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Conifer and Vegetation Response in the BWBSmw1 12 Years after Mechanical and Herbicide Site Preparation

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Ministry of Forests Research Program

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During 1983, three vegetation management treatments were applied to a backlog rehabilitation site in the Boreal White and Black Spruce (bwbs) mw1 biogeoclimatic subzone near Dawson Creek, British Columbia. Two herbicides, glyphosate and hexazinone, were aerially applied at 3 and 4 kg ai/ha, respectively, to plots with a mixed stand of *Populus tremuloides* (aspen), *Salix bebbiana* (willow), *Populus balsamifera* ssp. *balsamifera* (balsam poplar), *Betula papyrifera* (birch), and *Calamagrostis canadensis* (bluejoint reedgrass). A third area was not treated with herbicide (control). The treated and control areas were cleared of all vegetation and debris in the subsequent winter and planted the following May with *Picea glauca* (white spruce) seedlings.

The trial site was remeasured during 1995 (12 years post-treatment) to determine whether the treatments had any lasting effects on the growth and development of the planted spruce. Both the glyphosate and hexazinone treatments produced spruce seedlings significantly larger (3.5 and 3.4 times, respectively) than those found in the control area. No significant difference was evident in the number of well-spaced spruce per hectare between the herbicide and control areas. However, the control area had significantly less free-growing spruce than the herbicide-treated areas because of the presence of a balsam poplar overstorey.

Differences in broadleaf vegetation were apparent between the treatment areas. The control area had an overstorey of poplar (12 000 stems per hectare) and a shrub layer of browsed willow and birch (3800 stems per hectare). The hexazinone-treated areas contained 3600 stems per hectare of overstorey *Alnus viridis* (Sitka alder) found in patches, and a shrub layer of browsed willow and birch (1500 stems per hectare). In contrast, the glyphosate-treated areas had only a shrub layer of heavily browsed willow and birch (3200 stems per hectare).

Separate vegetation assessments were completed in August 1996. The results suggested lower species diversity in the hexazinone area when compared to the control and glyphosate areas. Analysis of the percentage of cover of forage species showed significantly greater cover in the control area compared to the herbicide-treated areas. This difference was primarily due to the increased cover of poplar in the control area. The five main species found within the research site were bluejoint reedgrass, horsetail, balsam poplar, white spruce, and willow.

ACKNOWLEDGEMENTS

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Field assistance was provided by Balvinder Biring (Research Branch) and Gary Flaterud Contracting. Edgar Fuchs assisted with the analysis of the August 1996 vegetation data, and review comments were provided by Balvinder Biring, Phil Comeau, Chris Hawkins, and Peter Ott of the Research Branch, Richard Kabzems of the Fort St. John Forest District, and Raj Prasad of the Canadian Forest Service.

Tables

Figures

1 INTRODUCTION

Experimental project (ep) 1195 was established in 1995 to remeasure previously established vegetation management research trials. This project was developed in response to operational and land management needs for long-term data on crop tree response to vegetation management treatments. Research on the silvicultural implications of vegetation management treatments has historically focused on providing short-term data to support plantation establishment information needs. However, the demand for long-term information has increased substantially because of recent changes in provincial forestry legislation and policy (*Forest Act, 1988* and *The Forest Practices Code of B.C. Act, 1995*) and societal concern over the management of Crown lands. The forest industry is now required to regenerate young forests. As well, social change has put pressure on land managers to reduce herbicide use and develop vegetation management alternatives that are both effective and non-intrusive on other forest resources. These developments have intensified the need for long-term information that assesses the effects of brushing activities. Information is required for timber growth-and-yield projections, to assess impacts on non-timber resources and resource user groups, to expand our knowledge of applied forest biology, and ultimately to improve forest management practices.

During 1994 and 1995, several vegetation management trials were evaluated (> 5 years post-treatment) for the possibility of remeasurement to obtain long-term conifer response data. Candidate research trials were screened using published and unpublished reports, experimental design, field surveys, and communications with operational and research staff. Of those candidate trials, the Sunset Prairie and Stewart Lake projects in the Dawson Creek Forest District were chosen for remeasurement. These trials were established by Les Herring (research silviculturist) in 1982–1983. This report summarizes the data collected during November 1995 and August 1996 at the Stewart Lake herbicide trial.

2 OBJECTIVES

The primary objectives were:

1. To document and compare spruce seedling response to the three 1983 site preparation treatments 12 years after planting (Velpar® gridballs and winter-shearing, Roundup® and winter-shearing, and winter-shearing alone).
2. To compare the number of stems per hectare of conifer and broadleaf species and of well-spaced and free-growing spruce seedlings (B.C. Ministry of Forests 1990) 12 years after three site preparation treatments (Velpar® gridballs and winter-shearing, Roundup® and winter-shearing, and winter-shearing alone).
3. To document and compare vegetation development, species diversity, and forage use on the three site preparation treatment areas during the 1996 growing season.

3.1 Site Description

The trial was established near Stewart Lake at kilometre 24 on the Stewart Lake Forest Service Road (Table 1), which originates approximately 50 km west of Dawson Creek along Highway 97 near Groundbirch (Figure 1). The trial site falls within the Boreal White and Black Spruce biogeoclimatic zone (bwbs) in the Peace Moist Warm BWBSmw1 variant. Historically, the area contained spruce, pine, and poplar forest types. Before 1969, a sawmill was located at Stewart Lake and the surrounding area was actively logged. During 1969 and 1971, major wildfires occurred in the area. In the early 1980s, over 20 000 ha were declared "not satisfactorily restocked" (nsr) in the Peace tsa. The resulting post-logging/wildfire stands were composed of *Populus tremuloides* (aspen), *Salix bebbiana* (willow), *Populus balsamifera* ssp. *balsamifera* (balsam poplar), *Betula papyrifera* (birch), and *Calamagrostis canadensis* (bluejoint reedgrass).

TABLE 1 *Stewart Lake herbicide trial site information*

Component	**Detail**
District	Dawson Creek Forest District
Location	Kilometre 24 on the Stewart Lake Forest Service Road
Map sheet opening / size	93P095-04 polygons 85, 109, 143, 146
Longitude / latitude	121° 10' 00" / 55° 57' 00"
UTM grid zone	10
UTM east / UTM north	614400 / 6202000
Biogeoclimatic zone	Peace Moist Warm BWBS (BWBSmw1)
Mean elevation	935 m
Site class	Medium to high
Slope / aspect	10% average / east
Soil texture / depth	Brunisolic Gray Luvisols on calcareous loamy till covered by 15 cm of sandy gravel capping (Ae, Bm, Bt, calcareous C)
Plantation / seedlot	Planted May 1984, white spruce seedlot no. 3962
History	Logged before 1969, wildfire 1969–1971
Herbicide trial treatments	Herbicide application May and June 1983, cleared December 1983 (D-7 and D65 Komatsu crawlers with angled blades)

3.2 Trial Design

During 1983–1984, three site preparation treatments were established at the Stewart Lake site (Table 2). The objective of the treatments was to compare the effectiveness of herbicides in eliminating established vegetation before winter-shearing and planting treatments. Three areas were selected during early 1983 (Figures 1 and 2). The herbicides hexazinone (Velpar® gridballs) and glyphosate (Roundup®) were applied by helicopter to two

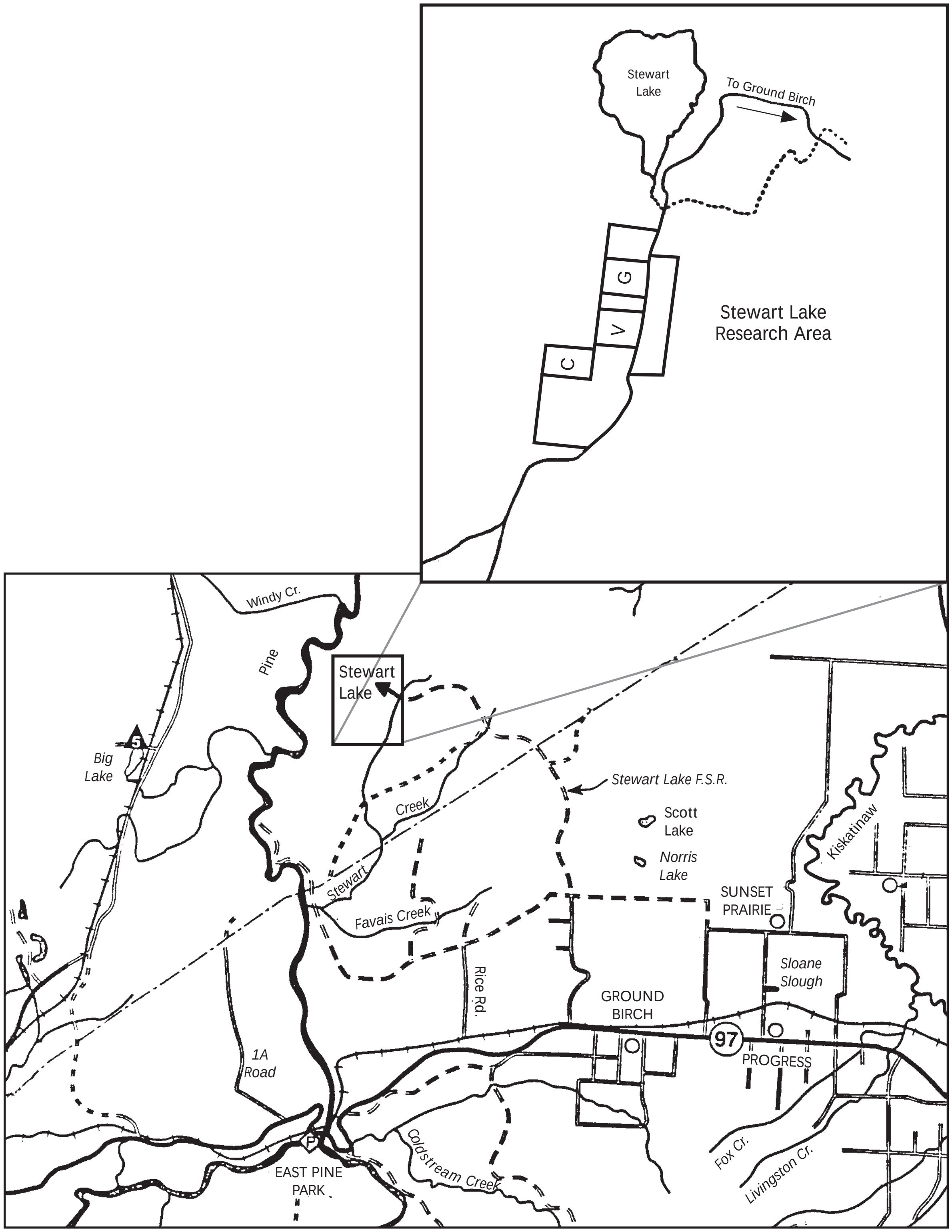


FIGURE 1 *Location map for Stewart Lake herbicide trial.*

treatment areas (approximately 2.5 ha each). Untreated buffer strips between the herbicide treatment areas were also established (a minimum 30 m wide). The third area was left untreated as a control. All three blocks (hexazinone, glyphosate, and the untreated control) were winter-sheared (cleared) during the first week of December 1983 with D-7 and D-65 (Komatsu) crawlers equipped with angled dozer blades. Because of the frozen soil conditions, these blades effectively sheared off vegetation and piled the debris without excessive soil disturbance. *Picea glauca* (white spruce) seedlings (2+0 psb 415) from seedlot no. 3962 were planted the following spring (May 1984).

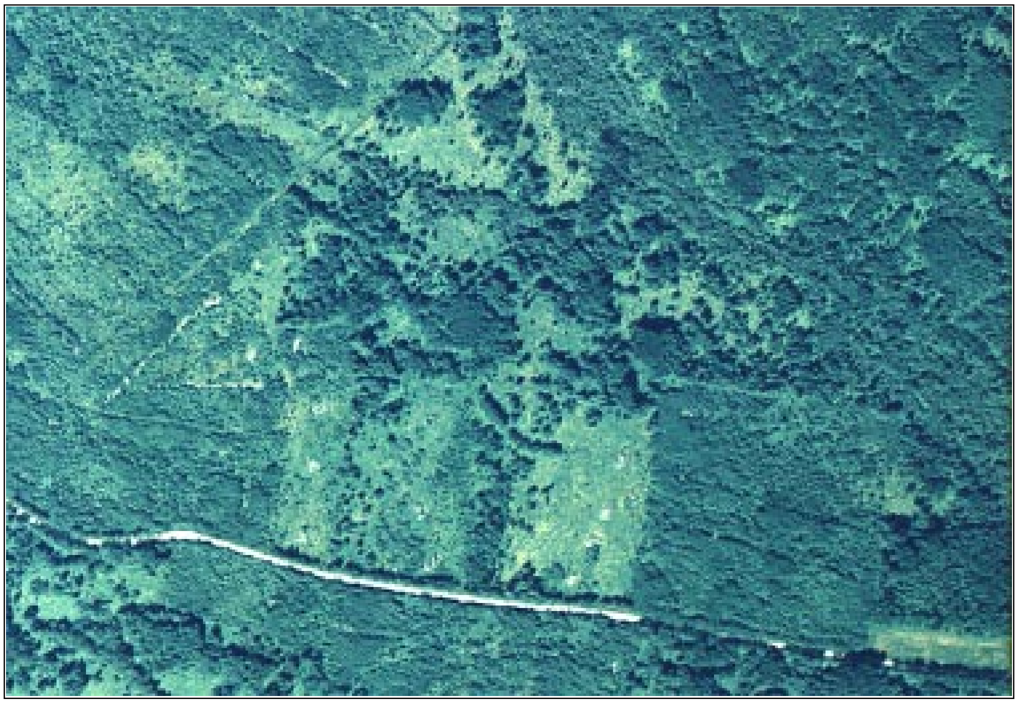
TABLE 2 *Herbicide treatments*

Treatment	Application rate	Equipment used
Glyphosate	3 kg ai/ha glyphosate (Roundup®) June 1983	Bell 206B with Simplex Model 2700 nozzle in boom spray system
Hexazinone	4 kg ai/ha hexazinone (Velpar® gridball) May 1983	Bell 206B with Chadwick aerial bucket
None (control)	Not treated	Not treated

The trial design consisted of two large demonstration plots for the hexazinone gridball treatment separated by an untreated and unsheared buffer (Figure 2). A single control and a single glyphosate treatment area were also established. The hexazinone treatment area consisted of two plots of 100 × 150 m divided by a buffer of approximately 70 m. The size of the control area was approximately 150 × 150 m. The glyphosate treatment area was approximately 100 × 250 m separated by a unsprayed and uncleared buffer 70 m wide. The uncleared buffers and other areas surrounding the plots were not planted.

3.3 Sampling Method

On November 2, 1995, planted spruce seedlings and surrounding hardwood vegetation were sampled within each treatment plot. In each treatment area, 30 spruce seedlings were selected using a systematic selection technique with a random start (every third seedling selected along a transect). Also, three 3.99 m radius plots were randomly established within each treatment area to measure total stems per hectare of conifer and deciduous components and free-growing crop trees, and the height and basal diameter of five deciduous stems (randomly selected). Conifer and deciduous stems were assessed for condition and damage using codes provided by Herring and Pollack (1985) (Appendix 1). No differentiation was made between types of deciduous stems (main stem, basal sprouts, or suckers). Spruce total height and height for every odd year was measured back to the earliest post-treatment year possible, which was 1985 in most cases. For some seedlings, height in 1985 could not be accurately determined because of difficulty in locating the terminal a)



b)

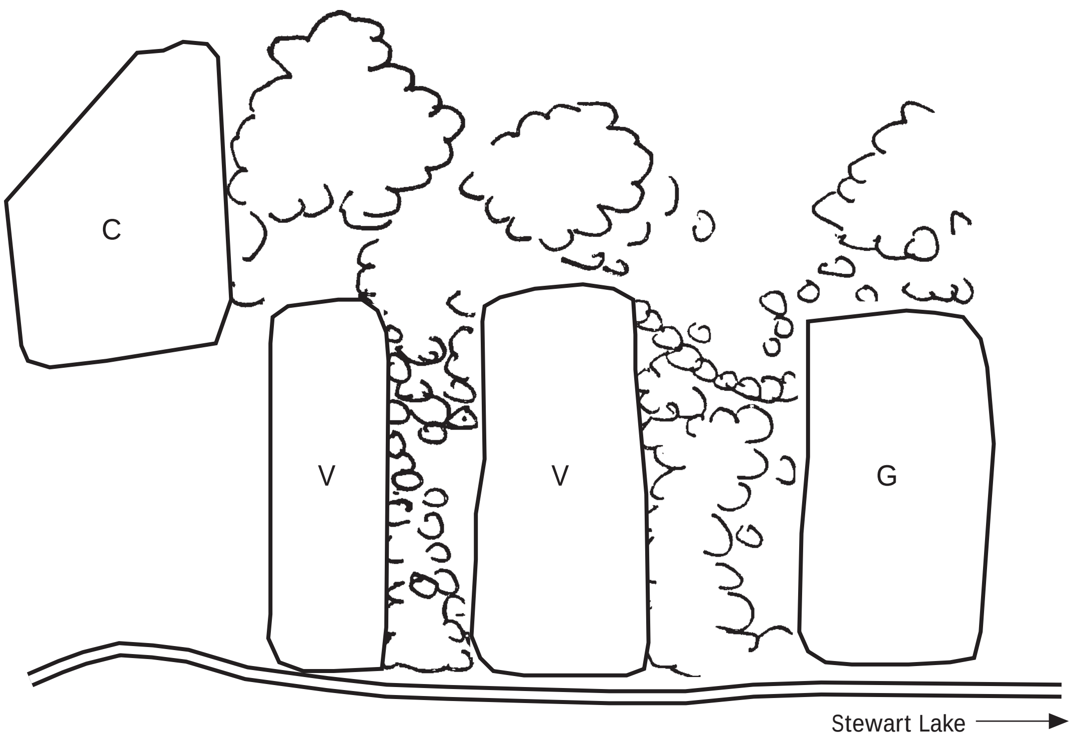


FIGURE 2 *a) Enlargement of 1994 aerial photo of trial site (BCC 94011#178) and b) schematic of trial site and plots: control (C), hexazinone (V), and glyphosate (G) with buffer areas.*

bud scar. The 10 m wide area along the treatment plot boundaries was not sampled to avoid the influences of boundary edges. The data collected include

- spruce seedling stem diameter at ground level, crown width (N-S, E-W), and height in 1985, 1987, 1989, 1991, 1993, and 1995;
- spruce seedling condition (stem, leader, and foliage);
- height and stem diameter at ground level of broadleaf stems;
- percent cover of hardwoods overtopping spruce;
- stems per hectare of conifer and broadleaf species;
- stems per hectare of both well-spaced and free-growing spruce (B.C. Ministry of Forests 1990);
- notes on plot condition, location, wildlife browse, etc.; and
- complete plant species listing and assessment of species height, percent cover, vigour, distribution, and browse activity.

During August 1996, four 3.99 m radius plots were randomly established within each treatment area to assess vegetation development and species diversity. Percent cover and modal height were estimated for all plant species found. Assessments were conducted using procedures recommended by the Habitat Monitoring Committee (1990). All species were assessed for vigour, distribution, and browse activity (Appendix 2).

3.4 Statistical Analysis

Statistical analyses included an analysis of variance (anova) (Table 3) and planned comparisons (Table 4) using the sas statistical program (sas Institute Inc. 1985). To test for treatment differences (pseudoreplication), the 30 sample seedlings and data from the three 3.99 m radius survey plots as well as the four vegetation assessment plots were considered as experimental units. As such, testing of means represents a comparison of plots and is limited in its reference to similiar herbicide and site preparation treatments. The concern with pseudoreplication is that the effect produced by the treatment cannot be statistically differentiated from the effect of being in a particular plot. However, the large treatment areas sampled (2 ha minimum plot size) and the relative homogeneity of the environment for all three treatment levels (topography, aspect, slope, vegetation) does provide confidence in the general interpretation of the results.

TABLE 3 *Analysis of variance of treatment data*

Source of variation	Factor type	Level	Degrees of freedom (*df*)	Expected *F*-test (*df*)
Treatments T	Fixed	3	2	$\frac{\text{mean squares treatment}}{\text{mean squares seedlings}}$ (2, 87)
Seedlings S(T) (error term)	Random	30	87	
Total			89	

Note, results from a single study are applicable only to that site, and repeated studies located at different sites will be necessary to increase the confidence of the generalizations. Treatment response may be affected directly, or in interaction with a host of factors other than the treatments. Variation in stock quality, stock development, climate, soil nutrient and moisture regime, vegetation competition, or soil type may influence conifer and vegetation response to treatments. Herbicide efficacy is affected by such factors as phenology of target species, application rate, formulation, application method, and weather.

TABLE 4 *Planned comparisons of treatment data*

Contrast	Coefficient a	Coefficient b	Coefficient c
Control vs glyphosate (3 kg ai/ha)	1	–1	0
Control vs hexazinone (4 kg ai/ha)	1	0	–1
Glyphosate vs hexazinone	0	1	–1

anova and planned comparisons were used to determine whether the treatments had a significant effect on the diameter and height of the planted spruce and whether significant treatment differences existed in the number of well-spaced and free-growing seedlings. So that these comparisons could be made approximately 12 years after planting, we assumed that the spruce seedlings within each treatment area were of similar size and condition when planted. Vegetation data were also analyzed similarly for treatment differences.

4 CONIFER RESPONSE AND STOCKING ASSESSMENT RESULTS: 1995

4.1 Spruce Diameter, Height, Crown Dimensions, and Condition

anova and planned comparisons confirmed field observations that spruce seedlings from both herbicide treatments were significantly larger in diameter, height, and crown dimensions than spruce growing in the control areas (Table 5, Appendices 3 and 4). Even when 1985 or 1987 heights were used as covariates in a covariance analysis, the 1995 seedling height was significantly larger in the herbicide-treated areas than in the control area. No significant differences existed in spruce seedling diameter, height, or crown dimensions between the hexazinone and glyphosate treatment areas. Analysis of the spruce height: diameter ratio also showed significant herbicide versus control differences.

Analysis of spruce seedling condition suggests some interesting differences between treatments. As summarized in Table 6, a large amount of leader and lateral clipping or browse was observed. This damage was

TABLE 5 *Spruce diameter, height, and crown dimensions in 1995*

Treatment	Diameter (mm)	1995 height (cm)	N–S crown width (cm)	E–W crown width (cm)	Height: Diameter ratio
Glyphosate*	61.19b	285.93b	147.67b	139.67b	47.22b
	(15.86)†	(64.28)	(40.49)	(38.46)	(4.16)
Hexazinone	60.71b	279.67b	148.83b	143.17b	47.03b
	(17.11)	(73.17)	(35.69)	(35.37)	(7.41)
Control	37.45a	215.60a	114.87a	111.63a	59.13a
	(10.90)	(49.64)	(33.12)	(29.12)	(9.12)

* Means followed by different letters within each column signify statistical difference at $p \leq 0.05$.
† Standard deviation appears in parentheses.

observed consistently on the leader and sometimes on nearby lateral branch tips, leaving behind the sharp cut surface characteristically caused by snowshoe hare. The incidence of damage appeared to vary with the treatment and the presence of broadleaf cover (Section 4.3). Approximately 50% of the spruce seedlings in the control area were clipped, whereas no damage was noted on the spruce in the glyphosate-treated area. The percentage of forked leaders resulting from past leader damage or multiple leader growth was highest in the hexazinone and control areas. This high level of leader browsing may be because snowshoe hare prefer broadleaf forests with understorey willow (Peterson et al. 1996). In the glyphosate treatment area, 20% of the spruce seedlings had forked leaders although recent leader damage was not evident. Stem pitching was noted on three seedlings (two from the hexazinone treatment and one from the glyphosate area) from what appeared to be insect activity. Only one spruce seedling with the characteristic "Shepherd's crook" leader indicative of weevil damage (*Pissodes strobi*) was noted in the trial area.

TABLE 6 *Summary of spruce seedling condition*

Treatment	% forked leaders	% browsed leader damage			
		1993–1995	1995	1994	1993
Glyphosate	20	0	0	0	0
Hexazinone	47	13	0	13.3	0
Control	30	50	7	40	7

4.2 Spruce Height Data: 1985–1995

Table 7 and Figure 3 show the average spruce seedling height for the treatments from 1985 to 1995. Statistical analysis suggests that spruce seedlings from the hexazinone and glyphosate treatments were not significantly different in height during this time period. The spruce seedlings from the herbicide treatments were clearly taller than the control treatment seedlings. anova and planned comparisons confirm these visible differences in height from 1991 to 1995. Before 1991, statistical analysis shows that at least one of the herbicide treatments had significantly taller seedlings than the control treatment (Table 7, Appendix 5).

TABLE 7 *Spruce seedling heights: 1985–1995*

	Height (cm)					
Treatment	**1985**	**1987**	**1989**	**1991**	**1993**	**1995**
Glyphosate	30.61b*	48.57b	85.10ab	138.57b	189.17b	285.93b
	(8.51)†	(18.24)	(28.55)	(40.14)	(50.42)	(64.28)
Hexazinone	29.10b	44.50ab	86.30b	138.77b	189.07b	279.67b
	(8.74)	(15.57)	(27.35)	(43.26)	(50.54)	(73.17)
Control	23.63a	38.93a	73.00a	115.73a	152.20a	215.60a
	(6.08)	(10.85)	(18.81)	(30.27)	(36.71)	(49.64)

* Means followed by different letters within each column signify statistical difference at $p \leq 0.05$ using planned comparisons.
† Standard deviation appears in parentheses.

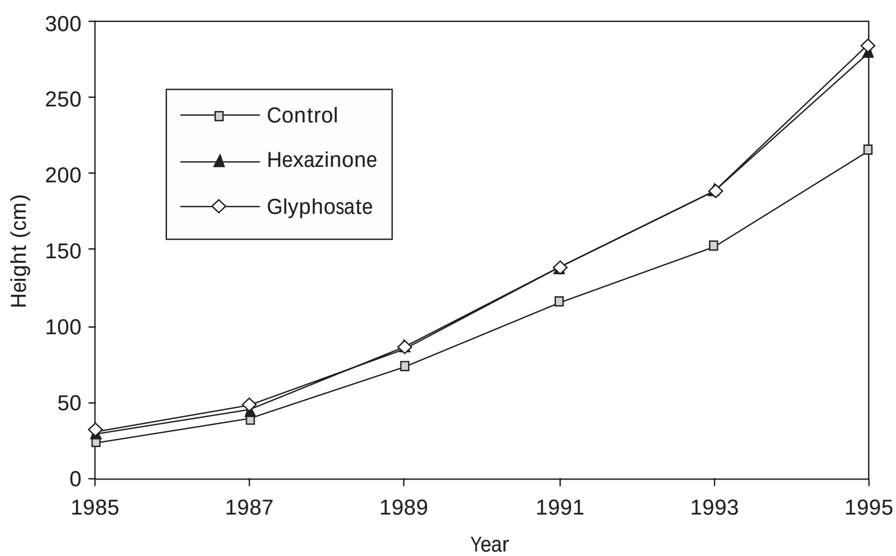


FIGURE 3 *Spruce seedling height: 1985–1995.*

Analysis of spruce seedling height increments (biennial growth, Table 8) suggested that height growth was significantly greater in the herbicide-treated areas than in the control area from 1989 to 1995. Before 1989, during the early establishment period, the spruce height growth differences between the treatments were not consistent. From 1985 to 1987, spruce seedling growth was significantly greater in the glyphosate-treated area. However, from 1987 to 1989, significant differences existed only between the hexazinone and control treatment areas. These results suggest that height growth response to the herbicide treatments did not become substantial until at least 5–7 years after treatment.

TABLE 8 *Spruce seedling height increments: 1985–1995*

	Height increment				
Treatment	**1985–87**	**1987–89**	**1989–91**	**1991–93**	**1993–95**
Glyphosate	27.67a* (7.35)†	36.53ab (13.98)	53.47a (18.77)	50.60a (16.57)	96.77a (18.32)
Hexazinone	21.40b (7.84)	41.80a (15.03)	52.47a (19.27)	50.30a (18.36)	90.60a (29.37)
Control	22.88b (5.02)	34.07b (11.56)	42.73b (14.27)	36.47b (12.58)	63.40b (20.41)

* Means followed by different letters within each column signify statistical difference at $p \leq 0.05$.
† Standard deviation appears in parentheses.

4.3 Silviculture Survey Information

Stand density and species composition information was collected on the 3.99 m radius silviculture survey plots. Conifer species composition did not vary between treatments. In general, the only conifers present in the herbicide-treated areas were the planted spruce seedlings (Table 9). A small number of naturally regenerated pine were found only in the control treatment area in addition to the planted spruce. All three treatment areas were stocked above the target stocking level (B.C. Ministry of Forests 1990). Both herbicide treatment areas can be considered free-growing plantations because the number of free-growing stems per hectare exceeds the minimum requirement of 700. However, the control treatment area had fewer than 70 stems per hectare of free-growing conifers because of the presence of a broadleaf overstorey.

The majority of the broadleaf species found at the Stewart Lake trial site were balsam poplar, willow, birch, Sitka or green alder, and aspen. However, aspen was not found in any of the silviculture survey plots.

TABLE 9 *Conifer stems per hectare, well spaced and free growing*

Treatment	Total conifers	Spruce	Pine	Spruce, well spaced*	Spruce, free growing *
Glyphosate	1733	1733	0	1600a	1600b
Hexazinone	1533	1533	0	1533a	1133b†
Control	1533	1467	67	1467a	67a†

* Means followed by different letters within each column signify statistical difference at $p \leq 0.05$ using planned comparisons.
† Hexazinone and control planned comparison statistical difference at $p \leq 0.07$.

Table 10 summarizes the broadleaf stocking information. The broadleaf vegetation response to the treatments is clearly delineated both in density and species composition. The broadleaf stem density in the control area exceeded 15 000 stems per hectare and was composed of approximately 75% balsam poplar and 25% willow and birch. The hexazinone treatment resulted in approximately 5000 total stems per hectare with 70% alder, 29% willow/birch, and 1% balsam poplar. In the glyphosate area, only willow and birch were found at 3200 stems per hectare. In all the treatments, willow and birch stems had been heavily browsed (moose) and, as a result, height rarely exceeded 1.5 m. The percent cover and composition of overstorey vegetation (broadleaves) gives a clear indication of stand development. The control areas were heavily dominated by balsam poplar with spruce in the understorey. The hexazinone areas were open with patches and clumps of overstorey alder. The glyphosate area consisted of spruce seedlings with a shrub layer of browsed willow and birch.

TABLE 10 *Broadleaf stocking information*

Treatment	Total broadleaves (sph)	Balsam poplar (sph)	Sitka alder (sph)	Willow/ birch (sph)	Broadleaf overstorey diameter* (mm)	Broadleaf height (cm)
Glyphosate	3 200	0	0	3 200	–	77
Hexazinone	5 200	67	3 600	1 533	47.0 (alder)	333
Control	15 867	12 067	0	3 800	53.3 (poplar)	475

* Basal diameter.

The vegetation species present were stratified into four categories according to vertical spacing, height, and taxonomy (Table 11). Analysis of the vegetation data included treatment comparison of percent cover, height, and number of species for these strata and for forage species (species of potential forage value) and browsed species (field evidence of browse noted). Appendix 6 contains the list of all species found, and Appendix 7 summarizes the vegetation assessment ANOVA test results. Figure 4 shows representative photos of the three treatment areas in August 1996.

FIGURE 4 *Representative photos of a) control, b) hexazinone, and c) glyphosate treatment areas on August 14, 1996.*

TABLE 11 *Vegetation strata (Habitat Monitoring Committee 1990)*

Strata	**Symbol**	**Attributes**
Tall shrub layer	B1	All woody plants between 2 and 10 m tall
Low shrub layer	B2	All woody plants less than 2 m tall
Herb layer	H	Herbaceous species regardless of their height and some low woody species
Moss layer	M	All mosses, lichens, and fungi

5.1 Species Diversity and Vegetation Cover

Several measures of biodiversity were calculated from the plant species information collected. Species richness (number of species), a modified Simpson's diversity index (inverse), and a modified Shannon-Wiener index (exponential form) were used for treatment comparison of plant diversity (Krebs 1989). The number of species found within each stratum was also compared (shrub, herb, and moss layer species richness). The modified Simpson's index was calculated as:

$$\left[\sum_{i=1}^{n} p_i^2\right]^{-1}$$

and, the modified Shannon-Wiener index as:

$$e^{-\sum_{i=1}^{n} p_i \log_e(p_i)}$$

where p_i represents the proportion of each plot covered by species *i*. The modified indices can be easily interpreted as the number of *common* species that are required to produce the observed species heterogeneity (Krebs 1989).

The results of the statistical analysis of diversity indices were dependent on the indices' sensitivity to rare species (Table 12). The modified Simpson's and the modified Shannon-Wiener indices, which put less weight on rare species than species richness, both suggested no significant difference in species diversity between the treatments. However, the unmodified Shannon-Wiener index (means not given) and species richness both indicated the hexazinone treatment area had significantly lower diversity (at $p = 0.0913$ and $p = 0.0931$, respectively). Analysis of species richness within each stratum indicated that the significant difference in diversity was due to a significantly smaller number of species within the herb layer of the hexazinone area ($p = 0.0085$). The species richness index, and to a lesser extent the unmodified Shannon-Wiener index, place more weight on rare species than on common species.

The modified Simpson's and Shannon-Wiener indices suggest that approximately 9–14 common or dominant species existed within the glyphosate and control areas (dependent on the index's rare species sensitivity). The hexazinone-treated area had between 6 and 10 common species. The species richness index suggested that 18 herb species occurred in both the control and glyphosate plots, but only 12 occurred in the hexazinone plots. In the tall shrub strata, a smaller number of species were found in the glyphosate treatment plots when compared to the control plots. However, the total number of tall shrub species is small (fewer than five), which restricts the interpretation of the data.

TABLE 12 *Species richness and diversity indices*

Treatment	Number of species: Trees	Shrubs	Herbs	Mosses and lichens	Total	Modified Simpson's index	Modified Shannon-Weiner index	Species richness
Glyphosate	3	11	28	1	43	13.91	9.08	29.25a*
Hexazinone	3	12	20	0	35	10.41	6.33	23.75b
Control	5	10	26	2	43	14.04	9.10	30.5a
p-value						0.2342	0.1786	0.0931
Site total	5	14†	34†	2	55†			

* Means followed by different letters within each column signify statistical difference at $p \leq 0.09$ using ANOVA and planned comparisons.
† *Salix* and *Viola* genera are not differentiated, therefore a possibility of additional species exists.

Despite differences in species richness, the average percent cover of the herb layer was comparable between the hexazinone and glyphosate areas at 139.8 and 148.3%, respectively, which exceeded coverage in the control area (113.3%), though not significantly (Figure 5). By contrast, the tall shrub stratum coverage was significantly higher in the control plot, 79% vs. 27.8% (glyphosate) and 30% (hexazinone), primarily due to the occurrence of poplar.

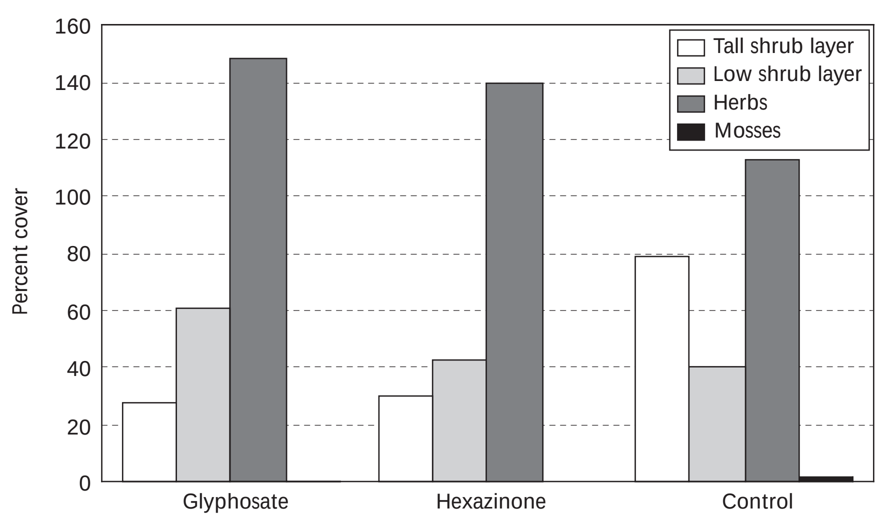


FIGURE 5 *Total percent cover by strata and treatment.*

Table 13 contains percent cover of species of significant presence found within the research site. Analysis of variance indicated significant treatment differences in percent cover of *Calamagrostis canadensis* (p = 0.038), *Picea glauca* (p = 0.029), and *Populus balsamifera* (p = 0.0009). In addition, apparent treatment differences are suggested in the percent cover of other species such as *Equisetum sylvaticum*, *Lonicera involucrata*, *Rubus idaeus,* and *Viburnum edule*. Mean percent cover and height of all species recorded can be found in Appendix 8.

The five main species with the highest coverage that could be compared across treatments were *Calamagrostis canadensis*, *Equisetum arvense,* poplar, *Picea glauca*, and *Salix.* No significant treatment difference in the total coverage of these five species was noted (Figure 6). Modal height for the five main species, while somewhat greater in the control, was also not significantly different between treatments.

TABLE 13 *Mean percent cover for species of significant presence*

Species	Glyphosate	Hexazinone	Control	ANOVA *p*-value
Alnus viridis	1.75	8.5	2.0	0.362
Betula papyrifera	2.5	5.3	4.75	0.519
Calamagrostis canadensis	57.5ab*	72.5a	39.25b	0.038
Cornus canadensis	6.3	1.5	3.5	0.509
Epilobium angustifolium	2.8	4.0	5.0	0.333
Equisetum arvense	14.5	13.75	8.3	0.550
Equisetum sylvaticum	3.5	12.5	4.75	0.121
Heracleum lanatum	12.5	17.5	15.5	0.686
Lonicera involucrata	4.5	7.0	13.75	0.171
Picea glauca	32.8a	19b	15.5b	0.029
Populus balsamifera ssp. *balsamifera*	0.8b	1.0b	41.25a	0.0009
Rosa acicularis	10.5	5.0	3.75	0.252
Rubus idaeus	6.0	4.5	1.9	0.107
Rubus pubescens	0.75	1.0	3.75	0.297
Salix spp.	17.5	7.75	16.25	0.567
Viburnum edule	3.0	8.75	7.5	0.164

* Means followed by different letters within each row signify statistical difference at $p \leq 0.05$.

5.2 Vigour and Distribution

Species vigour was rated according to the habitat monitoring scale of 0–5, with 5 indicating optimal health (Habitat Monitoring Committee 1990). Species were most often given a rating of 2 or 3 on all treatments (fair or good). An attempt to compare vigour between treatments was made by establishing a ratio that related the number of specimens rated as less

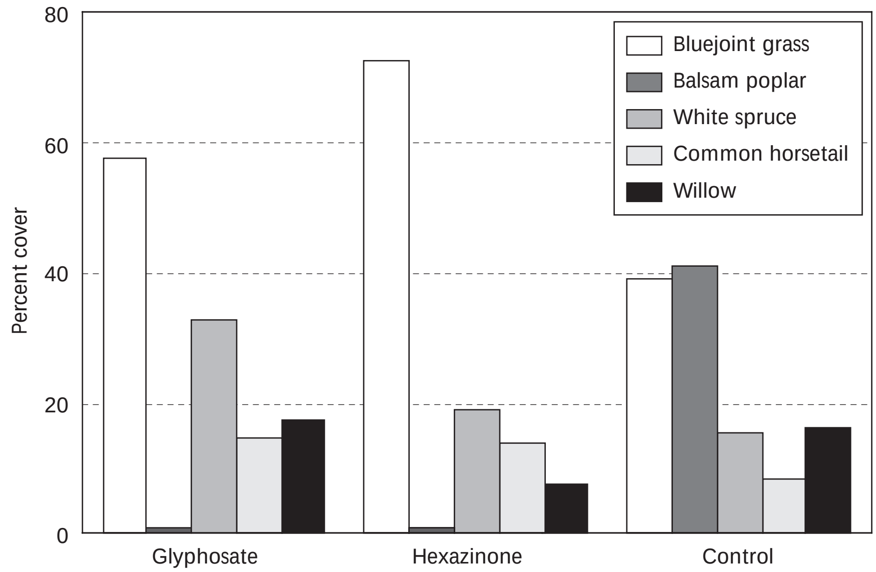


FIGURE 6 *Percent cover of five main species by treatment.*

than or equal to 2 to those rated as greater than or equal to 3. Comparison on this basis by anova revealed that there was no discernible treatment influence on vigour. The glyphosate treatment mean of the ratio was 0.96 versus 0.57 and 0.48 for the control and hexazinone-treated plots, respectively. This suggests that the glyphosate-treated area had a lower mean vigour than the other treatment areas.

5.3 Wildlife Forage and Utilization Level

5.3.1 Forage species composition and cover Forage species were identified based on Balfour (1989). Appendix 9 lists these species. Analysis of variance results suggest that no significant difference in forage species composition exists between treatments. The mean number of species per treatment was 10.5, 10.25, and 9.25 for the control, glyphosate, and hexazinone treatments, respectively. Three species were unique to the control area (*Abies lasiocarpa, Carex deweyana, Populus tremuloides*), two were unique to the glyphosate plot (*Smilacina racemosa, Streptopus amplexifolius*), and one was unique to the hexazinone plot (*Cornus stolonifera)*. These unique species represented less than 3% of forage cover on the treatments where they occurred and consequently do not account for differences in forage cover between treatments.

Total forage percent cover was significantly greater in the control area ($p < 0.0035$). The difference was primarily because of the higher percentage of *Populus balsamifera*, *Lonicera involucrata*, and *Athyrium filix-femina* found in the control plots. Compared to the control, poplar was virtually absent from the herbicide-treated areas. The control plots had a mean forage cover of 113.5% versus 56% and 46.5% for glyphosate- and hexazinone-treated areas, respectively.

5.3.2 Browse utilization level Browse utilization assessments followed the procedures outlined by the Habitat Monitoring Committee (1990) and used a 0–5 scale of browse activity (Appendix 2). Species with browsing damage are listed in Table 14. Moderate to heavy browse was recorded on *Salix*, *Betula papyrifera*, and, when available, *Amelanchier alnifolia*. Less extensive browsing was seen on *Populus balsamifera*, *Lonicera involucrata*, and *Viburnum edule*. This pattern of preference was repeated over all treatments and suggested that the browsed species were equally palatable across the treatments. Because of the small number of plots and distribution of utilization classes, categorical analysis was not successful. Analysis of variance using the 0–5 classes suggested a higher level of browse activity in the control area for *Epilobium angustifolium* ($p = 0.0866$). No other differences could be discerned.

TABLE 14 *Utilization classes for browsed species*

Browsed species	Glyphosate	Hexazinone	Control
Alnus viridis	3*	1	–
Amelanchier alnifolia	4	2	–
Betula papyrifera	2, 4, 4, 4	4, 4, 5	2, 4, 4
Cornus stolonifera	–	2	–
Epilobium angustifolium	1, 3	2	2, 2, 2, 4†
Heracleum lanatum	1, 1, 1	1	1, 2
Lonicera involucrata	2	2	1, 2, 2, 3
Populus balsamifera ssp. *balsamifera*	3	3	2, 2, 2, 2
Populus tremuloides	–	–	4
Ribes triste	–	2	–
Salix spp.	4, 4, 4, 5	4, 4	3, 4, 4, 4
Viburnum edule	1, 2	2	1

* Utilization classes (Habitat Monitoring Committee 1990) shown for plots where browse occurred.
† anova *p*-value = 0.087

6 DISCUSSION

The summary of 1995 remeasurement data shows that the spruce seedlings apparently respond positively to the herbicide treatments in contrast to the untreated control areas. Diameter and height measurements show that spruce seedlings from the glyphosate- and hexazinone-treated areas are 3.5 and 3.4 times larger, respectively, in stem volume ([height x basal area] ÷ 3) than the spruce from the control area. This considerable gain in size is probably because the herbicide reduced vegetation competition. Twelve years post-treatment, spruce height growth in the herbicide-treated areas continues to be significantly greater than in the control area. Similar long-term response of white spruce to weed control treatments has been reported by Sutton (1995) where "inital weed control was still exerting highly significant effects on performance of white spruce" after 28 years.

The spruce height:diameter ratio is significantly larger in the control area than in the herbicide treatment areas. Lieffers and Stadt (1994) showed that increases in white spruce height:diameter ratio were related to a decrease in overstorey transmitted light. The height:diameter ratio of the control spruce (i.e., 59) when compared to Lieffers and Stadt (1994) and to unpublished operational research data (Silviculture Practices Branch, B.C. Ministry of Forests) suggests that the degree of white spruce suppression in the control area was not severe (e.g., 70+).

Differences in the broadleaf vegetation community are also apparent between the treatments. The control area has a relatively high density of balsam poplar, which is reducing the availability of light and resources for spruce growth. The significantly larger height:diameter ratio of the control spruce is evidence of such a light-limited environment. In general, however, the spruce in the control area are healthy, which indicates that the balsam poplar canopy is allowing enough light to penetrate for spruce survival and growth. The glyphosate treatment has resulted in a significantly reduced broadleaf cover, with willow and birch the only broadleaf species present. Repeated ungulate browsing of the willow and birch has kept these species in dwarf form. The hexazinone treatment has promoted the establishment of alder in clumps and patches. The alder has established in microsites where the clearing and hexazinone treatment created mineral soil or good seedbed conditions. In both herbicide treatment areas, the bluejoint grass cover is heavy and this has probably slowed or precluded the re-establishment of broadleaf species.

The percentage of spruce with leader browse damage may initially be of concern. However, this damage may have been present for some years, and previously damaged seedlings continue to grow in height with or without the development of forked leaders. The higher incidence of browse damage within the control area may be a result of the increased level of cover provided by the poplar overstorey, especially during the winter. Small animals such as snowshoe hares would prefer the increased cover from predators and weather. It follows that a preferred area would sustain more browse damage.

All treatment areas were sufficiently stocked with well-spaced spruce. Only the control area does not meet minimum free-growing stocking standards and requires conifer release treatments. Alder stems in the hexazinone treatment are concentrated in clumps and patches. This has resulted in approximately 400 stems per hectare of spruce that are not free growing. Even though the alder is competing for site resources and has reduced light levels, its presence may provide an additional source of nitrogen. Height and diameter results suggest that spruce growth is not compromised by the alder; however, the added wildlife cover may increase the incidence of leader and lateral damage.

Vegetation assessments indicate that a large number of predominantly herbaceous species are present across all treatment areas. Bluejoint grass has the largest cover of all species present. Even within the understorey of the control area, cover of this species was more than 35%, although it was significantly reduced from that found in the open hexazinone-treated area. No discernible differences in vegetation vigour and distribution were found.

Analysis of percent cover of forage species suggests that the control area had a significantly greater availability of forage. This difference was primarily due to the significantly greater percent cover of poplar found in the control area. Analysis of the number of forage species and incidence of browse damage did not suggest any significant treatment differences. Twelve species were actively browsed. Willow and birch were frequently used, and, to a lesser extent, black twinberry, fireweed, poplar, and highbush-cranberry.

Significant treatment differences in species diversity existed. The number of herb species in the hexazinone-treated area was significantly smaller than in the control and glyphosate areas. This difference may be due to the greater control of herbaceous species by the soil-active hexazinone herbicide. The high percent cover of bluejoint grass in the hexazinone-treated area suggests that the grass has displaced the other herb species.

Several measures of biodiversity were analyzed for treatment differences. The hexazinone treatment areas consistently had the lowest diversity indices (species richness, modified Simpson's, modified Shannon-Wiener). Analysis indicated that the hexazinone-treated area had significantly lower species richness than the control and glyphosate areas and that this difference was because of a significantly smaller number of herb layer species. Analysis of the indices that placed more weight on common species (modified Simpson's, modified Shannon-Wiener) suggests that no significant differences in species diversity existed between the treatment areas.

6.1 Stand Yield Projections

The spruce seedling data collected in 1995 provide an opportunity to estimate spruce site index and predict stand yield using available managed stand yield tables. The computer program Wintipsy (Mitchell and Grout 1995; Stone et al. 1996) was used to generate yield tables and economic projections based on initial estimates of site index for the treatment areas. Site index estimates were calculated using the variable growth intercept model for interior spruce suggested by Nigh (1996):

$$SI = 100 \cdot (H - 1.3) \div (A - 0.5)$$

where: A = breast height age (years) and H = total tree height (m).

Two main scenarios were followed based on the determination of spruce site index (Table 15):

- In scenario A, a separate site index is assumed to exist for each treatment area. This is based on the premise that the site preparation treatments have influenced site index.
- In scenario B, only a single site index is assumed to exist for the three treatment areas. The treatments have no influence on the availability of site resources.

For scenario A, each treatment area (control, glyphosate, and hexazinone) was treated separately to determine three individual site index assessments. Calculations were based on the top 7% of dominants in each treatment data set. This corresponds to approximately 100 stems per hectare for the 1500 stems per hectare stocking level. The calculated site index was subsequently used by the computer program WinTIPSY to generate stand yield tables (Mitchell and Grout 1995) and economic analyses (Stone et al. 1996). Table 15 lists the spruce yield and economic projections (A1, A2, and A3). For scenario B4, the entire spruce data set was used to select the top 7% of dominants and determine a site index for the whole trial site. This site index of 27.4 m is midway between the herbicide determinations and reflects the dominant seedling size of those treatments.

TABLE 15 *Stand yield projections for spruce derived from WinTIPSY*

Treatment scenario	SI* (m)	Silviculture costs ($/ha)	NPV ($/ha) physical rotation†	MAI‡ rotation age (years)	Total (m^3/ha)	MAI (m^3/ha)
A1: control	23.2	1200	397	66	485	7.34
A2: glyphosate	27.8	1466	1385	52	494	9.49
A3: hexazinone	27.1	1466	1175	53	485	9.16
B4: all combined (herbicide and control areas)	27.4	1466	1267	53	493	9.30
B5: control and thinning	23.2	1800	–8	66	485	7.34

* Spruce site index, metres at breast height age 50 (Nigh 1996).
† Net present value discounted at 4%.
‡ Mean annual increment.

The site index for each treatment (A1, A2, A3) suggests that stand value is significantly increased and physical rotation age reduced with the herbicide site preparation treatments. Conversely, the site index of the control area has been reduced by 4 m because of the presence of a poplar overstorey. However, this projection has not accounted for overall stand volume and value because of the inherent problems of modelling mixedwood stands.

The proposition of a reduced site index for the control area is based on observed spruce growth under a balsam poplar canopy of approximately 12 000 stems per hectare. The development of this broadleaf overstorey has effectively created an even-aged, mixedwood stand. The poplar, through competition for light and site resources, has reduced the spruce site index and will continue to suppress it until the broadleaf component is removed or thinned. Scenario B5 projections are based on the added cost of thinning the poplar stand at age 10 to a density that is more compatible with maintaining a higher spruce site index.

The management of broadleaf overstorey density and understorey light regime has generated considerable interest and research (Comeau and Thomas 1996). One of the more pressing management questions is how mixedwood silviculture can be modelled to determine future yields. Site index projections may require that the present approach based on single species be modified to an approach that considers stand understorey light regime. When considering scenario B5, the more realistic spruce site index will be higher than 23.2 m, but somewhat less than the monoculture spruce site index of 27.4 m.

7 MANAGEMENT IMPLICATIONS

The use of combined mechanical and herbicide site preparation treatments on backlog NSR sites can significantly affect the subsequent white spruce growth by eliminating broadleaf competition. The positive effect of the herbicide treatments on the growth and development of white spruce 12 years after treatment suggests that early weed control can substantially increase stand volume. However, using a broadcast herbicide treatment may reduce plant species diversity and management flexibility through the loss of commercially valuable broadleaf species.

Other resource values (i.e., wildlife habitat and forage availability) may also be directly or indirectly affected by the use of herbicides. The presence of broadleaf species such as balsam poplar will provide habitat diversity for many wildlife species. Mixedwood stands provide important moose habitat for feeding and shelter. Mixedwood environments such as those found in the control area are also a preferred snowshoe hare habitat (Peterson et al. 1996).

The use of winter-shearing alone (control) did allow the establishment of planted white spruce. The control area did not develop a high poplar density, which would have caused the severe survival and growth problems noted on other sites. The use of spot, intermittent broadcast, or low-rate herbicide treatments may provide the broadleaf control necessary for conifers to establish and grow, but also allow a reduced broadleaf component to establish as well.

Lastly, the interpretation of results from a single study are applicable only to that site, and repeated studies located at different sites will be necessary to increase the confidence of the generalizations. The lack of true replication in this trial (pseudoreplication) is a concern; however, the information presented in this report is valuable as an indicator of long-term response to vegetation management treatments. Continued monitoring and research on crop tree and vegetation response to operational treatments across a variety of sites is essential to improve our understanding of the long-term effects of forest vegetation management practices.

Foliage codes	**Stem codes**	**Damage codes**
h - healthy	h - healthy	a - none
y - chlorotic	p - bark peeled or abraded	h - herbicide
m - mottled	b - stem bent	m - mechanical equipment
n - necrotic	s - stem smashed, crushed, trampled	t - tools
a - needles absent, defoliated	c - stem cut, clipped, broken	s - falling slash (human cause)
b - browsed	d - tree dead, dying	x - falling or sliding debris
d - dead buds on lateral branches	m - tree missing	e - climate, frost
o - other (specify)	o - other (specify)	n - snow press
		v - vegetation press
Leader codes		w - climate, drought
h - no visible effect (healthy)		r - rodents, small animals
c - curled		b - big game
f - forked		l - livestock
b - browsed		f - fire
t - dead terminal bud		i - insects
s - snapped, broken		d - disease
a - absent, missing		o - other (specify)
o - other (specify)		u - unknown

APPENDIX 2 Forage utilization classes (Habitat Monitoring Committee 1990)

Code	Class	Range (%)	Description
0	Nil	0	Plants show no evidence of livestock or wildlife browse
1	Slight	1–5	Plants show very little evidence of browse; may be topped or slightly used
2	Light	16–35	Plants may be topped, skimmed, or grazed in patches; low-value plants are ungrazed and 60–80% current leafage intact
3	Moderate	36–65	Plants rather uniformly grazed; 15–25% of current leafage intact
4	Heavy	66–80	Plants almost entirely used, with less than 10% of current leafage intact
5	Extreme	> 80	Plants carry the grazing load and are closely cropped; there is no evidence of reproduction or current seed stalks

APPENDIX 3 Sum of squares, mean squares, and probability values from ANOVA

Source of variation	Groundline diam. (mm)	Ht. (cm)					
		1995	1993	1991	1989	1987	1985
Treatment (T):							
Sums of squares	11053.21	90905.87	27256.96	10519.36	3247.4	1403.27	431.15
Mean square	5526.6	45452.93	13628.48	5259.68	1623.7	701.63	226.58
p-value	0.0001	0.0001	0.0027	0.032	0.085	0.053	0.035
Error (Seedlings) (E):							
Sums of squares	19230.58	346541.73	186874.83	127552.6	55591.0	20090.73	3233.83
Mean square	221.04	3983.24	2147.99	1466.12	638.98	230.93	63.41
Total:							
Sums of squares	30283.79	437447.6	214131.79	138071.96	58838.4	21494.0	3686.98

APPENDIX 4 SAS mean squares and probability values for planned contrasts of groundline stem diameter and 1985–1995 heights (ANOVA)

Contrast	Groundline diam. (mm)	Ht. (cm)					
		1995	1993	1991	1989	1987	1985
Control vs hexazinone:							
Mean square	8117.74	61568.07	*20387.27*	7958.02	2653.35	464.82	266.45
p-value	0.0001	0.0002	0.0028	0.022	0.045	0.16	0.046
Control vs glyphosate:							
Mean square	8458.56	74201.67	20498.02	7820.42	2196.15	1392.02	413.41
p-value	0.0001	0.0001	0.0027	0.023	0.067	0.016	0.014
Hexazinone vs glyphosate:							
Mean square	3.50	589.07	0.15	0.60	21.60	248.07	21.63
p-value	0.90	0.70	0.99	0.98	0.86	0.30	0.56

APPENDIX 5 SAS mean squares and probability values for planned contrasts of height increment (ANOVA)

Contrast	Height increment (cm)				
	1985–87	1987–89	1989–91	1991–93	1993–95
Control vs hexazinone					
Mean square	19.34	897.07	1421.07	2870.42	11097.60
p-value	0.53	0.030	0.035	0.0012	0.0001
Control vs glyphosate					
Mean square	194.49	91.27	1728.07	2996.27	16700.02
p-value	0.050	0.48	0.02	0.0010	0.0001
Hexazinone vs glyphosate					
Mean square	372.04	416.07	15.0	1.35	570.42
p-value	0.0077	0.14	0.83	0.94	0.31

Species code	Scientific name	Common name
Trees and shrubs		
ABIEBALS	*Abies balsamea*	Balsam fir
ALNUVIRI	*Alnus viridis*	Sitka or green alder
AMELALNI	*Amelanchier alnifolia*	Saskatoon
BETUPAPY	*Betula papyrifera*	Paper birch
CORNSERI	*Cornus stolonifera*	Red-osier dogwood
LINNBORE	*Linnaea borealis*	Twinflower
LONIINVO	*Lonicera involucrata*	Black twinberry
PICEGLAU	*Picea glauca*	White spruce
POPUTREM	*Populus tremuloides*	Trembling aspen
POPUBALS	*Populus balsamifera* ssp.	Balsam poplar
RIBELACU	*Ribes lacustre*	Black gooseberry
RIBEOXYA	*Ribes oxyacanthoides*	Northern gooseberry
RIBETRIS	*Ribes triste*	Red swamp currant
ROSAACIC	*Rosa acicularis*	Prickly rose
RUBUIDAE	*Rubus idaeus*	Red raspberry
RUBUPUBE	*Rubus pubescens*	Trailing raspberry
SALIX	*Salix* spp.	Willow
SPIRPYRA	*Spiraea pyramidata*	Pyramid spirea
VIBUEDUL	*Viburnum edule*	Highbush-cranberry
Herbs		
ACHISIBI	*Achillea sibirica*	Siberian yarrow
ACTARUBR	*Actaea rubra*	Baneberry
ANAPMARG	*Anaphalis margaritacea*	Pearly everlasting
ANGEGENU	*Angelica genuflexa*	Kneeling angelica
ARALNUDI	*Aralia nudicaulis*	Wild sarsaparilla
ASTECILI	*Aster ciliolatus*	Fringed aster
ASTECONS	*Aster conspicuus*	Showy aster
ATHYFILI	*Athyrium filix-femina*	Lady fern

Species code	Scientific name	Common name
Herbs (continued)		
CALACANA	*Calamagrostis canadensis*	Bluejoint grass
CAREDEWE	*Carex deweyana*	Dewey's sedge
CASTMINI	*Castilleja miniata*	Common red paintbrush
CORNCANA	*Cornus canadensis*	Bunchberry
DELPGLAU	*Delphinium glaucum*	Tall larkspur
EPILANGU	*Epilobium angustifolium*	Fireweed
EQUIARVE	*Equisetum arvense*	Common horsetail
EQUISYLV	*Equisetum sylvaticum*	Wood horsetail
FRAGVESC	*Fragaria vesca*	Woodland strawberry
GALITRIF	*Galium trifidum*	Small bedstraw
GEUMMACR	*Geum macrophyllum*	Large-leaved avens
GYMNDRYO	*Gymnocarpium dryopteris*	Oak fern
HERALANA	*Heracleum lanatum*	Cow-parsnip
LATHOCRO	*Lathyrus ochroleucus*	Creamy peavine
MERTPANI	*Mertensia paniculata*	Tall bluebells
OSMOCHIL	*Osmorhiza chilensis*	Mountain sweet-cicely
PETAPALM	*Petasites palmatus*	Palmate coltsfoot
RANUUNCI	*Ranunculus uncinatus*	Small-flowered buttercup
RHINBORE	*Rhinanthus* spp.	Rattle box
SMILRACE	*Smilacina racemosa*	False Solomon's seal
STREAMPL	*Streptopus amplexifolius*	Clasping twistedstalk
TARAOFFI	*Taraxacum officinale*	Common dandelion
THALOCCI	*Thalictrum occidentale*	Western meadowrue
URTIDIOI	*Urtica dioica*	Stinging nettle
VICIAMER	*Vicia americana*	American vetch
VIOLA	*Viola* spp.	Violet
Moss and lichens		
AULAPALU	*Aulacomnium palustre*	Ribbed bog moss
POLYJUNI	*Polytrichum juniperinum*	Juniper moss

	Criteria	Treatment mean squares	Residual mean squares	*F*-value	Result
Number of species by strata	B1 (tall shrubs)	2.33	0.47	4.94	A ($p < 0.0036$)
	B2 (low shrubs)	4.08	1.94	2.1	F
	B (total shrubs)	0.58	2.63	0.22	F
	C (herbs)	48	5.89	8.15	A ($p < 0.0095$)
	D (moss)	0.58	0.17	3.50	F
	Z (all strata)	52.33	15.80	3.31	F
Percentage cover by strata	B1 (tall shrubs)	3355.08	104.97	31.96	A ($p <$ 8.15E –05)
	B2 (low shrubs)	501.64	454.35	1.10	F
	B (total shrubs)	2216.58	502.45	4.41	A ($p < 0.046$)
	C (herbs)	1333.00	566.25	2.35	F
	D (moss)	2.77	2.08	1.33	F
	Z (all strata)	725.27	802.91	0.90	F
Forage species	Count	1.75	2.72	0.64	F
	% cover	5257.00	467.30	11.25	A ($p < 0.0035$)
Conifers	% cover	329.15	61.83	5.32	A ($p < 0.03$)
Main five species	% cover	90.58	343.94	0.26	F

Species code	Control		Glyphosate		Hexazinone	
	Cover %	Modal height (m)	Cover %	Modal height (m)	Cover %	Modal height (m)
ABIEBALS	0.13	0.20				
ACHISIBI	1.25	0.81			0.75	0.74
ACTARUBR	2.0	0.72	2.25	0.35	0.75	0.70
ALNUVIRI	2.0	4.50	1.75	1.12	8.5	3.02
AMELALNI			1.25	0.98	1.25	0.80
ANAPMARG			0.25	0.73		
ANGEGENU	1.25	1.65				
ARALNUDI	0.88	0.30	0.25	0.24	0.25	0.28
ASTECILI	1.50	0.66			2.5	0.68
ASTECONS	2.50	0.70	13.0	0.56		
ATHYFILI	8.0	0.54	0.50	0.49		
AULAPALU	1.25	0.03				
BETUPAPY	4.75	1.28	2.5	1.14	5.3	0.92
CALACANA	39.25	1.17	57.5	1.21	72.5	1.45
CAREDEWE	0.50	0.70				
CASTMINI			0.25	0.60		
CORNCANA	3.50	0.13	6.3	0.05	1.5	0.09
CORNSERI					0.75	1.10
DELPGLAU	0.13	0.45	1.0	1.18	0.50	1.40
EPILANGU	5.0	0.58	2.8	0.51	4.0	0.70
EQUIARVE	8.3	0.34	14.5	0.34	13.75	0.48
EQUISYLV	4.75	0.42	3.5	0.31	12.5	0.45
FRAGVESC	6.25	0.21	5.0	0.16	2.5	0.14
GALITRIF	0.13	0.30	0.13	0.10	0.13	0.15
GEUMMACR	0.13	0.20	0.13	0.15		
GYMNDRYO	0.25	0.10	0.50	0.06		
HERALANA	15.5	1.11	12.5	0.86	17.5	0.88
LATHOCRO	0.50	0.33	3.5	0.35		
LINNBORE	0.50	0.04				
LONIINVO	13.75	0.94	4.5	0.79	7.0	0.88
MERTPANI	2.75	0.19	7.0	0.23	1.5	0.19
OSMOCHIL			0.13	0.17		
PETAPALM	2.75	0.20	3.8	0.24	1.75	0.20

Species code	Control		Glyphosate		Hexazinone	
	Cover %	Modal height (m)	Cover %	Modal height (m)	Cover %	Modal height (m)
PICEGLAU	15.5	2.29	32.8	2.92	19.0	3.32
POLYJUNI	0.38	0.02	0.50	0.02		
POPUBALS	41.25	3.7	0.8	1.56	1.0	2.75
POPUTREM	0.50	1.30				
RANUUNCI					0.25	0.80
RHINBORE			2.4	0.55	0.13	0.40
RIBELACU	1.25	0.42	4.8	0.76	1.25	0.46
RIBEOXYA			0.13	0.60	1.0	0.54
RIBETRIS	2.13	0.56	2.75	0.29	3.1	0.42
ROSAACIC	3.75	0.53	10.5	0.57	5.0	0.69
RUBUIDAE	1.88	0.48	6.0	0.37	4.5	0.68
RUBUPUBE	3.75	0.15	0.75	0.17	1.0	0.14
SALIX	16.25	2.04	17.5	1.56	7.75	1.75
SMILRACE			0.25	0.70		
SPIRPYRA						
STREAMPL			0.25	0.90		
TARAOFFI	0.25	0.16	0.13	0.18		
THALOCCI	1.75	0.57	7.5	0.61	1.6	0.38
URTIDIOI					0.50	1.00
VIBUEDUL	8.75	0.65	3.0	0.60	7.5	0.73
VICIAMER	0.13	0.35	1.25	0.59	0.13	0.70
VIOLA	0.38	0.05	0.63	0.04		

Species code	Scientific name	Common name
AMELALNI	*Amelanchier alnifolia*	Saskatoon
ATHYFILI	*Athyrium filix-femina*	Lady fern
BETUPAPY	*Betula papyrifera*	Paper birch
CAREDEWE	*Carex deweyana*	Dewey's sedge
CORNSERI	*Cornus stolonifera*	Red-osier dogwood
LONIINVO	*Lonicera involucrata*	Black twinberry
POPUBALS	*Populus balsamifera* ssp. *balsamifera*	Balsam poplar
POPUTREM	*Populus tremuloides*	Trembling aspen
RIBELACU	*Ribes lacustre*	Black gooseberry
RIBEOXYA	*Ribes oxyacanthoides*	Northern gooseberry
RIBETRIS	*Ribes triste*	Red swamp currant
ROSAACIC	*Rosa acicularis*	Prickly rose
RUBUIDAE	*Rubus idaeus*	Red raspberry
RUBUPUBE	*Rubus pubescens*	Trailing raspberry
SALIX	*Salix* spp.	Willow
SMILRACE	*Smilacina racemosa*	False Solomon's seal
STREAMPL	*Streptopus amplexifolius*	Clasping twistedstalk
VIBUEDUL	*Viburnum edule*	Highbush-cranberry

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