborea	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Habenaria obtusata	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria viridus	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
Hedysarum alpinum	-	-	0.2	0.2	-	-	-	-	-	-	-	-	0.9	0.5	2.9	0.7
Hedysarum boreale	0.9	0.3	-	-	0.7	0.4	0.3	0.2	0.6	0.3	1.3	0.4	1.3	0.8	1.0	0.9
Heracleum lanatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heuchera parvifolia	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Hieraceum umbellatum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Lathyrus ochroleucus	+	+	+	+	+	+	+	+	+	+	0.1	0.2	+	+	-	-
Lechea intermedia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lilium philadelphicum	-	-	-	-	-	-	+	+	+	+	0.1	0.1	+	+	0.1	0.1
Linnaea borealis	-	-	2.6	0.8	-	-	-	-	-	-	1.1	0.5	1.5	0.8	3.0	1.4
Maianthemum canadense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malaxis paludosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Matricaria matricarioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mertensia paniculata	0.2	0.1	-	-	0.5	0.4	0.7	0.4	0.7	0.6	0.5	0.2	0.3	0.1	0.6	0.3
Mitella nuda	-	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Moneses uniflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orchis rotundifolia	-	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	+	+
Orthilia secunda	-	-	0.1	0.1	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.3	0.2
Oryzopsis species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Osmorhiza chilensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxycoccus microcarpus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxytropis monticola	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1	-	-
Oxytropis splendens	-	-	-	-	+	+	-	-	0.1	0.1	0.3	0.2	0.3	0.2	0.6	0.4
Parnassus fimbreata	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-
Pedicularis bracteosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petasites palmatus	-	-	1.1	0.3	-	-	-	-	-	-	0.1	0.1	0.3	0.2	0.3	0.2
Petasites saggitatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantago major	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Polygonum viviparum	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Potentilla anserina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla norvegica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anemone occidentalis	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Pyrola asarifolia	-	-	0.1	0.1	-	-	-	-	-	-	0.1	0.1	0.2	0.1	0.4	0.2
Pyrola minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyrola spp.	-	-	+	+	-	-	-	-	-	-	+	+	0.1	0.1	0.1	+
Ranunculus acris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus acaulis	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Rubus pubescens	-	-	+	+	-	-	-	-	-	-	+	+	+	+	-	-
Rubus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table 5.1 (cont'd). Relative abundance (% cover) of plant species in mature SPRUCE forests and scarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				Scarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Senecio pauperculus	-	-	+	+	-	-	-	-	-	-	-	-	+	+	0.1	0.1
Senecio pseudaureus	+	+	-	-	-	-	0.1	0.1	0.7	0.4	0.2	0.1	0.1	+	-	-
Senecio spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3
Senecio streptanthifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sisymbrium species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sisyrinchium montanum	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
Smilacina racemosa	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Smilacina stellata	-	-	-	-	-	-	-	-	-	-	0.2	0.1	0.2	0.1	0.4	0.3
Solidago decumbens	+	+	-	-	0.1	0.1	+	+	0.1	0.1	-	-	0.1	0.1	+	+
Solidago gigantea	-	-	-	-	-	-	-	-	-	-	0.4	0.1	-	-	+	+
Solidago spp.	-	-	-	-	-	-	+	+	-	-	+	+	-	-	0.2	0.1
Sonchus arvensis	-	-	-	-	-	-	+	+	0.1	0.1	+	+	-	-	-	-
Spiranthus romanzoffiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longipes	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Streptopus amplexifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taraxacum officianale	-	-	+	+	-	-	+	+	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.1
Thalictrum venulosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tofieldia glutinosa	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Tragopogon dubius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium repens	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Unknown Forb	0.2	0.1	+	+	-	-	0.2	0.1	+	+	-	-	+	+	0.1	0.1
Veronica spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vicia americana	-	-	-	-	-	-	-	-	-	-	0.1	0.1	+	+	0.2	0.1
Viola renifolia	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Zizia cordata	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Zygadenus elegans	+	+	-	-	+	+	0.2	0.1	0.1	+	0.8	0.3	0.4	0.2	1.2	0.4
Forb Total	1.7		6.5		2.4		2.3		4.3		9.7		11.0		23.9	
Ferns and Fern Allies																
Botrychium lunaria	-	-	-	-	-	-	-	-	-	-	0.1	0.1	-	-	+	+
Equisetum arvense	-	-	0.7	0.9	-	-	-	-	-	-	-	-	+	+	+	+
Equisetum pratense	-	-	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum scirpoides	-	-	0.1	+	-	-	-	-	-	-	-	-	-	-	+	+
Equisetum spp.	-	-	+	+	-	-	-	-	-	-	0.1	+	-	-	-	-
Equisetum sylvaticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gymnocarpium dryopteris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium annotinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fern/Fern Ally Total	-		1.1		-		-		-		0.2		-		-	
Grasses																
Agropyron spicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3
Agropyron subsecundum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agropyron trachycaulum	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.2	-	-
Agrostis alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agrostis scabra	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Bromus inermis	-	-	-	-	0.1	0.1	+	+	0.1	0.1	0.1	0.1	1.4	0.9	5.2	1.1
Bromus marginata	+	0.1	-	-	-	-	0.1	0.1	-	-	-	-	-	-	-	-
Bromus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calamagrostis canadensis	-	-	-	-	-	-	-	-	-	-	+	+	+	+	0.1	0.2
Calamagrostis montanensi	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.2	0.1	0.2
Calamagrostis purpurescei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deschampsia caespitosa	0.6	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elymus canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elymus innovatus	5.7	1.5	1.5	0.7	26.9	5.0	25.9	4.5	47.1	5.7	19.2	2.5	17.4	2.5	21.4	3.4

Appendix Table 5.1 (cont'd). Relative abundance (% cover) of plant species in mature **SPRUCE** forests and scarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				Scarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Festuca rubra	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Festuca spp.	-	-	-	-	1.1	0.7	-	-	-	-	-	-	-	-	-	-
Glyceria striata	0.2	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phleum alpinum	-	-	-	-	+	+	-	-	+	+	-	-	-	-	-	-
Phleum pratense	-	-	-	-	+	+	0.1	0.1	0.1	0.1	-	-	-	-	-	-
Poa palustris	-	-	-	-	-	-	+	+	0.1	0.1	+	+	-	-	-	-
Poa pratense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	0.1
Poa secunda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Poa spp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Unknown Grass	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Grass Total	6.5		1.5		28.1		26.1		47.4		19.4		19.2		27.2	
Mosses and Lichens																
Cladonia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moss spp.	-		30.6	7.0	-	-	-	-	-	-	-	-	4.1	1.6	20.3	5.5
Lichen spp.	-	-	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Peltigera apthosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moss and Lichen Total	-		30.8		-		-		-		-		4.1		20.3	
Sedges and Rushes																
Carex aquatilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex aurea	-	-	-	-	-	-	-	-	0.2	0.1	1.2	0.5	0.8	0.4	1.4	0.8
Carex capillaria	-	-	-	-	-	-	-	-	1.9	0.7	-	-	0.5	0.4	-	-
Carex eburnea	7.9	2.3	-	-	-	-	0.6	0.3	1.3	0.6	0.6	0.3	0.7	0.3	1.8	0.9
Carex flava	9.5	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex interior	0.4	0.6	-	-	-	-	+	+	+	0.1	-	-	-	-	+	+
Carex lacustris	-	-	-	-	-	-	-	-	0.2	0.2	-	-	-	-	-	-
Carex spp.	3.2	1.8	-	-	2.2	1.3	1.6	0.8	0.2	0.2	-	-	-	-	2.2	1.1
Juncus balticus	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus nodosus	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Juncus parryi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luzula parviflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sedge and Rush Total	21.0		-		2.2		2.2		3.7		1.8		2.0		5.4	

Appendix Table 5.2. Relative abundance of plant species in mature SPRUCE forests and unscarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				Unscarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Dwarf Shrubs																
Arctostaphylos uva-ursi	-	-	0.7	0.8	-	-	-	-	-	-	11.3	3.9	13.3	4.1	18.7	5.0
Clematis occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus communis	2.6	1.1	-	-	0.2	0.3	0.1	0.2	0.3	0.5	1.6	1.7	2.5	2.4	4.0	2.8
Juniperus horizontalis	0.8	0.5	-	-	0.1	0.1	0.1	0.1	0.1	0.2	0.5	0.6	1.1	1.1	2.2	2.1
Spiraea betulifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Vaccinium caespitosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium vitis-idaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dwarf Shrub Total	3.4		0.7		0.3		0.2		0.4		13.4		16.9		24.9	
Forbs																
Achillea millifolium	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Actaea rubra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agoseris glauca	-	-	-	-	+	+	+	+	+	0.1	+	+	-	-	-	-
Alyssum murale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anaphalis margaritacea	-	-	-	-	-	-	-	-	-	-	0.2	0.1	-	-	-	-
Androsace chamaejasme	-	-	+	+	-	-	-	-	-	-	-	-	+	+	+	+
Anemone multifida	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Anemone parviflora	-	-	0.2	0.1	-	-	-	-	-	-	+	+	0.1	+	0.5	0.2
Antennaria pulcherrima	+	+	+	+	0.1	0.1	0.2	0.2	0.6	0.4	-	-	0.3	0.1	0.7	0.2
Apocynum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aquilegia brevistyla	+	+	-	-	+	+	+	+	+	0.1	0.2	0.1	+	+	+	+
Aralia nudicaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arceuthobium pusillum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arnica cordifolia	-	-	-	-	-	-	-	-	-	-	0.1	+	+	+	-	-
Aster ciliolatus	-	-	0.2	0.1	-	-	-	-	-	-	-	-	0.7	0.2	1.4	0.4
Aster conspicuus	+	+	-	-	1.1	0.7	+	+	-	-	-	-	-	-	-	-
Aster sibiricus	0.1	+	-	-	-	-	0.1	0.3	-	-	0.1	0.1	0.1	0.1	0.1	0.1
Aster spp.	-	-	-	-	+	+	-	-	1.5	0.6	0.4	0.1	-	-	-	-
Astragalus alpinus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	0.1	0.1
Astragalus drummondii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus frigidus	-	-	+	+	-	-	-	-	-	-	0.6	0.3	0.6	0.3	1.6	0.6
Astragalus striatus	-	-	-	-	-	-	-	-	-	-	+	+	0.1	0.1	+	0.1
Braya richardsonii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	+	+	+	+	0.1	0.1	+	+	+	+	0.1	+	+	+	+	+
Castilleja miniata	-	-	-	-	-	-	+	+	-	-	+	+	0.1	0.1	0.1	0.1
Cerastium arvense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium album	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Comandra pallida	-	-	-	-	-	-	-	-	-	-	0.1	+	-	-	+	+
Cornus canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cypripedium calceolus	-	-	0.1	0.1	-	-	-	-	-	-	+	+	+	+	-	-
Cypripedium passerinum	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Delphinium glaucum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disporum trachycarpum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dodecatheon radicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epilobium angustifolium	-	-	-	-	+	+	+	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Epilobium latifolia	-	-	-	-	+	+	-	-	-	-	-	-	-	-	+	+
Erigeron caespitosus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Erigeron glabellus	-	-	-	-	-	-	+	+	-	-	+	+	-	-	+	+
Erigeron ochroleucus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron philadelphicus	-	-	-	-	+	0.1	+	+	+	+	-	-	-	-	-	-
Erigeron spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fragaria virginiana	-	-	+	+	0.3	0.2	-	-	-	-	0.6	0.2	0.7	0.3	1.3	0.5
Galium boreale	-	-	0.1	0.1	-	-	-	-	-	-	0.8	0.2	0.6	0.2	1.6	0.4

Appendix Table 5.2 (cont'd). Relative abundance of plant species in mature **SPRUCE** forests and unscarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				**Unscarified**											
	Yr 4 1960		**Yr 39 1995**		**Yr 3 1959**		**Yr 4 1960**		**Yr 5 1961**		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Galium triflorum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gentianella amarella	-	-	+	+	+	+	-	-	-	-	-	-	0.1	0.1	-	-
Gentianella crinata	0.1	+	-	-	-	-	+	+	+	+	0.2	0.1	+	+	0.1	0.1
Geocalon lividum	-	-	1.6	0.6	-	-	-	-	-	-	0.8	0.2	1.3	0.3	2.0	0.5
Geranium bicknellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geum rivale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geum triflorum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodyera repens	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Habenaria hyperborea	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Habenaria obtusata	-	-	+	+	-	-	-	-	-	-	-	-	+	+	-	-
Habenaria viridus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Hedysarum alpinum	-	-	0.2	0.2	-	-	-	-	-	-	-	-	0.7	0.5	2.1	0.6
Hedysarum boreale	0.9	0.3	-	-	1.7	0.7	1.3	0.5	2.3	1.0	1.9	0.9	1.5	0.7	1.5	0.9
Heracleum lanatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heuchera parvifolia	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Hieraceum umbellatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Lathyrus ochroleucus	+	+	+	+	-	-	0.1	0.1	-	-	+	+	-	-	-	-
Lechea intermedia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.2
Lilium philadelphicum	-	-	-	-	-	-	+	+	+	+	0.1	0.1	+	+	0.1	+
Linnaea borealis	-	-	2.6	0.8	-	-	-	-	-	-	3.5	1.3	2.6	1.0	7.6	2.2
Maianthemum canadense	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Malaxis paludosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Matricaria matricariodes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mertensia paniculata	0.2	0.1	-	-	0.5	0.5	0.2	0.2	0.4	0.4	0.3	0.1	0.3	0.1	0.4	0.2
Mitella nuda	-	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Moneses uniflora	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Orchis rotundifolia	-	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Orthilia secunda	-	-	0.1	0.1	-	-	-	-	-	-	0.3	0.1	+	+	0.3	0.2
Oryzopsis species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Osmorhiza chilensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxycoccus microcarpus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxytropis monticola	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Oxytropis splendens	-	-	-	-	0.1	0.1	-	-	+	+	0.1	+	+	0.1	0.1	0.1
Parnassus fimbreata	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Pedicularis bracteosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petasites palmatus	-	-	1.1	0.3	-	-	-	-	-	-	0.2	0.1	0.3	0.1	0.4	0.2
Petasites saggitatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantago major	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polygonum viviparum	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Potentilla anserina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla norvegica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anemone occidentalis	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Pyrola asarifolia	-	-	0.1	0.1	-	-	-	-	-	-	0.4	0.1	0.2	0.1	0.4	0.2
Pyrola minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.1
Pyrola spp.	-	-	+	+	-	-	-	-	-	-	-	-	0.1	0.1	0.2	0.2
Ranunculus acris	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Rubus acaulis	0.1	0.1	-	-	-	-	+	+	0.1	0.1	-	-	-	-	0.1	0.1
Rubus pubescens	-	-	+	+	+	+	-	-	-	-	0.1	0.1	0.1	0.1	-	-
Rubus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio pauperculus	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+
Senecio pseudaureus	+	+	-	-	-	-	0.6	0.3	0.7	0.3	0.2	0.1	+	+	-	-

Appendix Table 5.2 (cont'd). Relative abundance of plant species in mature SPRUCE forests and unscarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				Unscarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Senecio spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1
Senecio streptanthifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sisymbrium species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sisyrinchium montanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smilacina racemosa	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Smilacina stellata	-	-	-	-	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.3	0.2
Solidago decumbens	+	+	-	-	-	-	+	+	+	+	-	-	0.1	0.1	+	+
Solidago gigantea	-	-	-	-	-	-	-	-	-	-	0.3	0.1	+	0.1	+	+
Solidago spp.	-	-	-	-	-	-	-	-	-	-	+	+	-	-	0.2	0.1
Sonchus arvensis	-	-	-	-	-	-	-	-	+	+	+	+	+	+	-	-
Spiranthus romanzoffiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Streptopus amplexifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taraxacum officianale	-	-	+	+	+	+	+	+	+	+	0.1	0.1	+	+	0.1	0.1
Thalictrum venulosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tofieldia glutinosa	-	-	-	-	-	-	-	-	-	-	+	+	0.1	0.1	0.1	0.1
Tragopogon dubius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium repens	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Unknown Forb	0.2	0.1	+	+	-	-	1.0	0.4	-	-	-	-	+	+	+	+
Veronica spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vicia americana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.1
Viola renifolia	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Zizia cordata	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Zygadenus elegans	+	+	-	-	0.2	0.2	0.5	0.5	0.1	0.1	0.3	0.1	0.2	0.1	0.3	0.1
Forb Total	1.7		6.5		4.2		4.2		6.0		12.3		11.0		25.1	
Ferns and Fern Allies																
Botrychium lunaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum arvense	-	-	0.7	0.9	-	-	-	-	-	-	-	-	0.5	0.4	1.0	0.5
Equisetum pratense	-	-	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum scirpoides	-	-	0.1	+	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum spp.	-	-	+	+	-	-	-	-	-	-	0.7	0.3	-	-	+	+
Equisetum sylvaticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gymnocarpium dryopteris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium annotinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fern/Fern Ally Total	-		1.1		-		-		-		0.7		0.5		1.0	
Grasses																
Agropyron spicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agropyron subsecundum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agropyron trachycaulum	-	-	-	-	+	0.1	+	+	-	-	+	+	-	-	-	-
Agrostis alba	-	-	-	-	-	-	0.4	0.7	+	+	+	+	-	-	+	+
Agrostis scabra	-	-	-	-	0.1	0.2	+	+	+	+	-	-	0.1	0.1	-	-
Bromus inermis	-	-	-	-	0.2	0.3	0.1	0.2	0.2	0.2	0.6	0.3	3.2	0.9	1.8	0.7
Bromus marginata	+	0.1	-	-	-	-	+	+	+	+	-	-	-	-	-	-
Bromus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calamagrostis canadensis	-	-	-	-	0.2	0.2	-	-	-	-	2.9	1.1	0.1	0.1	-	-
Calamagrostis montanensis	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1	-	-
Calamagrostis purpurescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	0.1
Deschampsia caespitosa	0.6	0.6	-	-	-	-	+	+	+	+	+	+	-	-	-	-
Elymus canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table 5.2 (cont'd). Relative abundance of plant species in mature **SPRUCE** forests and unscarified cutblocks.

Form Class and Species	Spruce Forest															
	Mature				Unscarified											
	Yr 4 1960		Yr 39 1995		Yr 3 1959		Yr 4 1960		Yr 5 1961		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Elymus innovatus	5.7	1.5	1.5	0.7	33.4	5.5	23.6	4.0	35.0	5.0	14.2	2.0	9.4	1.7	15.7	3.4
Festuca rubra	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Festuca spp.	-	-	-	-	2.3	1.4	-	-	-	-	-	-	-	-	-	-
Glyceria striata	0.2	0.3	-	-	0.9	0.8	0.9	0.6	1.6	1.2	-	-	-	-	-	-
Phleum alpinum	-	-	-	-	0.2	0.2	-	-	-	-	-	-	-	-	-	-
Phleum pratense	-	-	-	-	+	+	0.1	0.1	0.1	0.1	-	-	-	-	-	-
Poa palustris	-	-	-	-	-	-	-	-	+	0.1	+	+	-	-	-	-
Poa pratense	-	-	-	-	+	0.1	+	+	-	-	-	-	+	+	+	+
Poa secunda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poa spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unknown Grass	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Grass Total	6.5		1.5		37.3		25.1		37.0		17.8		12.8		17.5	
Mosses and Lichens																
Cladonia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moss spp.	-		30.6	7.0	-	-	-	-	-	-	-	-	6.1	2.5	15.2	4.5
Lichen spp.	-	-	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Peltigera apthosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moss and Lichen Total	-		30.8		-		-		-		-		6.1		15.2	
Sedges and Rushes																
Carex aquatilis	-	-	-	-	-	-	-	-	0.2	0.3	-	-	-	-	+	+
Carex aurea	-	-	-	-	-	-	-	-	-	-	0.9	0.5	0.7	0.3	0.7	0.5
Carex capillaria	-	-	-	-	-	-	-	-	5.5	1.8	+	+	2.0	0.8	-	-
Carex eburnea	7.9	2.3	-	-	-	-	1.6	1.1	2.3	1.2	0.9	0.5	1.0	0.4	2.7	1.2
Carex flava	9.5	2.1	-	-	-	-	-	-	0.1	0.1	-	-	-	-	-	-
Carex interior	0.4	0.6	-	-	-	-	0.5	0.6	1.3	1.1	-	-	-	-	-	-
Carex lacustris	-	-	-	-	-	-	-	-	0.6	0.5	-	-	-	-	-	-
Carex spp.	3.2	1.8	-	-	3.5	1.7	2.6	1.4	-	-	0.4	0.5	1.2	1.2	6.8	1.9
Juncus balticus	+	+	-	-	+	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.7	0.6	0.3	0.2
Juncus nodosus	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Juncus parryi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Juncus spp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Luzula parviflora	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Sedge and Rush Total	21.0		-		3.5		4.8		10.1		2.5		5.4		10.5	

Appendix Table 5.3. Relative abundance of plant species in mature **MIXEDWOOD** forests and cutblocks.

Form Class and Species	Mixedwood Forest													
	Mature		Scarified						Unscarified					
	Yr 39 1995		Yr 26 1982		Yr 32 1988		Yr 39 1995		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Dwarf Shrubs														
Arctostaphylos uva-ursi	0.7	0.6	2.2	1.3	6.7	2.6	12.0	4.4	3.6	1.7	5.6	2.4	3.4	2.1
Clematis occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus communis	0.1	0.1	-	-	-	-	-	-	+	+	-	-	-	-
Juniperus horizontalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiraea betulifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium caespitosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium vitis-idaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dwarf Shrub Total	0.8		2.2		6.7		12.0		3.6		5.6		3.4	
Forbs														
Achillea millifolium	0.1	+	0.7	0.2	0.5	0.1	2.6	0.5	0.5	0.1	0.2	0.1	0.4	0.2
Actaea rubra	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agoseris glauca	-	-	+	+	0.1	0.1	0.1	0.1	+	+	+	+	-	-
Alyssum murale	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anaphalis margaritacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Androsace chamaejasme	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anemone multifida	-	-	+	+	+	+	0.1	0.1	+	+	+	+	+	+
Anemone parviflora	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Antennaria pulcherrima	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Apocynum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aquilegia brevistyla	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Aralia nudicaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arceuthobium pusillum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arnica cordifolia	+	+	-	-	-	-	-	-	-	-	+	+	+	+
Aster ciliolatus	1.3	0.5	-	-	0.4	0.3	4.3	0.8	-	-	0.9	0.3	2.9	0.7
Aster conspicuus	1.0	0.4	-	-	0.2	0.2	0.2	0.3	-	-	0.2	0.2	-	-
Aster sibiricus	-	-	+	+	-	-	-	-	+	+	-	-	-	-
Aster spp.	-	-	1.1	0.2	-	-	+	+	1.1	0.3	-	-	+	+
Astragalus alpinus	-	-	-	-	0.2	0.1	0.3	0.2	-	-	0.1	0.1	0.1	0.1
Astragalus drummondii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus frigidus	0.2	0.3	0.4	0.2	0.2	0.2	0.5	0.5	0.1	0.1	0.1	0.1	+	+
Astragalus striatus	-	-	+	0.1	-	-	0.1	0.1	+	+	-	-	-	-
Braya richardsonii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	-	-	0.2	0.1	+	+	+	+	0.1	+	+	+	+	+
Castilleja miniata	-	-	-	-	-	-	+	+	-	-	+	+	-	-
Cerastium arvense	-	-	0.1	0.1	-	-	+	+	-	-	-	-	-	-
Chenopodium album	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Comandra pallida	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Cornus canadensis	0.3	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Cypripedium calceolus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cypripedium passerinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delphinium glaucum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disporum trachycarpum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dodecatheon radicatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epilobium angustifolium	1.1	0.4	0.8	0.2	0.4	0.3	0.5	0.3	0.4	0.1	0.7	0.2	1.0	0.4
Epilobium latifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron caespitosus	-	-	-	-	0.1	0.1	+	+	-	-	+	+	-	-
Erigeron glabellus	-	-	+	+	0.1	0.1	0.1	0.2	0.1	0.1	+	+	0.1	0.1
Erigeron ochroleucus	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Erigeron philadelphicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron spp.	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Fragaria virginiana	2.3	0.5	1.5	0.3	2.0	0.5	4.8	0.8	1.9	0.4	2.9	0.6	5.1	0.9
Galium boreale	0.3	0.1	1.7	0.3	1.5	0.2	3.8	0.5	0.9	0.2	0.8	0.2	0.8	0.2

Appendix Table 5.3 (cont'd). Relative abundance of plant species in mature **MIXEDWOOD** forests and cutblocks.

Form Class and Species	**Mixedwood Forest**													
	Mature		**Scarified**						**Unscarified**					
	Yr 39 1995		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Galium triflorum	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Gentianella amarella	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gentianella crinata	-	-	0.1	0.1	+	+	+	+	0.1	0.1	+	+	+	+
Geocalon lividum	0.4	0.1	-	-	-	-	-	-	-	-	+	0.1	0.1	0.1
Geranium bicknellii	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geum rivale	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Geum triflorum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodyera repens	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria hyperborea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria obtusata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria viridus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hedysarum alpinum	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Hedysarum boreale	-	-	0.1	0.1	0.2	0.1	0.5	0.3	0.1	0.1	0.1	0.1	0.2	0.2
Heracleum lanatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heuchera parvifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hieraceum umbellatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lathyrus ochroleucus	3.0	0.5	1.0	0.2	1.5	0.3	12.2	2.0	0.8	0.2	0.9	0.2	3.8	0.8
Lechea intermedia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lilium philadelphicum	+	+	+	+	+	+	+	+	+	+	+	+	0.1	0.1
Linnaea borealis	5.3	1.2	+	+	+	+	0.2	0.1	0.7	0.3	0.8	0.3	10.2	2.4
Maianthemum canadense	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Malaxis paludosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Matricaria matricarioides	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Mertensia paniculata	-	-	-	-	0.3	0.1	-	-	+	+	-	-	-	-
Mitella nuda	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moneses uniflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orchis rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthilia secunda	+	+	+	+	+	+	-	-	+	+	-	-	-	-
Oryzopsis species	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Osmorhiza chilensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxycoccus microcarpus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxytropis monticola	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxytropis splendens	-	-	0.2	0.1	0.5	0.4	0.3	0.3	0.1	0.1	0.2	0.2	-	-
Parnassus fimbreata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pedicularis bracteosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petasites palmatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petasites saggitatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantago major	-	-	+	+	-	-	-	-	+	+	+	+	0.1	0.1
Polygonum viviparum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla anserina	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla norvegica	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anemone occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyrola asarifolia	+	+	-	-	+	+	+	+	+	+	-	-	-	-
Pyrola minor	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Pyrola spp.	+	+	-	-	-	-	+	+	-	-	-	-	0.1	0.1
Ranunculus acris	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus acaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubus pubescens	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Rubus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio pauperculus	-	-	-	-	+	+	+	+	-	-	+	+	-	-
Senecio pseudaureus	-	-	0.1	0.1	+	+	-	-	0.1	0.1	-	-	+	+
Senecio spp.	-	-	-	-	-	-	0.1	0.1	-	-	-	-	+	+
Senecio streptanthifolius	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Sisymbrium species	-	-	-	-	-	-	+	+	-	-	-	-	-	-

Appendix Table 5.3 (cont'd). Relative abundance of plant species in mature **MIXEDWOOD** forests and cutblocks.

Form Class and Species	**Mixedwood Forest**													
	Mature		**Scarified**						**Unscarified**					
	Yr 39 1995		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Sisyrinchium montanum	-	-	+	+	+	+	-	-	+	+	+	+	-	-
Smilacina racemosa	-	-	-	-	-	-	0.2	0.4	-	-	0.1	0.1	0.1	0.1
Smilacina stellata	0.6	0.3	1.8	0.4	1.4	0.4	0.8	0.3	1.0	0.2	1.3	0.4	1.5	0.5
Solidago decumbens	-	-	-	-	-	-	0.1	0.1	-	-	+	+	-	-
Solidago gigantea	-	-	0.1	0.1	-	-	-	-	0.1	0.1	-	-	-	-
Solidago spp.	-	-	-	-	-	-	0.2	0.2	-	-	-	-	+	+
Sonchus arvensis	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Spiranthus romanzoffiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longipes	-	-	+	+	+	+	0.1	0.1	+	+	+	+	-	-
Streptopus amplexifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taraxacum officianale	-	-	0.2	0.1	0.1	0.1	0.3	0.4	0.1	+	+	+	+	+
Thalictrum venulosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tofieldia glutinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tragopogon dubius	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Trifolium pratense	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium repens	-	-	0.4	0.4	+	+	0.3	0.5	0.2	0.1	+	0.1	0.2	0.4
Unknown Forb	+	+	-	-	+	+	+	+	-	-	+	+	+	0.1
Veronica spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vicia americana	0.1	0.1	0.9	0.4	0.6	0.1	2.4	0.8	0.5	0.1	0.5	0.2	0.7	0.4
Viola renifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zizia cordata	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Zygadenus elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Forb Total	16.1		10.6		9.0		23.0		8.0		9.2		23.6	
Ferns and Fern Allies														
Botrychium lunaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum arvense	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Equisetum pratense	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum scirpoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum sylvaticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gymnocarpium dryopteris	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium annotinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycopodium spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fern/Fern Ally Total	-		-		-		-		-		+		-	
Grasses														
Agropyron spicatum	-	-	+	+	+	+	-	-	+	+	-	-	-	-
Agropyron subsecundum	-	-	0.1	0.1	-	-	-	-	0.1	0.1	-	-	-	-
Agropyron trachycaulum	-	-	+	+	+	+	1.3	1.0	+	+	+	+	0.5	0.4
Agrostis alba	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Agrostis scabra	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bromus inermis	0.2	0.2	5.1	1.6	4.6	0.7	8.4	1.7	2.2	0.8	5.6	1.0	3.3	0.9
Bromus marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bromus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calamagrostis canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calamagrostis montanensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calamagrostis purpurescens	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Deschampsia caespitosa	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Elymus canadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elymus innovatus	7.9	1.3	16.8	2.4	12.9	1.6	21.6	2.3	12.6	1.8	9.8	1.4	15.7	2.5
Festuca rubra	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Festuca spp.	-	-	-	-	-	-	+	0.1	-	-	+	+	-	-
Glyceria striata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phleum alpinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table 5.3 (cont'd). Relative abundance of plant species in mature **MIXEDWOOD** forests and cutblocks.

Form Class and Species	**Mixedwood Forest**													
	Mature		**Scarified**						**Unscarified**					
	Yr 39 1995		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**		**Yr 26 1982**		**Yr 32 1988**		**Yr 39 1995**	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Phleum pratense	-	-	0.7	0.5	0.1	0.1	0.2	0.2	0.1	0.1	-	-	+	0.1
Poa palustris	-	-	0.5	0.2	0.2	0.2	-	-	0.2	0.1	0.1	0.1	-	-
Poa pratense	-	-	0.7	0.4	0.1	0.1	2.8	0.9	0.1	0.2	+	+	+	+
Poa secunda	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poa spp.	-	-	-	-	0.1	0.1	0.9	0.5	-	-	+	+	0.4	0.7
Unknown Grass	-	-	-	-	+	+	+	+	-	-	+	+	+	+
Grass Total	8.1		24.0		18.0		35.3		15.4		15.6		20.0	
Mosses and Lichens														
Cladonia spp.	-	-	-	-	-	-	+	+	-	-	+	+	0.1	0.1
Moss spp.	67.5	5.7	-	-	25.0	6.1	37.1	6.6	-	-	59.2	6.5	67.8	7.4
Lichen spp.	11.8	3.3												
Peltigera apthosa	-	-	-	-	1.1	0.4	2.4	1.3	-	-	1.3	0.6	2.3	0.9
Moss and Lichen Total	79.3		-		26.2		39.6		-		60.5		70.2	
Sedges and Rushes														
Carex aquatilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex aurea	-	-	-	-	0.8	0.4	0.6	0.3	0.1	0.1	0.1	0.1	+	+
Carex capillaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex eburnea	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex flava	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex interior	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex lacustris	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex spp.	+	+	0.6	0.3	-	-	0.4	0.4	0.3	0.2	+	+	-	-
Juncus balticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus nodosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus parryi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juncus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luzula parviflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sedge and Rush Total			0.6		0.8		1.0		0.4		0.1			

Appendix Table 5.4. Relative abundance of plant species on scarified and unscarified **PINE** forests.

Form Class and Species	Pine Forest											
	Scarified						Unscarified					
	Yr 26 1982		Yr 32 1988		Yr 39 1995		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Dwarf Shrubs												
Arctostaphylos uva-ursi	0.3	0.5	0.4	0.9	0.5	1.0	+	+	-	-	-	-
Clematis occidentalis	-	-	-	-	+	+	-	-	-	-	-	-
Juniperus communis	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus horizontalis	-	-	-	-	-	-	-	-	-	-	-	-
Spiraea betulifolia	0.1	0.1	0.2	0.1	0.4	0.4	0.1	0.1	0.2	0.1	0.5	0.3
Vaccinium caespitosum	0.3	0.2	0.7	0.7	1.0	0.9	0.4	0.6	1.0	1.2	1.2	1.5
Vaccinium vitis-idaea	-	-	0.1	0.1	-	-	-	-	-	-	-	-
Dwarf Shrub Total	0.6		1.4		2.0		0.6		1.2		1.7	
Forbs												
Achillea millifolium	+	+	+	+	+	+	+	+	+	+	+	+
Actaea rubra	0.3	0.2	0.3	0.2	0.6	0.4	+	0.1	+	+	-	-
Agoseris glauca	-	-	-	-	-	-	-	-	-	-	-	-
Alyssum murale	-	-	-	-	-	-	-	-	-	-	-	-
Anaphalis margaritacea	-	-	-	-	-	-	-	-	-	-	-	-
Androsace chamaejasme	-	-	-	-	-	-	-	-	-	-	-	-
Anemone multifida	-	-	-	-	+	+	-	-	-	-	-	-
Anemone parviflora	-	-	-	-	-	-	-	-	-	-	+	+
Antennaria pulcherrima	-	-	-	-	-	-	-	-	-	-	-	-
Apocynum spp.	-	-	-	-	0.1	0.1	-	-	-	-	-	-
Aquilegia brevistyla	-	-	-	-	-	-	-	-	-	-	-	-
Aralia nudicaulis	-	-	0.1	0.1	0.7	0.5	-	-	+	+	-	-
Arceuthobium pusillum	-	-	-	-	+	+	-	-	-	-	-	-
Arnica cordifolia	+	+	0.7	0.2	1.5	0.5	0.1	0.1	0.8	0.3	1.4	0.4
Aster ciliolatus	-	-	1.0	0.2	4.3	1.4	-	-	0.7	0.3	3.4	1.1
Aster conspicuus	-	-	1.1	0.4	0.8	0.5	-	-	1.3	0.6	0.9	0.9
Aster sibiricus	-	-	-	-	-	-	-	-	-	-	-	-
Aster spp.	1.0	0.2	-	-	-	-	0.8	0.2	-	-	-	-
Astragalus alpinus	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus drummondii	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus frigidus	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus striatus	-	-	-	-	-	-	-	-	-	-	-	-
Braya richardsonii	-	-	-	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-
Castilleja miniata	+	+	0.1	0.1	0.1	0.1	+	+	0.2	0.1	+	+
Cerastium arvense	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium album	-	-	-	-	-	-	-	-	-	-	-	-
Comandra pallida	-	-	-	-	-	-	-	-	-	-	-	-
Cornus canadensis	2.6	0.6	3.6	0.7	11.5	2.5	1.8	0.4	3.1	0.6	11.4	2.1
Cypripedium calceolus	-	-	-	-	-	-	-	-	-	-	-	-
Cypripedium passerinum	-	-	-	-	-	-	-	-	-	-	-	-
Delphinium glaucum	0.1	0.1	0.1	0.1	0.3	0.2	+	+	0.1	0.1	0.1	0.2
Disporum trachycarpum	-	-	-	-	-	-	-	-	-	-	-	-
Dodecatheon radicatum	-	-	-	-	-	-	-	-	-	-	-	-
Draba spp.	-	-	-	-	-	-	-	-	-	-	-	-
Epilobium angustifolium	5.1	0.9	6.9	1.2	14.0	2.8	4.2	0.7	8.9	1.5	11.9	1.7
Epilobium latifolia	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron caespitosus	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron glabellus	-	-	-	-	-	-	-	-	+	+	-	-
Erigeron ochroleucus	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron philadelphicus	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron spp.	-	-	-	-	-	-	-	-	-	-	-	-
Fragaria virginiana	0.4	0.2	0.5	0.2	1.1	0.4	0.4	0.1	0.5	0.2	1.2	0.5
Galium boreale	0.1	0.1	0.1	+	0.2	0.1	+	+	+	+	+	+

Appendix Table 5.4 (cont'd). Relative abundance of plant species on scarified and unscarified PINE forests.

Form Class and Species	Pine Forest											
	Scarified						Unscarified					
	Yr 26 1982		Yr 32 1988		Yr 39 1995		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Galium triflorum	+	+	+	+	0.1	0.1	+	+	+	+	0.1	0.1
Gentianella amarella	0.1	0.1	-	-	-	-	0.1	+	-	-	-	-
Gentianella crinata	+	+	+	+	+	+	+	+	+	+	+	0.1
Geocalon lividum	-	-	-	-	-	-	-	-	-	-	-	-
Geranium bicknellii	+	+	0.1	0.1	0.4	0.3	-	-	-	-	-	-
Geum rivale	-	-	+	0.1	-	-	-	-	+	+	-	-
Geum triflorum	-	-	-	-	-	-	-	-	-	-	-	-
Goodyera repens	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria hyperborea	+	+	-	-	+	+	-	-	-	-	-	-
Habenaria obtusata	-	-	-	-	-	-	-	-	-	-	-	-
Habenaria viridus	+	+	+	+	+	+	+	+	+	+	-	-
Hedysarum alpinum	-	-	-	-	-	-	-	-	-	-	-	-
Hedysarum boreale	-	-	-	-	-	-	-	-	-	-	-	-
Heracleum lanatum	0.7	0.4	1.3	0.7	2.7	1.2	0.3	0.3	0.8	0.6	1.7	1.3
Heuchera parvifolia	-	-	0.1	0.1	-	-	-	-	+	+	-	-
Hieraceum umbellatum	-	-	-	-	-	-	-	-	-	-	-	-
Lathyrus ochroleucus	0.1	+	0.1	0.1	0.5	0.3	+	+	+	+	+	+
Lechea intermedia	-	-	-	-	-	-	-	-	-	-	-	-
Lilium philadelphicum	-	-	+	+	-	-	-	-	-	-	-	-
Linnaea borealis	1.6	0.7	1.8	0.7	7.2	1.9	1.3	0.4	2.5	0.8	9.3	2.4
Maianthemum canadense	-	-	0.6	0.2	2.1	0.7	-	-	0.2	0.1	1.4	0.5
Malaxis paludosa	-	-	-	-	+	+	-	-	-	-	0.1	0.1
Matricaria matricarioides	-	-	-	-	-	-	-	-	-	-	-	-
Mertensia paniculata	0.9	0.2	1.0	0.3	3.7	1.1	0.6	0.2	1.2	0.3	4.0	1.2
Mitella nuda	-	-	-	-	1.3	0.5	-	-	+	+	1.0	0.5
Moneses uniflora	-	-	-	-	-	-	-	-	-	-	-	-
Orchis rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-
Orthilia secunda	+	+	-	-	0.1	0.2	-	-	-	-	0.1	0.1
Oryzopsis species	-	-	-	-	-	-	-	-	-	-	-	-
Osmorhiza chilensis	-	-	-	-	0.1	0.2	-	-	-	-	+	+
Oxycoccus microcarpus	+	+	-	-	0.1	0.1	+	+	-	-	+	0.1
Oxytropis monticola	-	-	-	-	-	-	-	-	-	-	-	-
Oxytropis splendens	-	-	-	-	+	+	-	-	-	-	-	-
Parnassus fimbreata	-	-	+	+	-	-	-	-	-	-	-	-
Pedicularis bracteosa	-	-	-	-	-	-	-	-	-	-	+	+
Petasites palmatus	0.5	0.2	0.9	0.3	2.4	1.0	0.3	0.1	0.6	0.3	1.8	0.7
Petasites saggitatus	-	-	-	-	+	+	-	-	-	-	-	-
Plantago major	-	-	-	-	-	-	-	-	-	-	-	-
Polygonum viviparum	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla anserina	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla norvegica	-	-	-	-	-	-	-	-	-	-	-	-
Anemone occidentalis	-	-	-	-	-	-	-	-	-	-	-	-
Pyrola asarifolia	0.2	0.1	0.3	0.1	0.8	0.4	0.2	0.1	0.5	0.2	1.5	0.5
Pyrola minor	-	-	-	-	-	-	-	-	-	-	-	-
Pyrola spp.	-	-	0.1	0.1	+	+	-	-	+	+	-	-
Ranunculus acris	-	-	-	-	-	-	-	-	-	-	-	-
Rubus acaulis	-	-	-	-	0.1	0.1	-	-	-	-	-	-
Rubus pubescens	0.7	0.2	1.3	0.3	3.6	1.0	0.8	0.2	1.5	0.4	4.5	1.0
Rubus spp.	-	-	-	-	0.5	0.7	-	-	+	+	0.3	0.4
Senecio pauperculus	-	-	-	-	-	-	-	-	-	-	-	-
Senecio pseudaureus	+	+	-	-	-	-	-	-	-	-	-	-
Senecio spp.	-	-	-	-	-	-	-	-	-	-	-	-
Senecio streptanthifolius	-	-	-	-	-	-	-	-	-	-	-	-
Sisymbrium species	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table 5.4 (cont'd). Relative abundance (% cover) of plant species on scarified and unscarified **PINE** forests.

Form Class and Species	Pine Forest											
	Scarified						Unscarified					
	Yr 26 1982		Yr 32 1988		Yr 39 1995		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Sisyrinchium montanum	-	-	-	-	-	-	-	-	-	-	-	-
Smilacina racemosa	-	-	-	-	0.1	0.2	-	-	-	-	-	-
Smilacina stellata	+	+	+	+	+	+	-	-	+	+	-	-
Solidago decumbens	-	-	-	-	-	-	-	-	-	-	-	-
Solidago gigantea	+	+	-	-	-	-	-	-	-	-	-	-
Solidago spp.	-	-	+	+	-	-	-	-	-	-	-	-
Sonchus arvensis	-	-	-	-	-	-	-	-	-	-	-	-
Spiranthus romanzoffiana	+	+	-	-	-	-	-	-	-	-	-	-
Stellaria longifolia	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longipes	-	-	-	-	-	-	-	-	-	-	-	-
Streptopus amplexifolius	0.3	0.1	0.1	0.1	0.4	0.3	0.2	0.1	0.1	0.2	0.2	0.2
Taraxacum officianale	+	+	0.1	0.1	0.1	0.1	+	+	+	+	0.1	0.1
Thalictrum venulosum	0.1	0.1	0.3	0.2	0.5	0.3	-	-	-	-	0.2	0.3
Tofieldia glutinosa	-	-	-	-	-	-	-	-	-	-	-	-
Tragopogon dubius	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium pratense	-	-	-	-	-	-	-	-	-	-	-	-
Trifolium repens	+	+	-	-	-	-	+	+	-	-	-	-
Unknown Forb	-	-	-	-	+	+	-	-	-	-	+	+
Veronica spp.	-	-	-	-	-	-	-	-	-	-	-	-
Vicia americana	+	+	0.2	0.2	1.5	0.9	+	+	0.1	0.1	+	+
Viola renifolia	-	-	-	-	-	-	-	-	-	-	-	-
Zizia cordata	-	-	-	-	-	-	-	-	-	-	-	-
Zygadenus elegans	-	-	-	-	-	-	-	-	-	-	-	-
Forb Total	14.9		22.9		63.0		11.3		23.4		56.5	
Ferns and Fern Allies												
Botrychium lunaria	-	-	-	-	-	-	-	-	-	-	-	-
Equisetum arvense	0.3	0.1	0.3	0.2	0.5	0.3	0.2	0.1	0.3	0.2	0.3	0.2
Equisetum pratense	-	-	-	-	0.1	0.2	-	-	-	-	-	-
Equisetum scirpoides	-	-	-	-	+	+	-	-	-	-	-	-
Equisetum spp.	-	-	-	-	+	+	-	-	-	-	+	+
Equisetum sylvaticum	-	-	-	-	+	+	-	-	-	-	+	+
Gymnocarpium dryopteris	-	-	+	+	0.1	0.1	-	-	+	+	+	+
Lycopodium annotinum	-	-	-	-	+	+	-	-	-	-	-	-
Lycopodium spp.	-	-	+	+	+	0.1	-	-	-	-	0.5	1.0
Fern/Fern Ally Total	0.3		0.3		0.8		0.2		0.3		0.9	
Grasses												
Agropyron spicatum	-	-	-	-	-	-	-	-	-	-	-	-
Agropyron subsecundum	-	-	-	-	-	-	-	-	-	-	-	-
Agropyron trachycaulum	-	-	+	+	-	-	-	-	-	-	-	-
Agrostis alba	+	+	-	-	-	-	+	+	-	-	-	-
Agrostis scabra	-	-	-	-	-	-	-	-	-	-	-	-
Bromus inermis	+	+	+	+	0.4	0.4	-	-	+	+	0.2	0.2
Bromus marginata	-	-	-	-	-	-	-	-	-	-	-	-
Bromus spp.	-	-	-	-	-	-	-	-	-	-	-	-
Calamagrostis canadensis	6.7	1.8	8.4	1.5	11.2	2.7	6.8	2.2	9.0	2.3	8.5	2.2
Calamagrostis montanensis	-	-	-	-	-	-	-	-	-	-	0.8	0.7
Calamagrostis purpurescens	-	-	-	-	-	-	-	-	-	-	-	-
Deschampsia caespitosa	-	-	-	-	-	-	-	-	-	-	-	-
Elymus canadensis	-	-	-	-	+	+	-	-	-	-	-	-
Elymus innovatus	11.7	2.9	7.2	1.8	10.4	2.9	19.5	3.4	14.2	3.0	16.7	3.5
Festuca rubra	-	-	+	+	-	-	-	-	-	-	-	-
Festuca spp.	-	-	-	-	-	-	-	-	+	0.1	0.1	0.2
Glyceria striata	-	-	-	-	-	-	-	-	-	-	-	-
Phleum alpinum	-	-	-	-	-	-	-	-	-	-	-	-

Appendix Table 5.4 (cont'd). Relative abundance of plant species on scarified and unscarified **PINE** forests.

Form Class and Species	Pine Forest											
	Scarified						Unscarified					
	Yr 26 1982		Yr 32 1988		Yr 39 1995		Yr 26 1982		Yr 32 1988		Yr 39 1995	
	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE	Mean	2xSE
Phleum pratense	-	-	-	-	-	-	+	+	+	+	-	-
Poa palustris	+	+	+	+	-	-	+	+	-	-	-	-
Poa pratense	+	+	+	+	+	+	+	+	+	+	0.1	0.1
Poa secunda	-	-	-	-	-	-	-	-	-	-	-	-
Poa spp.	-	-	-	-	+	+	-	-	-	-	+	+
Unknown Grass	-	-	-	-	0.1	0.1	-	-	-	-	-	-
Grass Total	18.3		15.7		22.2		26.3		23.3		26.3	
Mosses and Lichens												
Cladonia spp.	-	-	+	+	+	0.1	-	-	0.1	0.1	+	+
Moss spp.	-	-	11.7	4.4	20.4	5.8	-	-	7.6	3.3	20.2	5.7
Lichen spp.	-	-	-	-	-	-	-	-	-	-	-	-
Peltigera apthosa	-	-	0.1	0.1	+	+	-	-	0.1	0.1	0.1	0.1
Moss and Lichen Total	-		11.8		20.4		-		7.8		20.3	
Sedges and Rushes												
Carex aquatilis	-	-	-	-	-	-	-	-	-	-	-	-
Carex aurea	-	-	+	+	+	+	-	-	+	+	+	+
Carex capillaria	-	-	-	-	-	-	-	-	-	-	-	-
Carex eburnea	-	-	-	-	-	-	-	-	-	-	-	-
Carex flava	-	-	-	-	-	-	-	-	-	-	-	-
Carex interior	-	-	-	-	-	-	-	-	-	-	-	-
Carex lacustris	-	-	-	-	-	-	-	-	-	-	-	-
Carex spp.	0.1	0.1	+	+	0.1	0.1	+	+	+	+	0.1	0.1
Juncus balticus	+	+	-	-	-	-	-	-	-	-	-	-
Juncus nodosus	-	-	-	-	-	-	-	-	-	-	-	-
Juncus parryi	-	-	-	-	-	-	-	-	-	-	-	-
Juncus spp.	-	-	-	-	-	-	+	+	-	-	-	-
Luzula parviflora	-	-	-	-	-	-	+	+	+	+	-	-
Sedge and Rush Total	0.1		+		0.1		0.1		+		0.1	

APPENDIX 6. INSTRUCTIONS FOR FUTURE DATA COLLECTION

Data Forms

Form 1: Vegetation Cover Data. Record species and percent cover information on all plant ground cover within a 1 m^2 (1 m x 1 m square) quadrat. Record for each plot with 100 plots per block.

Form 2: Shrub Stem Density and Use Data. Record data on the intensity of use, density and height class of all shrubs and trees (coniferous and deciduous) within a 1 m^2 (1 m x 1 m square) quadrat. Record for each plot with 100 plots per block.

Form 3: Tree Stem Density. Record data on the density of tree stems by species and height class on a 25 m^2 circular plot (2.82 m radius) centered on the plot stake. Record for each plot with 100 plots per block.

Form 4: Tree Dimensions and Snags. Record data on the conifer trees required for crown canopy cover calculations. These are species, crown width, dbh, and height class. Record up to 4 trees per plot using a point quarter survey technique to choose samples. Also record all snags within a 50 m^2 (4 metre radius) circular plot, plus attributes including height class, dbh, condition codes, species, and presence of wildlife cavities. Record for each plot with 100 plots per block.

Form 5: Visibility Board. Using a 2.5 m tall by 0.3 m wide Visibility Profile Board, thirty (30) sample points are measured within each block (2 per grid line). The profile board was divided into five 0.5 metre sections. Samples are taken 20 m northwest of each sample point (plot stake). Percent visibility classes of each board section is then estimated and recorded: Layer 1 (0–0.5 m above ground), Layer 2 (0.5–1.0 m), Layer 3 (1.0–1.5 m), Layer 4 (1.5–2.0 m) and Layer 5 (2.0–2.5 m).

Form 6: Browse Mass and Use. Plot size is 1 m^2 (1 m x 1 m). Every fifth (5th) plot, beginning at the fourth (4th) plot, until 20 plots are clipped. Not performed until all other plant density and cover information has been obtained. Clipping of browse/forage (<2.5 m in height) was done at a 3 m distance away from the plot in a constant direction. Each survey should record which direction the clip plot is located so that subsequent surveys do not survey the same areas. Weighed plants are labeled and dried. Dry masses are then recorded.

Form 7: Down Wood Cover. Using the 15 grid lines as the sampling unit, a 50 m survey chain is stretched out from the first plot towards the last plot. Each down wood piece >7.5 cm diameter at the point of intersection is measured. Diameter and condition code is recorded. Total survey of 750 m per plot.

Form 8: Wildlife Pellet Counts. Record species and wildlife pellet group counts on a 25 m^2 circular plot (2.82 m radius) centered on the plot stake. Record for each plot with 100 plots per block.

Other Observations

In addition to the data forms, carry a field book and make the following observations on a daily basis or as they occur. For example:

Weather Conditions	Estimate the temperature, wind speed, cloud cover, precipitation type and intensity
Wildlife Observations	Note all observed wildlife or their signs. Identify to most specific taxonomic level possible. Note numbers of occurrences of the animal or sign.

Rare Plant Species	Note any species which is within the sample but does not show up in any of the plots.
Damages	Note any human or natural caused disturbances
Errors/Omissions	Note any changes to the plot numbers from how it is currently recorded.
Unknown Plants	Record attributes of plants for lab identification.

Detailed Data Measurement and Recording Methods

Basic Survey Information on all Data Forms

Forest:	Record Forest Type as **SPRUCE**, **MIXEDWOOD**, or **PINE**
Block/Treatment	Record as Mature, Scarified, or Unscarified
Sample:	Record 1 or 2
Date:	Record Day, Month, and Year
Observers:	Record 1st initials and last name of all observers. The data recorder should list his or her name first.
Rep:	Replicate Number – each sample is split into 5 replicates so record number from 1–5.
Grid:	Each Replicate is transected with 6 potential grid lines, so record number from 1–6.
Plot:	Each Gridline has 7 plots marked with metal stakes, so record number from 1–7.

Vegetation Cover Measurements in 1 m^2 plots (Form 1)

Species Code:	GEnus SPecies = GESP - all non-erect-woody vascular plant species plus selected moss and lichen species are inventoried. Includes dwarf or creeping shrubs such as bearberry and juniper (see table below).
Cover (%):	All given as percent values by combining 10 x 10 cm covers (=1%) with trace status given as a + and worth 0.1% in the data analysis.

Appendix Table 6.1. List of Species and Codes for vegetation cover.

Species Code	Species Name	Form Type
ACMI	*Achillea millifolium*	Forb
ACRU	*Actaea rubra*	Forb
AGAL	*Agrostis alba*	Grass
AGGL	*Agoseris glauca*	Forb
AGSC	*Agrostis scabra*	Grass
AGSP	*Agropyron spicatum*	Grass
AGTR	*Agropyron trachycaulum/subsec.*	Grass
ALMU	*Alyssum murale*	Forb
ANCH	*Androsace chamaejasme*	Forb
ANMA	*Anaphalis margaritacea*	Forb
ANMU	*Anemone multifida*	Forb
ANPA	*Anemone parviflora*	Forb
ANOC	*Anemone occidentalis*	Forb
AESP	*Anemone spp.*	Forb
ANPU	*Antennaria pulcherrima*	Forb
ANSP	*Androsace spp.*	Forb
APSP	*Apocynum spp.*	Forb
AQBR	*Aquilegia brevistyla*	Forb
ARNU	*Aralia nudicaulis*	Forb
ARPU	*Arceuthobium americanum*	Forb
ARSP	*Arnica spp.*	Forb
ARST	*Arenaria stricta*	Forb
ARUV	*Arctostaphylos uva-ursi*	Dwarf Shrub
ASAL	*Astragalus alpinus*	Forb
ASCI	*Aster ciliolatus*	Forb
ASCO	*Aster conspicuus*	Forb
ASDR	*Astragalus drummondii*	Forb
ASFR	*Astragalus americanus / frigidus*	Forb
ASSI	*Aster sibiricus*	Forb
ASSP	*Aster spp.*	Forb
ASST	*Astragalus striatus*	Forb
BOBO	*Botrychium boreale/lunaria*	Forb
BOLU	*Botrychium lunaria*	Forb
BRIN	*Bromus inermis*	Grass
BRMA	*Bromus marginata*	Grass
BRRI	*Braya richardsonii/humilus*	Forb
BRSP	*Bromus spp.*	Grass
CAAQ	*Carex aquatilis*	Sedge
CAAU	*Carex aurea*	Sedge
CABA	*Carex backii*	Sedge
CACA	*Calamagrostis canadensis*	Grass
CACP	*Carex capillaris*	Sedge
CAEB	*Carex eburnea*	Sedge
CAFL	*Carex flava*	Sedge
CAIN	*Carex interior*	Sedge
CALA	*Carex lacustris*	Sedge
CAMI	*Castilleja miniata*	Forb
CAMO	*Calamagrostis montanensis*	Grass
CAPU	*Calamagrostis purpurescens*	Grass
CARO	*Campanula rotundifolia*	Forb
CASI	*Carex siccata*	Sedge

Species Code	Species Name	Form Type
CASP	*Carex spp.*	Sedge
CATE	*Carex tenuifolia*	Sedge
CEAR	*Cerastium arvense*	Forb
CESP	*Cerastium spp.*	Forb
CHAL	*Chenopodium album*	Forb
CIAL	*Circaea alpina*	Forb
CLOC	*Clematis occidentalis*	Forb
CLSP	*Cladonia spp.*	Lichen
COCA	*Cornus canadensis*	Forb
COPA	*Comandra umbellata/pallida*	Forb
COST	*Cornus stolonifera*	Shrub
CYCA	*Cypripedium calceolus*	Forb
CYPA	*Cypripedium passerinum*	Forb
DECA	*Deschampsia caespitosa*	Grass
DEGL	*Delphinium glaucus*	Forb
DITR	*Disporum trachycarpum*	Forb
DORA	*Dodecatheon radicatum*	Forb
DRSP	*Draba spp.*	Forb
ELCA	*Elymus canadensis*	Grass
ELGL	*Elymus glaucus*	Grass
ELIN	*Elymus innovatus*	Grass
EPAN	*Epilobium angustifolium*	Forb
EPLA	*Epilobium latifolium*	Forb
EQAR	*Equisetum arvense*	Fern Ally
EQPR	*Equisetum pratense*	Fern Ally
EQSC	*Equisetum scirpoides*	Fern Ally
EQSP	*Equisetum spp.*	Fern Ally
EQSY	*Equisetum sylvaticum*	Fern Ally
ERCA	*Erigeron caespitosus*	Forb
ERGL	*Erigeron glabellus*	Forb
EROC	*Erigeron ochroleucus*	Forb
ERPH	*Erigeron philadelphicus*	Forb
ERSP	*Erigeron spp.*	Forb
FEOR	*Festuca orina*	Grass
FERU	*Festuca rubra*	Grass
FESA	*Festuca saximontana*	Grass
FESP	*Festuca spp.*	Grass
FRVI	*Fragaria vesca/virginiana*	Forb
GABO	*Galium boreale*	Forb
GATR	*Galium triflorum*	Forb
GEAM	*Gentianella amarella*	Forb
GEBI	*Geranium bicknellii*	Forb
GECR	*Gentianella crinata*	Forb
GELI	*Geocaulon lividum*	Forb
GERI	*Geum rivale*	Forb
GESP	*Gentianella species*	Forb
GETR	*Geum triflorum*	Forb
GLST	*Glyceria striata*	Grass
GORE	*Goodyera repens*	Forb
GYDR	*Gymnocarpium dryopteris*	Fern
HAHY	*Habenaria hyperborea*	Forb
HAOB	*Habenaria obtusata*	Forb
HASP	*Habenaria spp.*	Forb

Species Code	Species Name	Form Type
HAVI	*Habenaria viridus*	Forb
HEAL	*Hedysarum alpinum*	Forb
HEFL	*Heuchera flabellifolia*	Forb
HELA	*Heracleum lanatum*	Forb
HEMA	*Hedysarum boreale /mackenzii*	Forb
HESP	*Hedysarum spp.*	Forb
HESU	*Hedysarum sulfurescens*	Forb
HIUM	*Hieraceum umbellatum*	Forb
HYSP	*Hylocomium splendens*	Moss
JUBA	*Juncus balticus*	Rush
JUCO	*Juniperus communis*	Dwarf Shrub
JUHO	*Juniperus horizontalis*	Dwarf Shrub
JUNO	*Juncus nodosus*	Rush
JUPA	*Juncus parryi*	Rush
JUSP	*Juncus spp.*	Rush
LAOC	*Lathyrus ochroleucus*	Forb
LEIN	*Lechea intermedia*	Forb
LIBO	*Linnaea borealis*	Forb
LICH	*Lichen species*	Lichen
LIPH	*Lilium philadelphicum*	Forb
LUPA	*Luzula parviflora*	Forb
LYAN	*Lycopodium annotinum*	Fern Ally
LYSP	*Lycopodium spp.*	Fern Ally
MACA	*Maianthemum canadense*	Forb
MAMA	*Matricaria matricarioides*	Forb
MAPA	*Malaxis paludosa*	Forb
MEPA	*Mertensia paniculata*	Forb
MINU	*Mitella nuda*	Forb
MOSS	*Unidentified Moss*	Moss
MOUN	*Moneses uniflora*	Forb
NONE	*Nothing present*	Forb
ORAS	*Oryzopsis asperifolia*	Forb
ORLU	*Oryzopsis luteus*	Forb
ORRO	*Orchis rotundifolia*	Forb
ORSE	*Orthilia secunda*	Forb
ORSP	*Oryzopsis species*	Forb
OSCH	*Osmorhiza chilensis*	Forb
OXMI	*Oxycoccus microcarpus*	Forb
OXMO	*Oxytropis monticola*	Forb
OXSP	*Oxytropis splendens*	Forb
PAFI	*Parnassia fimbriata*	Forb
PEAP	*Peltigera apthosa*	Lichen
PEBR	*Pedicularis bracteosa*	Forb
PELA	*Pedicularis labradorica*	Forb
PEPA	*Petasites palmatus*	Forb
PESA	*Petasites sagittatus*	Forb
PESP	*Petasites spp.*	Forb
PHAL	*Phleum alpinum*	Grass
PHPR	*Phleum pratense*	Grass
PLMA	*Plantago major*	Forb
PLSC	*Pleurozium schreberi*	Moss
POAL	*Poa alpina*	Grass
POAN	*Potentilla anserina*	Forb

Species Code	Species Name	Form Type
POFR	*Potentilla fruticosa*	Shrub
PONO	*Potentilla norvegica*	Forb
POPA	*Poa palustris*	Grass
POPR	*Poa pratense*	Grass
POSE	*Poa secunda*	Grass
POSP	*Poa spp.*	Grass
POVI	*Polygonum viviparum*	Forb
PTCR	*Ptilium crista-castrensis*	Moss
PYAS	*Pyrola asarifolia*	Forb
PYMI	*Pyrola minor*	Forb
PYSP	*Pyrola spp.*	Forb
RAAC	*Ranunculus acris*	Forb
RUAC	*Rubus arcticus/acaulis*	Forb
RUID	*Rubus idaeus*	Dwarf Shrub
RUPU	*Rubus pubescens*	Forb
RUSP	*Rubus spp.*	Dwarf Shrub
SEPA	*Senecio pauperculus*	Forb
SEPA	*Senecio palustris*	Forb
SEPS	*Senecio pseudaureus*	Forb
SESP	*Senecio spp.*	Forb
SEST	*Senecio streptanthifolius*	Forb
SIMO	*Sisyrinchium montanum*	Forb
SISP	*Sisymbrium species*	Forb
SMRA	*Smilacina racemosa*	Forb
SMST	*Smilacina stellata*	Forb
SOAR	*Sonchus arvensis*	Forb
SODE	*Solidago decumbens/spathulata*	Forb
SOGI	*Solidago gigantea*	Forb
SOSP	*Solidago spp.*	Forb
SPLU	*Spiraea lucida/betulifolia*	Forb
SPRO	*Spiranthes romanzoffiana*	Forb
STAM	*Streptopus amplexifolius*	Forb
STLF	*Stellaria longifolia*	Forb
STLO	*Stellaria longipes*	Forb
TAOF	*Taraxacum officianale*	Forb
THAB	*Moss species*	Moss
THSP	*Thalictrum spp.*	Forb
THVE	*Thalictrum venulosum*	Forb
TOGL	*Tofieldia glutinosa*	Forb
TRDU	*Tragopogon dubius*	Forb
TRPR	*Trifolium pratense*	Forb
TRRE	*Trifolium repens*	Forb
UNFO	*Unknown Forb*	Forb
UNGR	*Unknown Grass*	Grass
URDI	*Urtica dioica*	Forb
VACA	*Vaccinium caespitosum*	Dwarf Shrub
VAVI	*Vaccinium vitis-idaea*	Dwarf Shrub
VESP	*Veronica spp.*	Forb
VIAD	*Viola adunca*	Forb
VIAM	*Vicia americana*	Forb
VIRE	*Viola renifolia*	Forb
VISP	*Vicia spp.*	Forb
ZICO	*Zizia aptera / cordata*	Forb

Species Code	Species Name	Form Type
ZYEL	*Zygadenus elegans*	Forb

Shrub and Tree Data Measured in 1 m² Plots (Form 2)

Species Codes:	GEnus SPecies = GESP - all erect-woody plant species
USE-S	Summer use (visually estimated class* of recently browsed stems and leaves) - requires evidence of nipped leaves or green ended stems
USE-W	Winter use (visually estimated class* of last winters browsed stems) - requires evidence of sturdy brownish stem tips (Previous year browsing tends to show in greyer, more brittle dry tips with evidence of new growth past the tips). This requires some practice to get correctly. Note that the very high use class could result in a dead or missing stem which would be missed in the inventory.
H1	stem count of shrubs 0.0–0.2 m tall (0.1 m midpoint)
H2	stem count of shrubs 0.2–0.4 m tall (0.3 m midpoint)
H3	stem count of shrubs 0.4–0.6 m tall (0.5 m midpoint)
H4	stem count of shrubs 0.6–0.8 m tall (0.7 m midpoint)
H5	stem count of shrubs 0.8–1.0 m tall (0.9 m midpoint)
H6	stem count of shrubs 1.0–2.0 m tall (1.5 m midpoint)
H7	stem count of shrubs 2.0–3.0 m tall (2.5 m midpoint)
H8	stem count of shrubs 3.0–4.0 m tall (3.5 m midpoint)
H9	stem count of shrubs 4.0–6.0 m tall (5.0 m midpoint)
H10	stem count of shrubs 6.0–8.0 m tall (7.0 m midpoint)
H11	stem count of shrubs 8.0–10.0 m tall (9.0 m midpoint)
H12	stem count of shrubs >10.0 m tall (12.0 m assumed)
* Use Classes:	None (0%), Low (1–25%), Moderate(26–50%), High(51–75%), Very High (76–100%)

Appendix Table 6.2. Woody Species Codes.

Code	Scientific Name	Common Name	Form Type	Measured as Browse ?
ALCR	*Alnus crispa*	Green Alder	Shrub	Yes
AMAL	*Amelanchier alnifolia*	Saskatoon	Shrub	Yes
BEGL	*Betula glandulosa*	Bog Birch	Shrub	Yes
BEOC	*Betula occidentalis*	Black Birch	Shrub	Yes
COST	*Cornus stolonifera*	Red-osier Dogwood	Shrub	Yes
LEGR	*Ledum groenlandicum*	Labrador Tea	Shrub	No
LODI	*Lonicera dioica*	Twining Honeysuckle	Shrub	Yes
LOIN	*Lonicera involucrata*	Bracted Honeysuckle	Shrub	Yes
POFR	*Potentilla fruticosa*	Shrubby Cinquefoil	Shrub	No
PRPE	*Prunus pennsylvanica*	Pin Cherry	Shrub	Yes
PRVI	*Prunus virginiana*	Choke-cherry	Shrub	Yes
RISP	*Ribes species*	Gooseberry or Currant	Shrub	Yes
ROAC	*Rosa acicularis*	Prickly Rose	Shrub	Yes
RUST	*Rubus striatus*	Raspberry	Shrub	Yes
SARA	*Sambucus racemosa*	Red Elderberry	Shrub	No
SASP	*Salix species*	Willow	Shrub	Yes
SHCA	*Shepherdia canadensis*	Buffalo-berry	Shrub	Yes
SOSC	*Sorbus scopulina*	Western Mountain Ash	Shrub	Yes
SYAL	*Symphoricarpos albus*	Snowberry	Shrub	Yes
UNBR		Unknown Browse Species	Shrub	Yes
VIED	*Viburnum edule*	Low-bush Cranberry	Shrub	Yes
ABLA	*Abies lasiocarpa*	Subalpine Fir	Conifer Tree	Yes
PICO	*Pinus contorta*	Lodgepole Pine	Conifer Tree	No
PIGL	*Picea glauca*	White Spruce	Conifer Tree	No
PIMA	*Picea mariana*	Black Spruce	Conifer Tree	No
BEPA	*Betula papyrifera*	Paper Birch	Deciduous Tree	Yes
POBA	*Populus balsamifera*	Balsam Poplar	Deciduous Tree	Yes
POTR	*Populus tremuloides*	Aspen	Deciduous Tree	Yes

Conifer Tree Regeneration Data (Form 3)

This is measured in a 25 m^2 circular area. Be sure to record the size used if varied. A larger size may be used in less dense stands.

Species Code: GEnus SPecies = GESP. During Yrs 1–39, only conifer species have been recorded. In future measurements all tree species should be included.

H1*	stem count of shrubs 0.0–0.2 m tall (0.1 m midpoint)
H2	stem count of shrubs 0.2–0.4 m tall (0.3 m midpoint)
H3	stem count of shrubs 0.4–0.6 m tall (0.5 m midpoint)
H4	stem count of shrubs 0.6–0.8 m tall (0.7 m midpoint)
H5	stem count of shrubs 0.8–1.0 m tall (0.9 m midpoint)
H6	stem count of shrubs 1.0–2.0 m tall (1.5 m midpoint)
H7	stem count of shrubs 2.0–3.0 m tall (2.5 m midpoint)
H8	stem count of shrubs 3.0–4.0 m tall (3.5 m midpoint)
H9	stem count of shrubs 4.0–6.0 m tall (5.0 m midpoint)
H10	stem count of shrubs 6.0–8.0 m tall (7.0 m midpoint)
H11	stem count of shrubs 8.0–10.0 m tall (9.0 m midpoint)
H12	stem count of shrubs >10.0 m tall (12.0 m assumed
Total	sum of all stems

* In prior measurements all HT 1 stems were recorded. In future measurements this may not be required as it is very time consuming and one is unlikely to find all without an exhaustive search.

Conifer Tree Dimensions (Form 4)

Using the plot stake as a centre, mentally divide the area in 4 quarters. Then seek the nearest conifer seedling, sapling, or tree in each quarter (for HT 2 or higher).

Tree #.	Record 1 to 4.
Species:	Same codes as used above
Width:	Measure distance in metres from furthest outside branch to furthest outside branch, then measure the perpendicular value and divide by 2.
DBH:	Record in cm the diameter at 1.4 metres. If the tree is shorter than this, record as a slash. If the tree is just 1.4 m tall, record zero.
HT CL:	Record height class as 2–12 using the same values as in the tree and shrub surveys.

Snag Measurements (Form 4)

Measure in a 50 m^2 area around the centre (4 metre radius). All dead trees are recorded if they are >15 cm dbh. Note that snags which are leaning are not counted if the top of the dead tree bole is <1 m from the ground or if it is leaning on a piece of down wood <1 m from the ground.

Species	Record tree code if known. If not known to species level record genus or simply use HWD for hardwood and SWD for softwood and UKN for unknown.
Snag #	Record each snag with a separate number per plot
Condition:	Record Class and Qualifier (see below)
DBH:	Diameter at 1.4 metres height in centimeters. If the snag is <1.4 m tall record at the highest point.
HT CL:	Record the same height classes as used for trees and shrubs.
Cavities:	Count the number of woodpecker or other wildlife cavities on the snag.
In Use?:	Record Yes if a resident is seen, heard, or if it is reasonable to suspect current year usage (e.g. fresh scat, recent hair or feathers, unweathered wood at opening)

Snag Classes

1	Wet - Recently dead, may still have brown needles or leaves, sap still present, often infested with bark beetles, still moist between bark and sapwood.
2	Hard - Main stem dried out, fine branches still present, most of bark still present and firmly attached.
3	Hard - Fine branches gone, major branches still present, stem mostly sound, variable bark depending on the species.
4	Hard - Few or no branches, stem mostly intact but may be starting to soften, variable bark depending on the species.
5	Soft - No branches, stem starting to decompose (noticeably punky), bark variable depending on the species.
6	Decomposed - No branches, stem very punky or rotten, bark mostly absent.

Snag Class Qualifiers

SN: snag = any intact dead tree (no broken top) >10cm dbh.
ST: stub = any dead tree with a broken top >10cm dbh.
H: hollow = any snag or stub which is obviously hollow within the first 5 m from the ground
Lean (degree) = record the degree of lean for non-straight trees.

Visibility Board Measurements (Form 5)

The *Visibility Profile Board* is 2.5 metres tall by 0.3 metres wide with five 0.5 m height sections. The first section is painted black, the second section is white, the third is black, the fourth is white and the fifth is black. Each recording is made by visually estimating the percentage of the 5 board layers which is visible from a standing position at 20 m distance (perpendicular to the plot). The observer should stand at the plot stake. This can be redone in early spring before green up of deciduous trees and shrubs, then in mid-summer at full leaf. Record the visibility class for each layer.

Visibility Class	Visibility Range	Cover Range
0	0 %	100 %
1	1–20 %	80–99 %
2	21–40 %	60–79 %
3	41–60 %	40–59 %
4	61–80 %	20–39 %
5	81–99 %	1–19 %
6	100 %	0 %

Browse Measurements (Form 6).

3D Plot size is 1 m^2 (1 m x 1 m) on the ground by 2.5 metre height. Only those species known to be commonly used by ungulates are clipped. Before clipping, the percent use is estimated in classes (same as done for all shrubs). All live stems d 0.8 cm in diameter within the 2.5 m^3 volume are clipped. Leaves and stems of each species are then placed in labeled paper or cloth bags and all the bags for a plot are placed in a larger bag. These are immediately weighed to obtain the fresh (green) weight. These are taken back to a dry room and allowed to air-dry over several weeks. Space on the form allows for multiple weight recordings. Once the mass has ceased to decrease between weighings, the final weight is recorded. The bag is then emptied and weighed, and this is subtracted from the final weight to give the final dry mass.

Down wood Measurements (Form 7).

Along each 50 m grid line, using a 50 m survey chain to ensure accuracy in distance, each down wood piece >7.5 cm diameter at the point of intersection is measured. Note that leaning logs are only measured if they are within 1 m of the ground or if they are stacked on another log that is within 1 m. Diameter and condition code is recorded. Condition codes in the initial survey were simply S = Sound (wood will not break with a kick), or R = Rotten (Wood will break with a kick). A more elaborate code in future measurements may be devised such as:

1 Green Wood
2 Hard - Bark Coated Wood
3 Hard - Bark Lacking Wood
4 Dry Rotten Wood
5 Moist Rotten Wood
6 Rotten and Buried >50 %

Wildlife Pellet Counts (Form 8).

Record species and wildlife pellet group counts on a 25 m^2 circular plot (2.82 m radius) centered on the plot stake. A pellet group is a cluster of pellets from a single defecation. Scattered single pellets within 30 cm from each other are recorded as a single group. A pellet group is recorded if at least 50% of the pellets fall within the plot. The recorder must be familiar with deer, elk, moose, grouse, and hare pellet identification. Other pellets are also recorded and the recorder should have a good knowledge of other species, or must have a guidebook from which identification of species can be obtained. Summer and winter pellets can be identified in some species and pellets should be listed under the appropriate column. For species which this cannot be done, record under the first column only. Pellet group measurement must be done before green-up of the herbaceous plant layer, or else finding the groups will be very difficult. After each sample is completed, the recorder should estimate and record in the field book the probability of detection of pellet groups for each of the main species.

Summary Information Calculated From Raw Survey Data

1. Percentage Cover of Plants
- Plant cover of each species and genera
- Plant cover of all species combined
- Plant cover of species form classes (grasses, forbs, sedges, rushes, ferns and fern allies, dwarf shrubs, mosses, lichens)

2. Percent Frequency of Plants
- Frequency of each species
- Frequency of major taxonomic groups

3. Diversity Indices of Plants
- Species richness
- Shannon Weiner Index and Evenness
- Simpson's Index

4. Similarity Index of All Plants (cover and shrubs and trees)

5. Densities of Woody Stems
- Individual shrub species densities: totals and by height classes
- Tree (individual species) densities: totals and by height classes
- Combined shrub densities: totals and by height classes
- Combined tree densities: totals and by height classes
- Tree densities split by conifer and deciduous: totals and by height classes

6. Percent Frequencies of Woody Species

7. Mean Heights of Woody Species
- Mean heights of individual species
- Mean heights of combined shrubs and of conifers versus deciduous trees

8. Use of Woody Plants
- Percent summer, winter and total use of individual species
- Percent summer, winter, and total use of all species and of conifers versus deciduous

9. Conifer Regeneration Data
- Tree densities of each species and of all conifers: totals and by height classes
- Mean tree heights of each species and of all conifers
- Percent canopy closure of each species and of all conifers
- Diversity of tree species
- Percent composition of each species by density

10. Snag Data
- Snag densities: total and number with wildlife cavities
- Snag densities by height class, diameter class, and species
- Mean snag height and diameter
- Number and percent of snags with cavities
- Number of cavities per plot and per snag
- Comparison of diameter, height and species of snags with and without cavities

11. Browse Biomass and Use
- Browse biomass by species and total
- Browse use by species and total

12. Visibility Cover

- Visibility cover by height class and total

13. Wildlife Observations

- Relative density of individual species for which there is adequate pellet data
- Occurrence (Presence but not absence) of all other species based on casual observations

Analyses and Comparisons To Perform With Previous Years Measurements

Understory Vegetation Cover Comparisons

Compare totals for individual species, summed genera, form classes, and overall total plant cover against all other survey years for scarified and unscarified, and against the mature for all three forest types: **MIXEDWOOD**, **PINE** and **SPRUCE** for the following attributes.

- Cover (%)
- Diversity and species richness

Plot pie charts of relative genera proportions for mature, and selected years since logging

Calculate similarity of species composition between years and treatments.

Shrubs/Sapling Density, Height and Utilization

Compare totals for individual species, combined shrubs, deciduous trees and conifers between scarified and unscarified among all three forest types and against the mature for all three forest types: **SPRUCE**, **MIXEDWOOD**, and **PINE** for the following attributes.

- Density (numbers per square metre).
- Frequency (number of plots with the species divided by the number of plots: (%).
- Heights (metres).
- Densities in each of four height classes: seedlings (0–0.6 m), saplings (0.61–2.0 m), subcanopy (2.01–10.0 m), and canopy (>10 m).
- Percent Use
- Diversity and Species Richness

Plot mean values ± 2SE for each of the above calculations versus time since logging. Note that for frequency there can be no calculation of SE since all the plots are used to get one value.

3. Plot stacked bar histograms of species densities comparing treatment and time.
4. Calculate similarity index values comparing treatments and years.
5. Combine shrub and cover data for overall diversity, richness, and similarity index calculations.

Coniferous Regeneration Density, Height and Utilization

Compare totals and individual species between scarified, unscarified and mature treatments for all three forest types for the following attributes.

- Density (numbers per square metre).
- Heights (metres).
- Densities in each of four height classes: seedlings (0–0.6 m), saplings (0.61–2.0 m), subcanopy (2.01–10.0 m), and canopy (>10 m).
- Canopy Cover

Plot mean values ± 2SE for each of the above calculations versus time since logging. Note that for frequency there can be no calculation of SE since all the plots are used to get one value.

6. Plot stacked bar histograms of species densities comparing treatment and time.

Browse Biomass and Utilization

Compare totals and individual species values for the three treatments and 3 forest types for the following attributes:

- browse dry biomass (grams per square metre)
- percent use
- estimated consumed biomass

Wildlife Pellet Groups and Casual Observations

Compare total pellet group densities (number per square metre) for each wildlife group (Ungulates, Grouse, Carnivores, Lagomorphs) and separate species (deer, elk, and moose) between the three treatments and three forest types. Use means with 2 standard errors for all comparisons.

Compare relative occurrence of casual observations of other bird and mammal species. No statistics can be performed on these data, so be cautious when explaining the results.

Visibility

Compare visibility class (and percentage equivalent) averages for each height class, the entire 0–2.5 m height as well as by functional height classes (0–0.5 m, 0.5–1.5 m and 1.5–2.5 m).

Down wood

Compare among treatments and forests

- Percent down wood cover (divide diameter of wood by line length) (± 2 SE).
- Percent cover by sound and rotten classes
- Frequency distribution by 5 cm range classes
- Mean diameter (± 2 SE)

Snags and Wildlife Use

Compare between scarified, unscarified and mature treatments for all three forest types for the following attributes:

- Snag densities: total and number with wildlife cavities
- Snag densities by height class, diameter class, and species
- Mean snag height and diameter
- Number and percent of snags with cavities
- Number of cavities per plot and per snag
- Comparison of diameter, height and species of snags with and without cavities

Calculations Needed to Summarize Data before Statistical Calculations

Vegetation Cover Data

Total cover for all species in a plot or for form types within a plot can exceed 100%. Simply sum up the values recorded from the field using 0.1% for the trace value.

Species Richness is the count of all species present in a sample. Mean species richness is the average for plots within a sample.

Diversity and Evenness are measures of the distribution of species. Diversity is increased by both higher numbers of species and by similarity of the cover of species. Evenness is the relative diversity (proportion of maximum possible diversity). Diversity is calculated with Shannon's Index and Simpson's Index. Evenness is an extension of Shannon's Index.

These are done by the formulas:

$$\text{Shannon Diversity} = -\sum_{i=1}^{k} p_i \log p_i$$

where p_i = the proportion of the total cover accounted for by each species
k = the total number of species
base 10 logs are used

$$\text{Evenness} = \frac{\text{Shannon Diversity}}{\text{Maximum Diversity}}$$

Where Maximum Diversity = log k

$$\text{Simpson's Diversity} = 1 - \sum_{i=1}^{k} p_i^2$$

Similarity is a measure of how many species overlap between two samples relative to the number which do not overlap. It is computed between years for the same sample, between treatments in the same year and forest type, and between samples for the same treatment.

$$\text{Similarity} = \frac{2 \times C}{A + B}$$

C = the shared species between groups 1 and 2
A = total species in group 1
B = total species in group 2

Shrub and Tree Density Data

Seedling layer	=	Ht1+Ht2+Ht3
Sapling layer	=	Ht4+Ht5+Ht6
Subcanopy layer	=	Ht7+Ht8+Ht9+Ht10+Ht11
Canopy layer	=	Ht12

Shrub and tree data averaging techniques for density, height, and use:

1, Means are first done for species within samples & then among samples

- e.g. Mean = Σ (Σ(sample plot data)/100)/2 where there are 100 plots per sample and 2 samples

2. Standard Error is calculated within plots then the mean is taken for the two plots

- e.g. SE = Σ(SE(sample plot data))/2

3. Two Standard Errors are used in all graphical comparisons. This is approximately equal to a 95 percent confidence level.

4. Total Shrub Density is the sum of each individual species density.

- Shrub = ALCR+AMAL+BEGL+BEOC+COST+LEGR+LODI+LOIN+POFR+PRPE+RISP+ROAC+RUST+SARA+SASP+SHCA+SOSC+SYAL+UNBR+VIED

5. Total Conifer Density is the sum of all conifer species.

Conifer = ABLA+PICO+PIGL+PIMA

6. Total Deciduous Density is the sum of all deciduous species densities.

Decid = BEPA+POBA+POTR

7. Total Trees = Conifer + Decid

8. Overall Total = Shrub+Conifer+Decid

Mean height for each species is calculated before mean use, since mean ht is used to weight the use average. Mean Height is weighted by each layer's height in the following calculation. This has the effect of making the calculated height more affected by taller individual stems.

Mean Height = Σ(HtCl Count * Ht of HtCl * Ht of HtCl)/Σ(HtCl Count * Ht of HtCl)

Thus for each species Overall Mean Height = (Ht1*0.01+Ht2*0.09+Ht3*0.25+Ht4*0.49+Ht5*0.81+Ht6*2.25+Ht7*6.25+Ht8*12.25

+Ht9*25+Ht10*49+Ht11*81+Ht12*144)/(Ht1*0.1+Ht2*0.3+Ht3*0.5+Ht4*0.7+Ht5*0.9

+Ht6*1.5+Ht7*2.5+Ht8*3.5+Ht9*5+Ht10*7+Ht11*9+Ht12*12)

Seedling Layer Height =(Ht1*0.01+Ht2*0.09+Ht3*0.25)/(Ht1*0.1+Ht2*0.3+Ht3*0.5)

Sapling Layer Height = (Ht4*0.49+Ht5*0.81+Ht6*2.25)/(Ht4*0.7+Ht5*0.9+Ht6*1.5)

Subcanopy Layer Height = (Ht7*6.25+Ht8*12.25+Ht9*25+Ht10*49+Ht11*81)/(Ht7*2.5+Ht8*3.5+Ht9*5+Ht10*7+Ht11*9)

Canopy Layer Height is set at 12 m. Since no actual heights were measured there can be no other measurement.

9. Once individual species heights are determined, the mean heights of shrubs, trees, and overall mean height is determined. Again the same weighting method is used:

MeanHt = Σ(Species Count*Species Height*Species Height)/(Species Count*Species Height)

The same formula applies to conifer, deciduous, combined tree and overall total heights

10. Total use for each species is summed from winter and summer use to a maximum of 100%.

Use = Minimum (100, Summer Use + Winter Use)

11. Mean Use for shrubs, trees, and overall groups is weighted based the density of stems and on the square of mean height of the stems in the plot where the use was recorded.

Mean Use = Σ (Use*Stems*Ht*Ht) / Σ(Stems*Ht*Ht)

For example, if one plot had 15 rose stems with a height of 1 metre and 20% use and another had 5 rose stems at 0.5 m and 50% use, the average would not be simply (20 + 50) = 35%. Instead the average accounts for density and height and is =

(20*15*1*1 + 50*5*0.5*0.5)/(15*1*1+5*0.5*0.5) = (300+62.5)/(15+1.25) = 22.3%

The same formula is used for individual species and for species groups (i.e. shrubs, trees, and total woody plants)

12. Stem count means are unweighted averages for each species, remembering that each plot is used in the average whether the species is present or not.

Shrub and tree species cover is calculated in order to calculate diversity such that shrub, tree, and vegetation cover data can be combined. This is done by use of empirical equations for each shrub or tree species. Species for which data to determine an equation was unavailable have cover calculated using average shrub or tree equations.

The cover equations were taken from a study by W. Bessie (unpublished research) in the Foothills Model Forest. S = Stems per m^2. Use of this method assumes that the same mean variance in shrub sizes exists in the shrubs sampled to obtain regression equations as the data obtained in the Forest/Wildlife Study.

Shrubs	Cover = 10^(1.314 x log(S))
Deciduous Trees	Cover = 10^(2.330 x log(S))
Conifer Trees	Cover = 10^(2.019 x log(S))
Abies lasiocarpa	Cover = 10^(1.936 x log(S))
Alnus crispa	Cover = 10^(1.832 x log(S))
Amelanchier alnifolia	Cover = 10^(1.997 x log(S))
Betula glandulosa	Cover = 10^(1.454 x log(S))
Ledum groenlandicum	Cover = 10^(0.837 x log(S))
Lonicera dioica	Cover = 10^(0.925 x log(S))
Picea glauca	Cover = 10^(1.792 x log(S))
Picea mariana	Cover = 10^(2.441 x log(S))
Populus balsamifera	Cover = 10^(2.086 x log(S))
Populus tremuloides	Cover = 10^(2.685 x log(S))
Potentilla fruticosa	Cover = 10^(0.843 x log(S))
Ribes spp.	Cover = 10^(1.264 x log(S))
Rosa acicularis	Cover = 10^(1.234 x log(S))
Salix spp.	Cover = 10^(1.687 x log(S))
Shepherdia canadensis	Cover = 10^(1.692 x log(S))
Spirea betulifolia	Cover = 10^(1.423 x log(S))
Symphoricarpos albus	Cover = 10^(1.030 x log(S))
Viburnum edule	Cover = 10^(1.049 x log(S))

Browse Calculations

Estimated Used Mass = Use% * Dry Mass

Estimated Pre Use Mass = Dry Mass + Estimated Used Mass

Canopy Cover Calculations

Canopy cover was calculated from the stem numbers per height class from the regenerating conifer data. This represents winter canopy closure (when deciduous trees are not in leaf).

We have taken the data collected in 1988 and 1995/96 and calculated canopy cover values for conifer trees, based on tree crown width measurements and tree numbers per hectare.

First we used the 1995/96 crown width measurements to determine average widths for trees of various height classes. Only the 95/96 data was valid for this purpose because the 88 data was not set up to have both width and height class for the sampled trees. Up to 4 trees were sampled per plot for this purpose.

Crown widths were used to calculate crown areas assuming a circular crown base. Thus the formula was [pi(width)^2]/4.

The average areas were calculated for each conifer species (pine, white spruce, black spruce, fir) and were based on measurements at each forest and treatment where possible. If a tree of the appropriate size class was not measured on a given treatment block, the average from the other treatment for the same forest was used, and if one was not available from there, the average from the other forest types were used. (Of course, this substitution only applied to minor species in each treatment block since there were ample measurements of the main species).

The averages were then multiplied to the conifer tree per hectare values for each height class, and converted so that the results came out as % tree cover values. The formula used was:

Cover (%) =1/10000[Σ(density x crown area)] x 100%

where 1/10000 converts from ha to m^2, density is trees/ha, crown area is in m^2.

The resultant sum across all species and height classes gave the percent for each plot. These were then averaged for the 100 plots in each stand to get a mean and 2xSE value. The means and 2xSE were then averaged together for the two samples where appropriate. Note that for ease of comparison the 1988 **MIXEDWOOD** unscarified sample was only calculated for one sample, which was the same as the only sample remaining in 1995 after the other sample was destroyed.

Four different sums were calculated. This was done since we believe that it is not appropriate to have the cover of all height classes of trees, for some uses we are only interested in the canopy height level cover.

These are:

1. Total Tree Cover - this was obtained from all tree areas regardless of height, thus it includes the trees <2 m tall as well as all taller trees. This value tells us something about the total conifer tree resource and may be appropriate for small sized animals which can use any sized tree for cover.
2. Cover >2 m - this was obtained from the sum of all height class covers greater than or equal to 2 m in height. This height is the approximate height of a standing ungulate and thus determines the cover available for overhead protection. As well, these tree heights are now recognized as being trees rather than saplings and there is probably some sort of greater stability associated with trees at this level.
3. Cover >6 m - similar to the >2 m above but with 6 m as the criterion height. Not used for graphing.
4. Cover >10 m height. These height trees are considered to be mature canopy level conifers. These are the trees whose presence would normally define a maturing forest state. They are also providing the most canopy closure and the greatest opportunity for nesting and roosting of birds and arboreal mammals, as well as providing ample food supplies through cones.

In all these cases we refer to this measurement as cover, not canopy closure. This is because the typical measurement of canopy closure assumes that the canopy is a layer which varies in cover from 0 - 100%. The measurement is normally done visually by above or below ground techniques that compare the covered areas to non-covered areas. This measurement on the other hand is the sum of individual components of the tree layer, and due to overlap of tree bases the measurement is potentially much higher in given plots. In fact, the plot covers for each height class, before averaging were often over 100%. Thus, we do not think these values can be used as a surrogate for canopy closure, but rather they are another correlated measure of the canopy layer.

Wood Cover Calculations

Each sample was then entered onto a spreadsheet for the calculation of mean diameter, diameter distribution by decomposition class, and percent cover. Percent cover was calculated by assuming that none of the logs overlapped. The sum of all diameters was divided by the length of the survey lines and multiplied by 100 to obtain percent. Standard error was calculated for each sample. Where 2 samples existed (**PINE** and **SPRUCE** treatments) these were added for the two samples (which is the same as doubling each samples standard error then obtaining the mean). For the other treatments where only one sample existed (**SPRUCE** mature, All **MIXEDWOOD**) the standard error from the one sample was doubled. This allows the presentation of graphics with error bars that represent 95% confidence intervals for determining whether two or more means are the same.