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Effects of thinning and understory retention harvest on forest structure and understory plant communities

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Abstract

We examined the impact of two intensive forest management practices on forest structure and understory plant communities: 1) Salvage Thinning in lodgepole pine forests, and 2) Understory Protection harvesting in trembling aspen – white spruce mixedwoods. Salvage thinning reduced canopy tree density, basal area of deciduous trees, and snag density while resulting in increased growth of retained trees and an increase in the amount of downed coarse woody material. Thinned stands also had greater light available to the understory, although this decreased with time since thinning. Thinned stands showed an immediate reduction in understory plant species richness followed by an increase 3- to 5- years following thinning such that richness levels were higher than in control stands. This was attributable to colonization by and increased abundance of some ruderal species and those common to mesic aspen – spruce mixedwood forests. Thinned stands also had reduced abundance of species associated with undisturbed mature pine forests. Thinned stands also had greater shrub cover. Understory protection harvesting reduced density and basal area of deciduous trees and snags while retaining conifers, which showed positive growth responses.

Stands partially harvested by Understory Protection showed increased light to the understory but this effect was diminished in stands with higher levels of deciduous tree retention and those sampled longer after harvesting (13 years). As for the Salvage Thinning, the Understory Protection (UP) stands showed reduced understory plant richness immediately after disturbance but after a few years (3- to 13- years after harvest) the UP harvested stands had higher understory richness and a somewhat different understory species assemblage than control stands. This was attributable to addition of, and higher abundance of, shade intolerant and ruderal plant species. Differences between UP Harvested and control stands diminished over time since harvesting and were less when there was a higher level of canopy retention during the UP harvesting. Machine Corridors, which are used by harvesting and skidding equipment to access the site, had higher species richness than control stands and were dominated by grasses, shade intolerant and weedy species. Machine corridors also had much higher densities of deciduous tree regeneration than the UP harvested areas or control stands.

For both Salvage Thinning and Understory Protection harvesting it is likely that increased light, along with effects of disturbance to the forest floor, provide opportunities for new species to colonize forest stands as well as for some moderately shade tolerant species to experience an increase in abundance following partial harvesting. As such, these types of harvesting, which reduce canopy density, result in a shift in understory plant communities towards something that is likely more similar to what would be found at an earlier successional stage or in a different (more open, less conifer) type of forest.

Background and Objectives

Increasing demands for forest resources, combined with a desire to maintain ecological sustainability of forests has lead to interest in a greater diversity of silvicultural practices, including both "ecologically friendly" practices and intensive forest management (Gillis 1990; Tappeiner et al. 1997). The latter includes practices that are over and above the minimum required by policy or regulation and which are designed to improve yields of fibre on a designated portion of the landbase. The effectiveness of these practices for meeting fibre and non-fibre objectives has become of great importance to forest scientists and managers. Through effects on forest structure and composition, forest management for timber production also influences understory plant communities, plant diversity and, in turn, wildlife abundance (Thomas et al. 1999).

Several factors influence forest understory vegetation: 1) both above- (light) and below- (water, nutrients) ground resource availability (Grace 1999; Thomas et al. 1999); 2) microclimatic conditions, which are influenced by light and stand structure; and 3) disturbance processes, which facilitate regeneration. Silvicultural practices such as thinning or partial-cut harvests affect composition and density of the canopy, in turn influencing stand structure and microclimate, often increasing resource availability, at least temporarily (Parsons et al. 1994; Roberts & Gilliam 1995a,b; Van Velt & Franklin 1999; Johnson and Curtis 2001). Subsequent effects on understory vegetation are poorly understood, however. Ultimately, any changes in forest structure and understory development and composition might also impact habitat value of the future developing forest.

In this study we examined the effects of two intensive forest management practices, thinning [including both salvage thinning (ST) and commercial thinning (CT)] and understory protection (UP) harvesting, on forest structure, composition, and understory plant biodiversity in the western boreal forest. Both practices provide a potential economic advantage or increased volume yield and may also sustain important ecological features at the landscape scale, such as maintaining connectivity and providing habitat for wildlife.

Our key questions were as follows:

(1) How do these silvicultural practices affect stand structure, tree growth and environmental characteristics?

(2) What are the effects of these silvicultural practices on understory plant diversity and composition?

We present herein the results for salvage thinning and understory protection harvesting.

Methods

Salvage thinning was studied in lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) stands. In this practice ~ 1/3 of the basal area (1/2 of all stems) is removed, focusing on intermediate and suppressed trees in stands of 85+ years old. Understory protection harvesting was studied in mixed trembling aspen (*Populus tremuloides* Michx.) - white spruce (*Picea glauca* (Moench) Voss) stands; the understory white spruce trees are protected during harvesting of the aspen canopy.

For each of these treatments we sampled individual stands, which differed in time since treatment, and compared these to unharvested controls in order to understand the impact of the treatment and successional development following it. The salvage thinning (ST) study was conducted using 13 lodgepole pine stands near Whitecourt, Alberta (Table 1). We examined unthinned stands as well as stands which were 5-, 3-, and 1- years-since-thinning.

Understory protection harvesting was studied in 23 aspen-white spruce mixedwood stands at five locations in northern Alberta (Table 2; and see Sauder 1992). In six stands, there were two levels of retention of overstory aspen: high protection (more aspen left) and intermediate (less aspen left) (Sauder 1992). Five stands were treated with a one-pass harvesting system, in which most of the aspen overstory was removed at one time. Three stands were treated with a two-pass harvesting system, in which part of the aspen overstory and large conifers (DBH>25cm) were removed in the first-pass with a plan to remove the remaining canopy trees in a second pass two to five years later. One sampled stand had been treated with the two-pass harvesting system in which the second pass had been completed.

For both treatments we assessed various stand structural attributes and the vascular plant understory community using 14 sampling points in each stand. Understory vegetation was sampled in two 2 m^2 subplots at each sampling point. In one of the understory protection trials vegetation sampling was also conducted in plots located at the center of machine corridors, which were created to gain access to the forest for the harvesting and skidding equipment.

We calculated mean number of species (richness) per 2 m^2 plot within stands and total species richness per stand (combined over 28 subplots). Poisson regressions and mixed-model analyses of variance that included the thinning treatment as a fixed factor and stand as a random factor were used to assess the effect of the treatment. Ordination was applied to study the effects of thinning on understory species composition.

Table 1. Stands used for the salvage thinning study including site name, stand age (standard error), the years since thinning (year of first growing season post-thinning), and the location (latitude, longitude). Stands were sampled in summer 2000.

Site	Stand age	Years since thinning:	Location
WC1	104 (11.6)	5-yst (1995)	N54°04.795 W116°28.376
CH1	105 (3.9)	5-yst (1995)	N54° 11.980 W116°53.612
TH625	95 (6.6)	5-yst (1995)	N54°03.314 W116°14.874
TH626	106 (7.1)	3-yst (1997)	N54°02.959 W116°14.595
TH608	94 (16.5)	3-yst (1997)	N54°02.837 W116°15.457
TH621	99 (12.8)	3-yst (1997)	N54°02.453 W116°14.881
WW607	105 (5.3)	1-yst (1999)	N54°03.762 W116°31.535
WW604	102 (2.9)	1-yst (1999)	N54°05.574 W116°27.056
WW603	92 (8.5)	Control	N54° W116°
TH348	104 (5.7)	Control	N54°03.015 W116°15.397
TH347	90 (1.6)	Control	N54°02.671 W116°14.721
TH361	90 (43.7)	Control	N54°02.047 W116°15.298
WW606	117 (15.7)	Control	N54° W116°

Table 2. Stands used for the Understory Protection study including harvest treatment, location, replicates of treatments, the years since harvest (year of first growing season post-thinning), and the stand name. Calling Lake 1-pass stands were sampled in 2000, all others were sampled in 2001. The understory vegetation in control stands at Calling Lake was sampled in both years.

Harvest treatment	Geographic location	Replicates	Years since harvest	Stand names
One-pass and Two-pass understory protection	Calling Lake (N55º W113º)	3 Blocks with a total of:		
		3 stands of one-pass,	2-ysh (1998)	1U1-1, -2, -3
		3 stands with the 1st of a two-pass system,	3-ysh (1998)	1U2-1, -2, -3
		3 control stands.		1UC-1, -2, -3
One-pass and Two-pass understory protection	Hotchkiss (N57º W118º)	2 stands of one-pass,	7-ysh (1994)	F11, F2
		1 stand with the 1st and 2nd cut of a two-pass system,	7- / 2-ysh (1994, 1999)	F3
		2 control stands.		FC1, FC2
High and Intermediate Understory Protection	Drayton Valley (N53º W 115º)	2 stands of intermediate retention,	13-ysh (1988)	D1, D2
		1 control stand.		DC
	Hinton (N53º W117º)	2 stands of high retention,	13-ysh (1988)	H1, H2
		1 control stand.		HC
	Whitecourt (N54º W115º)	1 stand of high retention,	13-ysh (1988)	W1
		1 stand of intermediate retention,	13-ysh (1988)	W2
		1 control stand.		WC

Results

Salvage thinning: Thinned stands were characterized by lower tree density, basal area, and snag density, but greater diameter growth and amounts of downed coarse woody debris (Table 3). Thinned stands also had significantly greater light available to the understory (as measured by canopy openness, light below the canopy, and leaf area index; Table 3). Canopy openness was highest in the recently thinned stands (1-yst) and decreased progressively with time since thinning with the control stands having the lowest openness. There were no significant treatment effects on: tree height (range: 17.9 – 22.4 m); shrub height (1.25 – 1.89 m); diameter of downed wood (9.0 – 10.6 cm); organic layer depth (7.88 – 10.6 cm); litter depth (5.4 – 7.1 cm) or soil nutrient availability.

Thinned stands had significantly greater shrub cover than unthinned stands (Table 3). Understory species richness (number of species) was greater in older thinned stands than in either recently thinned or control stands; this was true both at the plot and the stand level (Figure 1).

Table 3. Effects of salvage thinning on various stand properties. Means (standard error) are given for control (unthinned) stands and stands at 1, 3, or 5 years since thinning (yst). P values in bold indicate a significant effect of thinning. Treatments with different letters had significantly different means.

	Unthinned	1-yst (th99)	3-yst (th97)	5-yst (th95)	Effect of Treatment (P value)
TREDEN (trees/ha)[1]	2499.3[a] (908.7)	935.4[b] (90.9)	1261.6[ab] (270.3)	790.3 [b] (454.4)	**0.05**
BASALAR (m^2/ha)	46.21[a] (4.57)	31.00[b] (7.23)	33.54[b] (5.91)	30.37[b] (5.91)	**0.10**
DECBA (m^2/ha)	17.15[a] (4.46)	4.96[b] (0.81)	6.21[b] (1.64)	5.77[b] (1.37)	**0.02**
EVERBA (m^2/ha)	29.05 (3.45)	26.04 (1.56)	27.33 (2.55)	24.59 (0.89)	0.54
TREGROW (mm/year)	1.05 [b] (0.09)	0.69[a] (0.15)	1.42 [c] (0.12)	1.16 [b] (0.12)	**<0.001**
SNAGDEN (snags/ha)[1]	671.2[a] (268.9)	178.5[bc] (70.7)	347.5[ab] (41.2)	66.7[c] (78.7)	**<0.001**
CWDCOV (%)	7.60[a] (0.01)	6.50[a] (0.01)	10.33[b] (0.01)	11.67[b] (0.01)	**0.02**
CANOPEN (%)	25.02[a] (1.89)	37.04[b] (2.31)	28.75[a] (1.89)	34.99[b] (1.89)	**<0.001**
Light-be (μmol/m^2/s)	3.33[a] (0.25)	4.58[b] (0.30)	3.96[b] (0.25)	4.06[b] (0.25)	**0.02**
LAI (m^2 leaf area/ m^2 ground area)	1.45[a] (0.08)	0.95[c] (0.09)	1.26[b] (0.08)	1.04[c] (0.08)	**<0.001**
SHCOV (%)	12.96[a] (13.96)	23.23[b] (20.68)	14.58[b] (2.22)	19.47[b] (2.35)	**0.05**
HERCOV (%)	12.77 (9.68)	7.37 (3.79)	18.81 (9.76)	15.83 (3.51)	0.47

Definition of variables:
TREDEN (trees/ha): total tree density; BASALAR (m^2/ha): total basal area; DECBA (m^2/ha): basal area of deciduous trees; EVERBA (m^2/ha): basal area of evergreen trees; TREGROW (mm/year): mean annual ring width over the 5 years prior to sampling; SNAGDEN (snags/ha): number of snags per ha; CWDCOV (%): percent cover of downed coarse woody debris; CANOPEN (%): percent canopy openness; Light-be (μmol/m^2/s): photosynthetic photon flux density below the canopy; LAI (m^2 of leaf area/m^2 of ground area): leaf area index; SHCOV (%): percent shrub cover, HERCOV (%): percent herb cover.

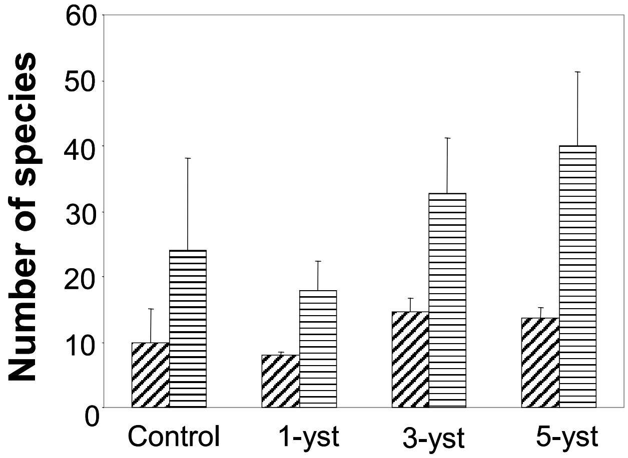

Figure 1. Understory plant species richness in control lodgepole pine stands and stands at different years since Salvage Thinning (-yst). Bars with diagonal hatching show mean species richness per 2 m^2 circular plot, bars with horizontal hatching show mean species richness per stand (28 2 m^2 sub-plots per stand).

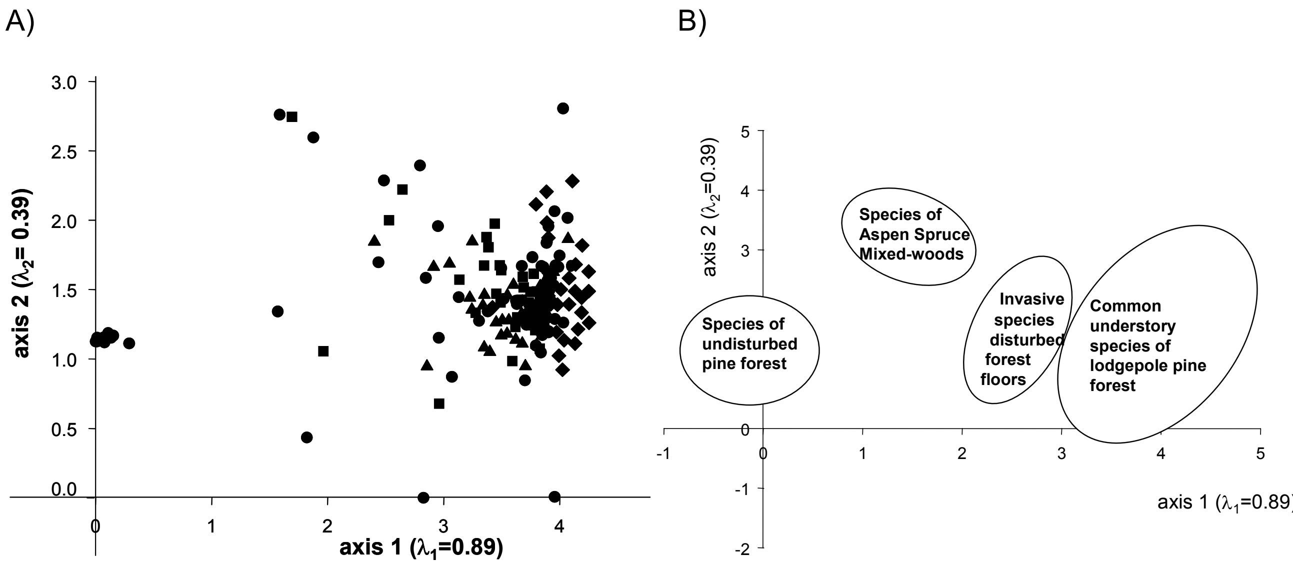

Figure 2. Results of ordination (Detrended Correspondence Analysis) examining understory plant species composition in control lodgepole pine stands and stands at different times since Salvage Thinning. A) symbols show plots from stands which were sampled: ◆ 1-yst; ▲ 3-yst; ■ 5-yst; ● control stands. Plots which are closer together were more similar in terms of understory species assemblage. B) general description of groups of species underlying the treatment differences shown in (A). Location of the species group on the graph shows an affinity with plots in a similar location in Figure 2A.

The results of ordination did not suggest a strong effect of thinning on understory species composition (Figure 2). There was some separation among plots by treatment; the most recently thinned plots were closely clustered towards the very right end of the first axis. To the left of these was a cluster of points including the plots sampled 3- and 5-yst. Plots from unthinned stands were spread across the entire ordination space with one group at the very left end of axis 1. The ordination suggested four relatively distinct species groups which corresponded loosely to the separation among plots (Figure 2B). The group at the left, bottom corner of the graph, includes species common to undisturbed lodgepole pine forests forest floors (*Symphoricarpos albus*, *Rubus acaulis*, *Vicia americana*, *Calamagrostis canadensis*, *Erigeron glabellus*, *Osmorhiza depauperata*).

Moving to the right, and associated with both thinned and unthinned plots, was a second group characterized by species of mixed-wood trembling aspen – white spruce forest (*Aster conspicuus*, *Ribes triste*, *Cornus stolonifera*, *Lonicera involucrata*, *Fragaria vesca*, *Actaea rubra*, *Pyrola virens*). The third group moving to the right, associated with thinned plots, includes opportunistic species often found colonizing exposed mineral soil and disturbed sites (*Epilobium angustifolium*, *Taraxacum officinale*, *Trifolium sp*., *Petasites palmatus*, *Rubus chamaemorus*, *Oplopanax horridus*, *Geranium bicknellii*, *Spiraea betulifolia*). The fourth group, associated with the most recently thinned plots, was comprised of common understory species of lodgepole pine forest (*Cornus canadensis*, *Rubus pedatus*, *Alnus crispa*, *Rubus idaeus*, *Vaccinium caespitosum*, *Sorbus scopulina*).

Understory Protection: Understory Protection harvesting reduced the density and basal area of deciduous trees, increased growth of retained trees, reduced snag density and greater amounts of newly-created downed coarse woody debris (Table 4). In the High / Intermediate Protection treatments, which were sampled 13-ysh, there were only no treatment effects on deciduous tree density, likely due to aspen regeneration, no effects on snag density and there was less downed wood in harvested stands. Understory protection also resulted in greater light available to the understory, as measured by canopy openness, light, and leaf area index but these effects were diminished in the stands sampled 13-ysh (Table 4). There were no significant treatment effects on other measured forest structure and environment variables.

In general, Understory Protection harvesting resulted in increased species richness per 2 m^2 plot and per stand (Table 5). This was largely due to addition of some shade intolerant understory species and a few ruderals. There was lower species richness per plot in the Hotchkiss stands that were sampled 2 years after the 2nd pass cut of a two-pass harvesting system, likely due to disturbance associated with the recent harvesting. The machine corridors of the Calling Lake Understory Protection stands were characterized by increased species richness, as compared to the control stands as well as a very different species composition (see below).

The ordination suggested an effect of Understory Protection harvesting on the understory species assemblage, with effects being diminished in the stands sampled a longer time since harvesting (Figure 3). At Hotchkiss the 1-pass stands, sampled 7-ysh, were quite similar to the control plots in terms of understory species composition. The stands sampled 2-years after the completion of the 2nd pass cut were somewhat different, showing closer clustering among plots and some separation from other plots along the first axis. For the stands sampled 13-ysh those treated with High Protection stands (more canopy left) were quite similar to the control stands while the Intermediate Protection (less canopy left) showed some degree of separation from the other plots, particularly with a group of plots located towards the lower left of the ordination diagram.

Table 4. Effects of understory protection harvesting on various stand structureand environment properties. Means (standard error) are given for control (unharvested) stands and stands exposed to different treatments and times since harvesting (ysh). P values in bold indicate a significant effect of treatment. Within treatment group, treatments with different letters had significantly different means.

	Hotchkiss	7-ysh	7- / 2- ysh		Calling Lake		3-ysh		High/Intermediate Protection		13-ysh	
	Control	1-pass	1^{st} & 2^{nd} of 2-pass	*P-*	Control	1-pass	1^{st} of 2-pass	*P-*	Control	High	Intermed	*P-*
TRE-Ever (trees/ha)[1]	228.57 (202.03)	485.71 (222.23)	728.57	0.30	800.00 (359.42)	963.81 (575.67)	897.75 (258.50)	0.44	566.67 (472.58)	704.76 (621.77)	152.38 (73.31)	0.34
TRE-Dec (trees/ha)[1]	757.14^{a} (60.61)	307.14^{b} (50.51)	171.43^{b}	**<0.001**	595.24^{a} (245.92)	129.84^{b} (52.07)	279.72^{a} (34.25)	**<0.001**	400.00 (371.43)	357.14 (51.51)	404.76 (129.62)	0.95
EVERBA (m^2/ha)	6.43 (4.51)	12.14 (4.51)	13.43 (6.38)	0.57	10.57 (2.63)	11.43 (2.63)	14.38 (2.62)	0.23	16.28 (3.88)	10.09 (3.88)	7.14 (3.88)	0.24
DECBA (m^2/ha)	39.43^{a} (4.84)	16.43^{b} (4.84)	9.71^{b} (6.84)	**<0.001**	14.29^{a} (1.56)	5.62^{b} (1.56)	11.74^{a} (1.56)	**<0.001**	19.90 (5.00)	10.00 (5.00)	11.14 (5.00)	0.31
TREGROW (mm/year)	0.992^{a} (0.11)	2.62^{b} (0.11)	3.21^{b} (0.16)	**<0.001**	1.61^{a} (0.10)	1.38^{a} (0.10)	2.14^{b} (0.12)	**<0.001**	1.42^{a} (0.31)	3.37^{b} (0.31)	2.87^{b} (0.31)	**<0.001**
SNAGDEN (/ha)	200 (0)	107.14 (70.71)	128.57	0.20	357.14^{a} (62.27)	184.44^{b} (176.95)	283.49^{ab} (76.94)	**0.0163**	133.33 (128.84)-	104.76 (100.34)	42.85 (42.15)	0.78
NewDW (%)	4.41^{a} (4.41)	24.80^{b} (4.41)	18.76^{ab} (6.24)	**0.0062**	12.97 (4.14)	20.20 (4.26)	14.31 (4.20)	0.2205	18.61^{a} (3.46)	8.94^{b} (3.46)	6.69^{b} (3.46)	**0.04**
CANOPEN (%)	16.43^{a} (0.85)	22.80^{b} (0.85)	27.19^{c} (1.20)	**<0.001**	29.45^{a} (4.02)	33.44^{b} (4.02)	27.96^{a} (4.02)	**<0.001**	26.06 (3.62)	31.96 (3.62)	35.37 (3.62)	0.19
Light-be (μmol/m^2/s)	5.22^{a} (0.48)	7.53^{b} (0.48)	8.61^{b} (0.67)	**<0.001**	5.85^{a} 0.82)	6.70^{b} (0.82)	5.39^{a} (0.82)	**0.001**	5.35^{a} (0.76)	6.03^{ab} (0.76)	7.76^{b} (0.76)	0.07
LAI (m^2/m^2)	1.95^{a} (0.04)	1.60^{b} (0.04)	1.37^{c} (0.06)	**<0.001**	1.32^{a} (0.14)	1.15^{b} (0.14)	1.32^{a} (0.14)	**<0.001**	1.34 (0.15)	1.20 (0.15)	1.14 (0.15)	0.67

Definition of variables:
TRE-Ever (trees/ha): density of conifers; TRE-Dec (trees/ha): density of deciduous trees; EVERBA (m^2/ha): basal area of evergreen trees; DECBA (m^2/ha): basal area of deciduous trees; TREGROW (mm/year): mean annual ring width; SNAGDEN (snags/ha): number of snags per ha; NewDW (%): percent cover of undecayed coarse woody debris; CANOPEN (%): percentage of canopy openness; Light-be (μmol m^{-2} s^{-1}): photosynthetic photon flux density below the canopy; LAI (m^2 of leaf area/m^2 of ground area): leaf area index.

Table 5. Mean species richness per 2 m^2 plot (standard error) and per stand (28 2 m^2 sub-plots) for mixed aspen – white spruce stands that were unharvested (control) or exposed to different types of understory protection harvesting. P- values in bold indicate a significant effect of treatment for a given group of stands.

	Richness/ plot	Richness / stand
Calling Lake (3-ysh)		
Control for 1-pass	19.14 (3.86)	46.33 (9.07)
1-pass	23.70 (1.70)	47.00 (2.65)
Control for 2-pass & MC	20.12 (3.17)	52.67 (10.26)
1st of 2-pass	27.55 (1.64)	63.33 (8.33)
Machine corridors	27.28 (1.49)	57.00 (8)
P-	**<0.001**	0.13
Hotchkiss (7-ysh)		
Control	21.07^{a} (1.82)	38 (2.83)
1-pass	21.39^{a} (1.06)	46.00 (8.48)
1st & 2nd of 2-pass (7- and 2- ysh)	17.79^{b}	34.00
P-	0.09	0.22
High and Intermediate Protection (13-ysh)		
Control	26.88^{ab} (1.76)	56.67^{a} (1.53)
High	25.36^{b} (1.67)	50.33^{a} (4.93)
Intermed	29.48^{a} (1.38)	70.33^{b} (6.81)
P-	**<0.001**	**0.04**

At the Calling Lake stands sampled 3-ysh the understory composition of the control stands showed separation from the 1- and 2-pass stands, which were largely overlapping (Figure 3). The machine corridor plots separated strongly from all other plots at the Calling Lake stands. This reflects the dominance of the Machine Corridors by grasses, shade intolerant and weedy species (*Agropyron trachycaulum, Petasites frigidus, Rosa acicularis, Rubus idaeus, Symphoricarpos albus, Taraxacum officinale*). In addition, the machine corridors were characterized by dramatically higher densities of trembling aspen and balsam poplar saplings (machine corridors: ~ 13,750/ha; UP harvested area: ~ 5,000/ha; control forest: ~ 1000/ha).

Overall, UP harvested stands tended to show increased abundance of species such as: *Calamagrostis canadensis, Elymus innovatus, Epilobium angustifolium, Lathyrus ochroleucus, Taraxacum officinale,* and *Vicia americana* but reduced abundance of *Aster conspicuus, Arnica cordifolia, Aralia nudicaulis* and bryophytes (mosses and liverworts).

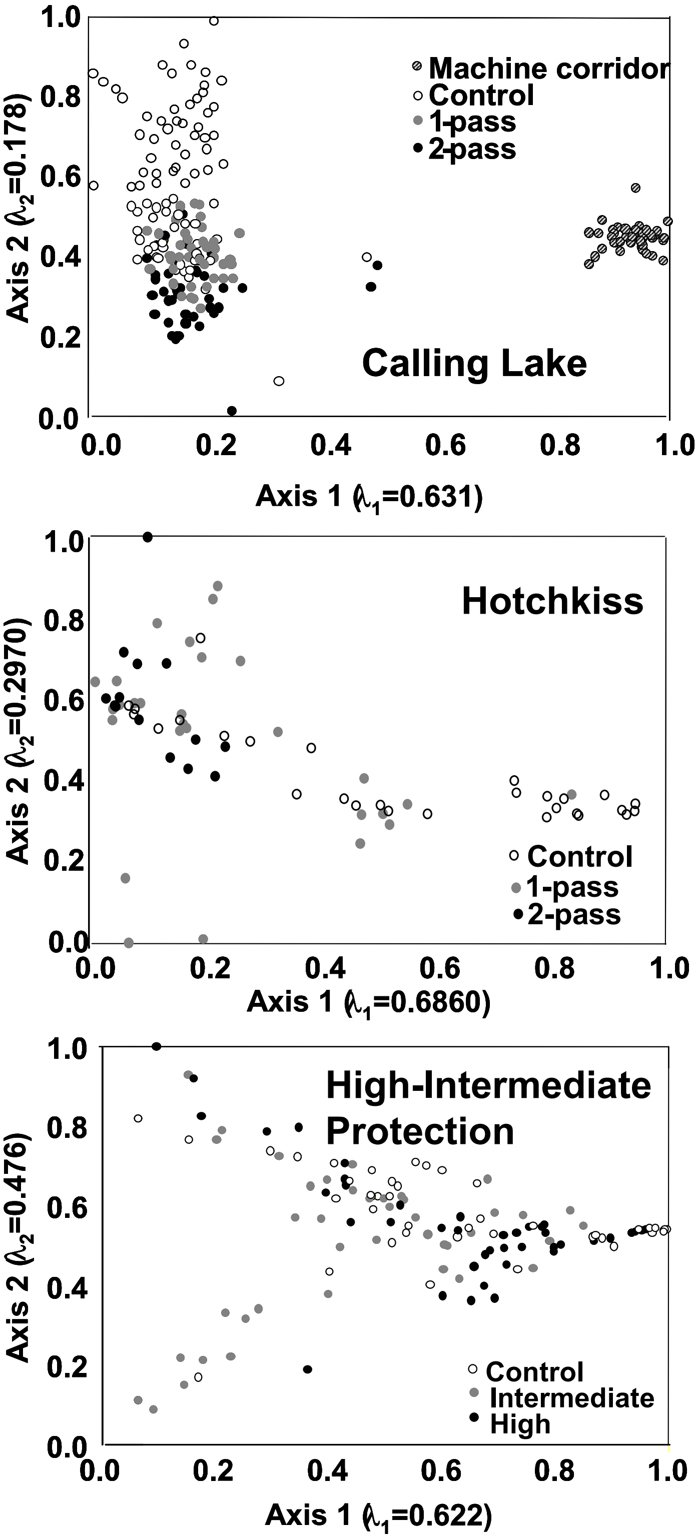

Figure 3. Results of ordination (Detrended Correspondence Analysis) examining understory plant species composition in mixedwood (aspen – white spruce) stands exposed to different types of understory protection harvesting. Stands at Calling Lake were sampled 3-years-since-harvest, at Hotchkiss 7-ysh for the 1-pass, 7-years since the 1st pass and 2-y since the 2nd pass for the 2-pass system; the High / Intermediate stands were sampled 13-ysh. Plots which are closer together were more similar in terms of understory species assemblage.

Summary of Results and Interpretation

Salvage Thinning resulted in a reduction in canopy density and increased growth of retained trees. In turn, salvage thinned stands had increased light available to the understory and greater shrub density. Immediately after thinning there was a reduction in the richness of understory vascular plants but 3 to 5 years after thinning understory plant richness was greater in thinned than in control stands. Thinned stands gained abundance of some ruderal species and those common to mesic aspen – spruce mixedwood forests. Thinned stands also had reduced abundance of species associated with undisturbed mature pine forests. It is likely that increased light, along with effects of disturbance to the forest floor, provide opportunities for new species to colonize forest stands following thinning as well as for some moderately shade tolerant species to experience an increase in abundance following thinning.

Understory Protection harvesting resulted in a reduction in canopy density along with a change in canopy composition towards greater dominance by conifers. The retained trees showed a positive growth response. Removal of the canopy resulted in increased light available to the understory. Effects of Understory Protection harvesting on canopy density and light were diminished in stands sampled 13 years after harvesting. This was likely due to the level of retention at the time of harvesting along with increased growth of retained trees and regeneration by deciduous trees.

Immediately following Understory Protection harvesting (2^{nd} pass of two-pass system) stands showed a reduction in understory species richness, likely due to disturbance associated with the harvesting. Stands sampled 3- to 7- and 13- years after harvesting showed increased understory species richness, largely due to the addition of shade intolerant and ruderal species. When there was a high level of canopy retention during the harvesting effects on the understory were diminished. Also effects of the harvesting on understory richness and composition appeared to diminish with time.

Machine corridors used to gain access to the stand by harvesting equipment and for removal of trees were dramatically different in terms of understory species richness and composition. Machine corridors had higher species richness than control stands and were characterized by a very different group of understory plants than either control stands or the harvested areas. Specifically, they were dominated by grasses, shade intolerant and weedy species and also had high densities of aspen and balsam poplar saplings. These effects are likely due to the complete removal of the canopy along with disturbance to the forest floor and possibly soil compaction.

As for Salvage Thinning, it is likely that increased light, along with effects of disturbance to the forest floor, provided opportunities for new species to colonize forest stands following Understory Protection harvesting as well as for some moderately shade tolerant species to experience an increase in abundance.

Key Findings and Deliverables

Reduction of canopy density and disturbance of the forest floor during partial harvesting operations, such as those employed during Salvage Thinning or Understory Protection harvesting will result in opportunities for new establishment or achievement of increased abundance by ruderal plant species and understory species which are less shade tolerant than the species normally found to dominate the understory in a closed canopy forest. As such, partial harvesting causes changes in understory plant diversity and composition that might be analogous to those observed at an earlier successional stage or in a different forest type (e.g., a more open forest or a forest with proportionally less conifer).

These effects will diminish over time as the canopy re-grows and closes. The less change there is in canopy density and composition at the time of harvesting the less effect there will be on the understory community and the quicker the effects will diminish. Long-term effects on the understory plant community will depend on the subsequent management practices in the stands.

The dramatic effects on understory plant diversity and composition seen in the machine corridors may have much longer-term implications and be of some cause for concern. Machine corridors could be providing an opportunity for weedy and ruderal species to establish throughout managed stands and achieve population sizes that could lead to greater invasion into intact forest stands, especially into ‘edge’ habitat. Active encouragement of tree regeneration along these corridors, in the same composition as the partially-harvested area, could help diminish these effects (e.g., planting or encouraging conifer regeneration).

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Macdonald, E., C. Mourelle, B. Dankert, and T. Fenniak. 2003. Effects of canopy manipulation on understory plant communities: a synthesis from the western boreal forest. Canadian Botanical Association Annual Meeting, Antigonish, Nova Scotia, June 2003. oral presentation.

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Mourelle, C. and E. Macdonald. 2002. Effects of salvage thinning on forest structure and understory composition of the Canadian western boreal. 4th International Workshop on Disturbance Dynamics in Boreal Forests, Prince George, BC, Aug. 9 – 14, 2002. oral presentation.

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To be submitted to refereed journals:

Mourelle, C., and S.E. Macdonald. Impacts of thinning in lodgepole pine on forest structure and understory plant diversity. Journal of Vegetation Science

Mourelle, C. and S.E. Macdonald. Impacts of thinning in lodgepole pine on understory plant community composition. Journal of Vegetation Science

Mourelle, C., S.E. Macdonald and B. Dankert. Effects of understory protection harvesting on forest structure and understory plant communities of the mixedwood boreal forest. Forest Ecology & Management

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Génin, Jean-Robert. 2002. Effects of understory protection harvest on forest stand structure and dynamics in the Western Boreal mixedwood. MSc (Forestry). Faculté de Foresterie et de Géomatique. Université Laval, Sainte-Foy, QC.