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Assessment of Silvicultural Systems Developed for Deep Snowpack, Mule Deer Winter Range in the Central Interior of British Columbia

Regeneration and Vegetation Components

2005

Silvicultural Systems

BRITISH COLUMBIA

Ministry of Forests Forest Science Program

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SUMMARY

In the central interior of British Columbia (Southern Interior Forest Region), Douglas-fir (*Pseudotsuga menziesii*) tends to occur in even-aged stands in the Interior Cedar–Hemlock Moist, Cool, Horsefly biogeoclimatic variant (ICHmk3). Douglas-fir stands are important from both forest industry and wildlife habitat management perspectives. Mule deer require mature and older Douglas-fir stands as winter range. In these ecosystems, Douglas-fir stands are typically clearcut, thereby seriously compromising habitat value as winter range. This is a pilot study to examine the response of vegetation (percent cover) and Douglas-fir regeneration (density and growth) to a range of opening sizes, opening orientation (along and across contours), and site preparation treatment (yes or no), 5 years post-harvest. The openings (15 × 165 m [0.25 ha], 30 × 165 m [0.5 ha], 60 × 165 m [1.0 ha], 60 × 330 m and 140 × 140 m [2.0 ha]) are options for group selection, patch cut, or clearcut silvicultural systems.

Although most of the 19 tree, shrub, and grass species that mule deer could eat did not change in percent cover from pre-harvest to 5 years postharvest, the species that did change were most strongly affected by harvesting, not opening size. A major diet component, western redcedar (*Thuja plicata*), was reduced from 9.6 to 1.4% in the site-prepared openings, and from 9.4 to 3.9% in the openings not site-prepared, when comparing the pre-harvest to the 5th-year post-harvest assessment. However, in the 5 years since harvesting, this species has increased from 533 stems per ha to 783 stems per ha (47%) and should increase steadily in cover over time. Of note was a big increase in red raspberry (*Rubus idaeus*) (from 0.1% up to 14%) and a moderate increase in birch-leaved spirea (*Spirea betufolia*) (from 1% up to 6%); however, they generally occur in small amounts (<1%) in mule deer diets.

Viable conifer seed was produced in every year, although amounts varied among species and years. The bulk of the viable seed for species of commercial interest, from 1998 to 2003, was from Douglas-fir, which is representative of the residual stand composition. Seedling establishment has been successful for all the commercial conifer species. In particular, the density of Douglas-fir natural regeneration and planted stock combined increased from 1500 stems per ha in 1998 to 2675 stems per ha in 2002. Overall, survival of planted Douglas-fir was 92% across openings and site preparation treatments (disc trenching); however, growth (height and diameter) was substantially reduced in the narrowest openings (15 m). Site preparation (specifically disc trenching) did not affect the planted stock response. Growth rates were similar on stock planted in openings that ran across contours and along contours. Seedlings planted within 2–5 m of a forest edge had lower survival, poorer condition, and lower growth rates than those planted further into the 60 m wide openings. The effects were strongest on the shadier aspects of the openings. Overall, openings of 15 m width are not recommended for sites similar to those in the study.

Vegetation competition reduced the growth performance of seedlings that became overtopped early by shrub species—mainly red raspberry, thimbleberry (*Rubus parviflorus*), and black twinberry (*Lonicera involucrata*). The presence of hardwood tree species has increased since harvest, but was a

minor component (12%) of the overtopping vegetation that caused a reduction in the planted seedling performance. Site preparation (specifically disc trenching) did not affect vegetation response.

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TABLE OF CONTENTS

Summary iii

Acknowledgements v

1 **Introduction** 1

2 **Methods** 4
  2.1 Study Area 4
  2.2 Description of Treatments 6
  2.3 TRENDS Plots 7
  2.4 Seedfall 10
  2.5 Seedling Response to Forest Edge 11

3 **Results** 12
  3.1 Vegetation 12
    3.1.1 Plant community and potentially competitive species 12
    3.1.2 Forage species 13
  3.2 Natural Regeneration 17
  3.3 Planted Regeneration Performance 22
  3.4 Opening Orientation and Stand Edge Effects 27

4 **Discussion** 29
  4.1 Forage 29
  4.2 Natural Regeneration 30
  4.3 Planted Stock 31
  4.4 Limitations of This Study 34
  4.5 Management Implications 34

5 **Conclusions** 36

References 37

TABLES

1 Pre-harvest stand description and treatment assignments by opening number 5

2 Mean coarse woody debris volume pre-harvest and 5 years after logging 6

3 Common name, scientific name, and plant code for species used in this report 8

4 Mean modal height and percent cover of tall and short shrubs and herbaceous vegetation with and without site preparation, and by opening size, prior to logging and 5 years after harvest 12

5 Mean percent cover values for plant layers and prominent species prior to logging and 5 years after harvest. 13

6 The species listed occur in mule deer diets in the central interior of British Columbia. 14

7 Mean percent cover and modal height of forage species by site preparation both pre-harvest and 5-years post-harvest 15

8 Mean percent cover and modal height of forage species by opening size both pre-harvest and 5-years post-harvest 16

9 Annual percentage of viable seed, by species, collected each spring from traps in the four 1.0-ha openings 18
10 Mean of viable Douglas-fir, pine, spruce, and subalpine fir seeds per hectare, and all western redcedar and birch seeds 19
11 Mean stems per hectare for the same conifer species found in seedfall traps 21
12 Year 5 post-harvest mean stems per hectare of conifer species by site preparation and opening size treatments 21
13 Results from analysis of variance using factorial model with three opening sizes and with or without site preparation, for height increment, height, and stem diameter of planted Douglas-fir seedlings 5 years after harvest 23
14 Percentage of seedlings affected by frost, Cooley spruce gall adelgid and foliar mottling 3 and 5 years after harvest by main treatments. 23
15 Fifth-year post-harvest mean morphological parameters of planted Douglas-fir, and percent cover and height of competing vegetation, for seedlings that were overtopped or not overtopped by competing vegetation in 2002 23
16 Stocking survey results at planting and 5 years later, plus 5th-year species composition 26
17 Comparison of planted Douglas-fir seedlings between blocks that run across and along contours using analysis of variance based on a completely randomized design. 27
18 Results from analysis of variance for height and diameter of planted Douglas-fir seedlings 5 years after harvest, by distance from forest edge on different exposures and all exposures combined 28

FIGURES

1 Layout of the openings on the study site 6
2 50 × 50 cm metal seedfall trap 10
3 Mean and standard error of density of viable, Douglas-fir seed relative to distance from edge for each year of the study. 20
4 Mean height, 5th-year height increment, and stem diameter at ground level for planted Douglas-fir seedlings five years after planting by opening size 24
5 Mean height, 5th-year height increment, and stem diameter at ground level for planted Douglas-fir seedlings five years after planting with or without mechanical site preparation. 24
6 Mean and standard error for height of planted Douglas-fir seedlings for the first 5 years of growth separated by seedlings not overtopped or overtopped by competing vegetation at the 2002 assessment 25

7 Species composition 5 years after harvest, of overtopping vegetation measured on 1 m radius, tree-centred plots of planted Douglas-fir seedlings, all TRENDS plots combined 25
8 Mean height of planted Douglas-fir seedlings, 5 years after harvest, with one or more of the four species growing within 1 m distance from the measured seedlings 26
9 Mean ground-level diameter with distance from the mature forest edge on different aspects 29

1 INTRODUCTION

Douglas-fir (*Pseudotsuga mensiesii*) forests provide valuable habitat for wintering mule deer in the central interior of British Columbia (Armleder et al. 1986). Deer seek out low-elevation winter ranges where mature and old Douglas-fir trees effectively reduce the depth of the snowpack, provide thermal cover, and supply forage. Armleder et al. (1994) found that when the open snowpack exceeded 25 cm, old forests (>140 years) with more that 36% crown closure are strongly selected by mule deer. When deer are forced to move through snow 50 cm deep, they expend five times more energy than on bare ground (Parker 1984).

In the central interior of British Columbia, the main diet item for mule deer is Douglas-fir foliage from larger, older trees (Dawson et al. 1990). On moister winter ranges, understory trees such as western redcedar (*Thuja plicata*) and subalpine fir (*Abies lasiocarpa*) are important forage species (Waterhouse et al. 1994). Shrubs are an important diet component, especially in moister winter ranges but become less available as the snowpack deepens (Waterhouse et al. 1994).

The goal of winter range management in the central interior of British Columbia is to maintain critical attributes of mule deer habitat. These attributes can be managed through selection of appropriate silvicultural systems (Dawson et al. 2002). Most of the winter range overlaps the Interior Douglas-fir (IDF) zone, where forests are multi-layered and/or multi-aged. For these forests, a low-volume, single-tree selection silvicultural system (cutting cycle 30–50 years) was developed and tested (Armleder et al. 1986). The treatments, based on 15–20% volume removal in small groups of two to seven trees, do not adversely affect deer use in winter (Armleder et al. 1998). Douglas-fir grows well in partial light, and a continuous forest cover of larger trees is maintained for snow interception and forage in these drier ecosystems.

A smaller portion of winter range (about 10 000 ha) occurs in the much wetter, Interior Cedar–Hemlock Moist, Cool, Horsefly variant (ICHmk3) where Douglas-fir is considered a seral species and the forest is even-agend. In the ICH, the removal of single trees to small groups of trees is less ecologically appropriate to regenerate Douglas-fir because lightly thinning the stand would promote climax species such as western redcedar and subalpine fir, and not provide enough light for Douglas-fir to grow well. Douglas-fir is more shade intolerant in the ICH than in the IDF because tolerance is greater on drier sites (Chen et al. 1996; Williams et al. 1998). A heavy thinning from below would improve light conditions for Douglas-fir but would reduce the snow interception capacity of the stand. D'Eon (2004) shows that by reducing the canopy closure by half, snow interception capacity of the forest similarly decreases. On deep snowpack winter ranges, such as the Horsefly winter range, where open snow depth often exceeds 70 cm and in some winters exceeds 100 cm, any increase in snow depth would have severe consequences for the survival of deer.

The clearcut silvicultural system is used successfully in the ICHmk3 variant; however, large blocks (>30 ha) are usually planted with a mixture of species. Although Douglas-fir is a primary species in the stocking guidelines, there is reluctance to plant it operationally in clearcuts because it has lower frost tolerance (Steen et al. 1990) that may slow the rate of growth until the trees escape through the frost layer. Also, Douglas-fir has slower initial growth than either lodgepole pine (*Pinus contorta*) or hybrid white spruce (*Picea glauca* × *engelmanii*). Planting a mix of species, primarily lodgepole pine and spruce, effectively removes large portions of the mule deer winter range for one rotation. Even if a block with a low frost rating is planted mostly with Douglas-fir, the clearcut is unusable winter habitat for a long period of time.

The silvicultural system with the greatest potential to retain usable deer habitat, and create a favourable environment for Douglas-fir seedling survival and growth, is the group selection silvicultural system. The openings need to be sufficiently large so most of the opening receives enough light to stimulate growth of Douglas-fir regeneration but small enough to provide some frost protection. The openings created by harvesting would continue to provide shrub forage in low snow conditions, and, over time, start providing snow interception cover. The residual matrix of older forest would provide a continuous network of usable habitat in the stand.

For coastal Douglas-fir forests, Nyberg and Janz (1990) recommend that opening sizes be no greater than two tree heights in width, and preferably less than one tree height wide, in order to minimize snow depth and allow for black-tailed deer movement throughout the winter range. The openings have to be sufficiently large to be economically feasible, and accommodate site preparation treatments such as disc trenching and mounding, or stumping root disease sites. Also, orientation of openings can affect regeneration performance and visual quality. If the long edges run east to west, there could be significant shading in the openings that could affect seedling performance. Openings oriented along contours are less visible.

Regeneration studies from other areas indicate that both planted and natural regeneration of commercial conifer species can occur successfully in small openings. In central Idaho (Geier-Hayes 1991) and southwest Montana (Joy and Hutton 1991), there has been successful regeneration of Douglas-fir using silvicultural systems such as group selection and strip clearcuts to relieve temperature and moisture stress. In ICH studies in northern British Columbia, Coates (2000) describes increased conifer seedling growth with increased opening size up to 0.1–0.2 ha, after which there is little improvement. Similarly, Jull et al. (1999) report good survival and growth of Douglas-fir planted in 0.24-ha openings. The residual forest can have an effect on the growth of vegetation, including tree seedlings, for some distance into the opening due to shading and root competition for moisture and nutrients (Hansen et al. 1993; Coates 2000; DeLong et al. 2000).

Disc trenching is a popular site preparation method used to improve planted seedling performance by creating good growing microsites and reducing competing vegetation (Coates and Haeussler 1988). In this ecosystem, there are many species that could become significant competitors with tree seedlings. According to Coates and Haeussler (1986), of particular importance are paper birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), cottonwood (*Populus balsamifera*), willow (*Salix* spp.), Sitka alder (*Alnus viridis*), Douglas maple (*Acer glabrum*), pinegrass (*Calamagrostis rubescens*), fireweed (*Epilobium angustifolium*), thimbleberry (*Rubus parviflorus*) and red raspberry (*Rubus idaeus*). Wet sites are often mounded to relieve moisture stress, while stumping is a typical method to control *Armillaria ostoyae* root disease (Morrison et al. 1991).

A proposed benefit of creating openings is increased abundance of grass, shrub, and tree regeneration species used as winter forage by deer. They would be available in openings until the snow buried them or the opening size prevented access to them. Even if the preferred species were available only in early winter, they could improve animal condition for reproduction and survival.

The goal of this project (EP1212) is to develop silvicultural systems that will adequately regenerate and grow Douglas-fir, while maintaining mule deer winter habitat. We are testing a range of opening sizes between 0.25 ha and 2.0 ha, in two topographic orientations that could be used in conjunction with group selection, patch cut, or clearcut silvicultural systems. Each opening size was created by varying the width (one-half to two tree heights). A 1-ha opening is 60 × 165 m, while the width is reduced to half (30 m) and to a quarter (15 m) to create 0.5-ha and 0.25-ha openings, respectively. Two 2.0-ha openings (60 × 330 m; about 140 × 140 m) were cut mostly to gather harvesting cost data. Other studies within EP1212 have examined the mule deer response, snowpack development, and windthrow issues (Waterhouse 1999); control options for *Armillaria ostoyae* root disease (Chapman et al. 2004); and harvesting methods and costs (Mitchell 2000). This report focuses on the response of vegetation, natural regeneration and planted Douglas- fir seedlings, 5 years after harvest.

Specifically, this study attempts to answer the following questions:

- Does opening size (width) or orientation affect survival and growth of planted Douglas-fir seedlings?
- How far into the 60 m wide openings (1.0 ha) does the residual forest affect survival and growth of planted Douglas-fir seedlings?
- Can mechanical site preparation improve survival and growth of planted Douglas-fir seedlings?
- Does opening size or site preparation affect the abundance and growth of vegetation species that are tree competitors or used as mule deer forage?
- How does natural regeneration, through seedfall and ingress, contribute to stocking in the various opening sizes, with and without site preparation?

2.1 Study Area

The study site is located in the central interior of British Columbia (19 km northeast of Horsefly, B.C.). It was laid out on the southwest aspect of Viewland Mountain above Horsefly Lake (52°25'23"N and 121°10'36"W) within the Horsefly Lake mule deer winter range. Most of the openings face southwest or west. The openings are at an average elevation of 1061 ± 53 m with a range of 965–1130 m; and slope ranges from 2 to 47% with an average of 17% ± 8%.

The soils are mainly Brunisols or Luvisols, with a sandy loam or silt loam texture, and an average coarse fragment content of 44% ± 17%, ranging from 14 to 83%. There was a root and water restriction layer at 41–63 cm. The average rooting depth is 33 ± 14 cm, and ranges from 18 to 60 cm. All, except the wet opening (opening 8), are moderately to well drained.

The area is classified as the Interior Cedar–Hemlock Moist, Cool, Horsefly biogeoclimatic variant (ICHmk3) (Steen and Coupé 1997). Climax tree species on zonal sites are western redcedar (*Thuja plicata*) and subalpine fir (*Abies lasiocarpa*), while Douglas-fir (*Pseudotsuga menziesii*) is the dominant seral species. Vegetation on the study site prior to harvesting was typical of the zonal to drier ICHmk3, with a moderate cover of falsebox (*Pachistima myrsinites*), soopolallie (*Shepherdia canadensis*), black huckleberry (*Vaccinium membranaceum*), and several low-growing herbs, and a nearly continuous cover of feathermosses. There were some small pockets of armillaria (*Armillaria ostoyae*) and tomentosus (*Inonotus tomentosus*) root rot throughout the area.

The pre-harvest stand, initiated by a hot fire about 100 years ago, was predominantly Douglas-fir (70%) with lesser amounts of lodgepole pine (18%), hybrid white spruce (*Picea glauca* × *engelmannii*) (9%), and western redcedar (2%). There was a small component of subalpine fir, trembling aspen, paper birch, and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). Species composition, age, stems per ha, basal area, and volume per ha are described for each opening in Table 1. Sample plots (one per opening) were leading in Douglas-fir pre-harvest, except for three plots that were leading pine. The Douglas-fir averaged 28 ± 4 m in height with a range between 21 and 40 m in the main canopy. Tree diameter at breast height (dbh) averaged 33 ± 12 cm with a range of 11–99 cm. Lodgepole pine in the main canopy was similar to the Douglas-fir in height, but averaged 30 ± 8 cm dbh with a range between 12 and 58 cm. Spruce in the main canopy were smaller, ranging in height from 21 to 33 m and averaging 26 ± 4 m; dbh ranged from 10 to 52 cm with an average of 30 ± 11. The net merchantable volume for the conifers was 412 m^3/ha accrued mostly from trees 25–55 cm in diameter.

Pre-harvest, the number of snags per ha varied among the openings (Table 1), ranging from as low as 11 snags per ha, to as high as 155 snags per ha with an average of 76 ± 52 over the trial site. Pre-harvest coarse woody debris accumulation was highly variable among the openings and is summarized by log decomposition classes and totals for the site in Table 2. The variation among openings in volume by classes was greater than their average, illustrating the high variability. However, a large part of the coarse woody debris volume was in the more decomposed classes of 4 and 5.

TABLE 1 *Pre-harvest stand description and treatment assignments by opening number. Species composition, mean age (±S.D.), basal area, and volume are for the main canopy dominant and codominant trees (Al and A2 layers). Stems per ha includes the sub-canopy trees (A3 layer). See Table 3 for species code definitions.*

Opening number	Site preparation	Species composition (% by basal area)	Mean age	Stems per ha	Basal area (m^2 per ha)	Volume (m^3 per ha)	Snags per ha
Opening: 0.25 ha (15 × 165 m)							
17	Y	Fdi 89 Pli 11	97 ± 2	455	50.1	568.1	67
18	Y	Fdi 63 Pli 28 Act 5 At 2 Bl 1 Sx 1	-	277	40.6	447.7	155
19	N	Fdi 77 Sx 16 Act 7	94 ± 8	422	56.3	548.0	133
20	N	Pli 56 Fdi 41 Cw 2 Ep 1	100 ± 8	367	45.2	490.8	111
Opening: 0.50 ha (30 × 165 m)							
13	Y	Fdi 91 Sx 5 Pli 2 At 2	92 ± 9	344	49.0	377.6	44
15	Y	Fdi 48 Pli 47 Cw 5	97 ± 4	355	38.3	365.7	123
14	N	Fdi 89 Pli 7 Ep 3 Sx 1	92 ± 4	289	41.5	487.0	22
16	N	Fdi 80 Pli 16 Sx 3 At 1	102 ± 6	522	56.6	553.5	33
Opening: 1.0 ha (60 × 165 m) along contour							
4	Y	Fdi 74 Sx 11 Pli 9 Ep 4 Bl 1 At 1	95 ± 4	455	51.6	442.6	33
11	Y	Fdi 79 Pli 10 At 5 Act 3 Sx 2 Ep 1	101 ± 7	456	62.4	657.3	66
8 (wet)	Y (mounded)	Fdi 54 Ep 27 Sx 14 Pli 5	101 ± 3	322	55.1	447.4	134
5	N	Fdi 94 Sx 3 Pli 2 Ep 1	95 ± 3	678	55.1	526.0	144
10	N	Fdi 63 Pli 31 Sx 3 At 2 Ep 1	94 ± 6	678	52.2	511.7	55
Opening: 1.0 ha (60 × 165 m) across contour							
7	Y	Fdi 82 Sx 9 At 5 Ep 3 Pli 1	100 ± 2	378	63.4	650.8	22
12	Y	Fdi 50 Pli 43 At 3 Sx 2 Ep 2	97 ± 5	400	37.0	354.5	11
6	N	Fdi 86 At 7 Sx 3 Cw 3 Bl 1	87 ± 11	234	36.0	355.0	33
9	N	Pli 61 Fdi 37 Ep 2	95 ± 7	333	38.3	299.9	133
Opening: 2.0 ha							
2 (60 × 330 m)	Y	Fdi 71 Pli 20 Sx 5 Ep 2 At 2	99 ± 6	433	58.4	580.8	11
1(140 × 140 m)	Y (stumped)	Pli 53 Fdi 47	108 ± 9	411	33.8	259.1	122

TABLE 2 *Mean (± S.D.) coarse woody debris volume (m³/ha) pre-harvest and 5 years after logging (n=11 for site-prepared openings and n=8 for openings not site-prepared)*

		Log decomposition classes[a]					
Year	Site prep	1 (Hard)	2 (Hard to partly decaying)	3 (Large pieces partly decaying)	4 (Small blocky pieces)	5 (Small pieces, soft portions)	Total
Pre-harvest	Y	13.0 ± 16.3	34.3 ± 49.1	20.8 ± 15.3	48.1 ± 43.8	53.3 ± 67.3	169.4 ± 106.4
Post-5th year	Y	16.5 ± 21.1	21.5 ± 25.4	15.1 ± 26.9	19.8 ± 28.6	38.1 ± 53.1	111.1 ± 96.6
Pre-harvest	N	8.9 ± 9.4	21.2 ± 15.5	30.2 ± 35.1	23.0 ± 40.8	72.1 ± 98.2	155.3 ± 113.7
Post-5th year	N	12.5 ± 14.9	36.3 ± 33.9	7.2 ± 9.0	11.2 ± 18.2	8.9 ± 12.7	76.2 ± 49.1

a See NIVMA TRENDS Field Manual (2002), or B.C. Ministry of Forests, Field Manual for Describing Terrestrial Ecosystems (Land Management Handbook 25) (1998).

2.2 Description of Treatments

Harvesting was completed between September and December 1997. Logging was done by fellerbuncher (99%), plus handfalling of oversized stems (1%). Whole trees were skidded with rubber-tired, grapple skidders to central landings for mechanical de-limbing and processing into short logs. Deciduous trees were stubbed during harvesting within the openings.

Approximately 20% of the stand (20 ha) was harvested in roads, landings, and openings. Harvesting created 19 openings in four sizes: 0.25 ha, 0.5 ha, 1.0 ha, and 2.0 ha (Table 1), and two orientations (across and along the contours). The openings running along the contours have the long edges running east to west so there is significant shading on the south edge for some distance into the opening. For the openings that run across contours, the long edges run northeast to southwest. The long edges facing southeast receive more light than the ones facing northwest. Figure 1 shows the layout of the openings.

When the openings were laid out, they were initially assigned to a moisture regime: mesic, drier than mesic, or wetter than mesic. A detailed

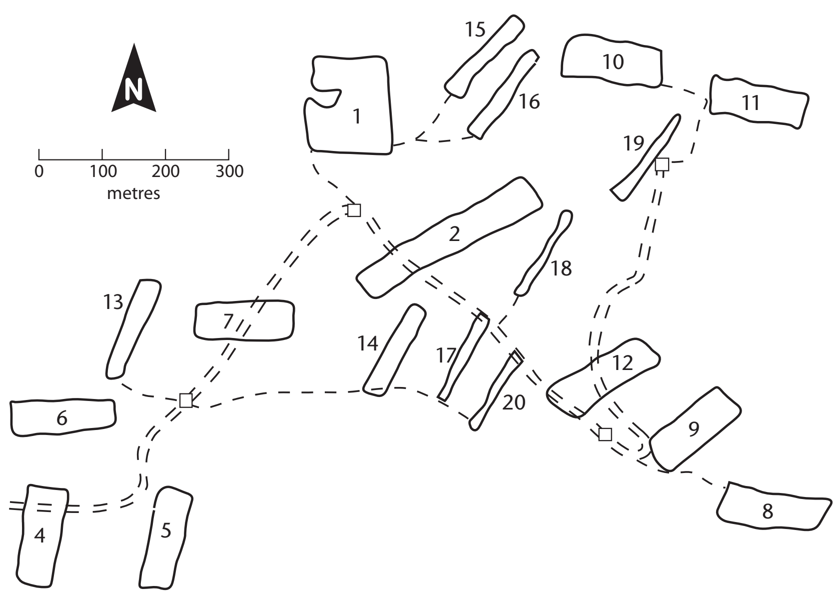

FIGURE 1 *Layout of the openings (0.25 ha, 0.50 ha, 1.0 ha, and 2.0 ha) on the study site.*

ecological classification was done when the TRENDS plots (see Section 2.3) were installed in each opening pre-treatment. They showed that the initial stratification did not reliably separate mesic and drier than mesic sites. Most of the plots were classified as mesic.

Openings of similar sizes were paired, then randomly assigned a site preparation option of disc trenching or no site preparation. The wet opening (8) was mounded. Within the armillaria-infected opening (1), half of the area was stumped, and the TRENDS plot was located in this treatment. The non-stumped half of opening 1 was treated with a biological control fungus (*Hypholoma fasciculare*) in September 1998 (Chapman et al. 2004). Site preparation was completed in May 1998.

All the openings were operationally planted the 3rd week of June 1998 with Douglas-fir seedlings, 1-year-old PSB415B, B.C. Ministry of Forests seedlot no. 14406. The seedlings were planted below the berm in the disc-trenched openings, on top of the mounds, and into higher microsites in the openings with no mechanical site preparation.

2.3 TRENDS Plots

Prior to harvest, permanent plots were established in the summers of 1996 and 1997 according to the silvicultural monitoring protocol (TRENDS© Treatment Regime Evaluation–Numerical Decision Support) developed by the Northern Interior Vegetation Management Association (NIVMA) (1996). One 30 × 30 m (0.09-ha) monitoring plot was established per opening, with a random placement. Each plot consisted of four 15 × 15 m quadrants, and data other than the repeatedly measured planted seedlings were collected at the quadrant level. Due to the size and shape of the blocks, modifications to plot placement were made. In the 0.25-ha openings that are only 15 m wide, the four quadrants of a plot were lined up in a row.

Pre-harvest measurements included: biogeoclimatic classification, site index, soil description, stand structure, coarse woody debris, and a description of all above-ground vegetation. These data were used to determine whether pairs of plots within an opening size and ecosystem combination were similar in attributes. An examination of the pre-harvest data concluded that paired plots were similar to each other with a few minor deviations reflecting the baseline variability within the stand (Adams 1999). The detailed descriptions of all above-ground vegetation also allowed us to monitor changes post-harvest, including coarse woody debris on the same 30 m transect line before and after treatment. Pre-harvest stand data from the TRENDS plots were compiled by opening to provide the study area description above (Section 2.1; Tables 1 and 2).

The plots were re-established post-harvest, and were re-measured 1, 2, 3, and 5 growing seasons post-harvest. Specific methodologies are described in the NIVMA TRENDS © Field Manual (2002) available on the Web at http://www.nivma.bc.ca/ManualCaveat.htm. This operational monitoring process was selected so that data collected from the site are included in a large regional database and results are available to forest managers. Analyses of data collected using the TRENDS protocol were completed using SPSS Version 10.0 (1999) and graphs in Microsoft® Excel 2002. Data were summarized, analyzed, and reviewed after each assessment at years 1, 2, 3, and 5. This report focuses on the 5th-year post-harvest results in comparison to pre-harvest conditions.

Shrubs, herbs (includes grasses), and mosses were described on the 0.09-ha plot by species and layer for percentage cover, distribution, and modal height.

The common and scientific names of all plant species referred to in this report are listed in Table 3, along with the codes (Douglas et al. 2002) used in tables and graphs. Shrubs were separated into two height classes: tall shrubs were >1.3 m, short shrubs were ≤1.3 m. Data were collected on four 15 × 15 m quadrants within the 0.09-ha plot. Percent cover was recorded for species greater than 4%; below that, a species was recorded as a value of 1 for present. Data were summarized for percent cover using the recorded values (i.e., cover of present to <5% was equal to 1) by summing the species covers and dividing

TABLE 3 *Common name, scientific name, and plant code for species used in this report*

Plant layer	Common name	Scientific name	Plant code
Trees	subalpine fir	*Abies lasiocarpa*	ABIELAS; Bl
	paper birch	*Betula papyrifera*	BETUPAP; Ep
	interior spruce	*Picea glauca* and hybrids	PICEGLA; Sx
	lodgepole pine	*Pinus contorta*	PINUCON; Pli
	trembling aspen	*Populus tremuloides*	POPUTRE; At
	black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	POPUTRI; Act
	Douglas-fir	*Pseudotsuga menziesii*	PSEUMEN; Fdi
	western redcedar	*Thuja plicata*	THUJPLI; Cw
	western hemlock	*Tsuga heterophylla*	TSUGHET; Hw
Shrubs	Douglas maple	*Acer glabrum*	ACERGLA
	sitka alder	*Alnus viridis* ssp. *sinuata*	ALNUSIN
	saskatoon	*Amelanchier alnifolia*	AMELALN
	red-osier dogwood	*Cornus stolonifera*	CORNSTO
	twinflower	*Linnaea borealis*	LINNBOR
	black twinberry	*Lonicera involucrata*	LONIINV
	tall Oregon-grape	*Mahonia aquifolium*	MAHOAQU
	falsebox	*Pachistima myrsinites*	PACHMYR
	prickly rose	*Rosa acicularis*	ROSAACI
	red raspberry	*Rubus idaeus*	RUBUIDA
	thimbleberry	*Rubus parviflorus*	RUBUPAR
	willow	*Salix* spp.	SALIX
	soopolallie	*Shepherdia canadensis*	SHEPCAN
	birch-leaved spirea	*Spirea betufolia*	SPIRBET
	common snowberry	*Symphoricarpos albus*	SYMPALB
	black huckleberry	*Vaccinium membranaceum*	VACCMEM
	highbush-cranberry	*Viburnum edule*	VIBUEDU
Grasses	redtop	*Agrostis stolonifera*	AGROSTO
	bluejoint	*Calamagrostis canadensis*	CALACAN
	nodding wood-reed	*Cinna latifolia*	CINNLAT
	blue wildrye	*Elymus glaucus*	ELMGLA
	western fescue	*Festuca occidentalis*	FESCOCC
	timothy	*Phleum pratense*	PHLEPRA
	Kentucky bluegrass	*Poa pratensis*	POA PRA
Herbs	showy aster	*Aster conspicuus*	ASTECON
	bunchberry	*Cornus canadensis*	CORNCAN
	wood strawberry	*Fragaria vesca*	FRAGVES
Mosses	step moss	*Hylocomium splendens*	HYLOSPL
	red-stemmed feathermoss	*Pleurozium schreberi*	PLEUSCH
	knight's plume	*Ptilium crista-castrensis*	PTILCRI

by four to produce a plot value. Height was the modal height for the quadrant with the maximum percent cover. Mean and standard deviation (±S.D.) of percent cover and modal heights by plant layer and species were initially summarized by site preparation and opening size, and compiled by the 19 openings when no treatment effects were present. Species previously identified as important mule deer winter forage were similarly summarized.

Small trees (<7.5 cm dbh) were tallied on subplots located at the centre of each quadrant. Number of stems, modal/maximum/ minimum height, percent cover, and distribution were collected by species within each of three layers: germinants (<2 years old), seedlings (<1.3 m height), and saplings (≥1.3 m height, <7.5 cm dbh). Trees ≥7.5 cm dbh remaining post-harvest, including stubbed aspen, were measured for height, dbh, crown width, percentage live crown, vigour, and condition, by species. Mean (±S.D.) stems per ha (sph), at 1 and 5 years post-harvest, was calculated from the small tree subplot data for the same conifer species as seed was collected for the four 1.0-ha openings with no site preparation treatment, as described in Section 2.4. The 5th-year mean (±S.D.) sph for all conifer species was calculated by site preparation and opening size to compare treatment differences.

Thirty-six planted Douglas-fir seedlings within each plot were selected at random to be repeatedly measured trees. Individual seedlings were tagged and measured at each assessment for height, annual height increment, groundline stem diameter, crown width and height to live crown, vigour, and condition. Initial microsite status was also recorded by assessing seedling position, planting site position, and rooting media as mineral, humus, or combination. Competing vegetation species within a planted-tree–centred 1 m radius plot were assessed for percent cover, height, and distribution, plus total percent cover and modal height for the cylinder.

Seedling performance data (5-year height, 5-year stem diameter, and 2002 height increment [leader]) were compared based on a factorial completely randomized design with opening size and site preparation as the factors. Disc trenched, mounded (opening 8), and stumped (opening 1) were combined as site-prepared. The opening size of 2.0 ha was not included because both were site-prepared and there are no unprepared comparisons. The MIXED model procedure in SAS Version 8.2 was used (SAS Institute Inc. 2001). Approximate (pseudo) F-tests, with denominator degrees of freedom calculated with Satterthwaite's method (SAS Institute Inc. 1996), were used to determine the statistical significance of effects of opening size, site preparation, and their interaction. Least square means (and standard errors) were calculated for all pairs of treatment means (opening size). To account for multiple comparisons, the significance levels were adjusted by Scheffé's method. Results were considered significant at α=0.05. Percentage of seedlings with frost and Cooley spruce gall adelgid, (*Adelges cooleyi* (Gill.)) damage 3 and 5 years after harvest were compared by main treatments.

Growth measurements for all 613 repeatedly measured seedlings surviving at year 5 after harvest/planting were pooled, and the population split by with and without overtopping competition based on the modal height for the 1-m vegetation cylinder at year 5 (2002). The two groups had 194 and 419 seedlings, respectively. Seedling performance data (5-year height, last two annual height increments, crown radius, stem diameter) and total cylinder percentage cover and modal height of the surrounding vegetation were summarized for both groups of seedlings (mean ± S.D.) and height growth curves were produced (mean ± S.E.) to compare the two populations. The species composition of the vegetation overtopping the seedlings 5 years after planting was determined by matching species height with the modal height for the 1-m vegetation cylinder. The list of 23 species found in the 1-m cylinder around each planted seedling was reduced to 10 species by including only those identified as potential competitors in the ICH (Davis 1998).

Single-story stocking surveys following the B.C. Ministry of Forests (1996) guidebook were conducted 5 years post-harvest, four subplots per plot, centred on each quadrant. Total well-spaced sph and a species composition label were generated for each opening.

2.4 Seedfall

The seedfall traps were rectangular, fixed-area trays that excluded rodents through 50 × 50 cm hardware cloth (Figure 2). They were initially set out post-harvest in the summer of 1998 on a 15 × 30 m grid in four of the 1.0 ha openings (5, 6, 9, and 10) that had not received mechanical site preparation (Table 1). Traps were placed at 15-m intervals across the width of the openings and at 30 m intervals along the length of the opening, for a total of 15 traps per opening. Openings 5 and 9 run approximately north northeast–south southwest, across the elevational contours, and are shaded from the southeast and northwest edges. Openings 10 and 6 run east–west along the contour, therefore shading and competition is received from the north and south edges of the mature forest. Seed density along edges (15 m) was averaged from the six traps located on the long edges of two blocks. For example, blocks 6 and 10 have a north edge, and the three centre traps from the line of five traps were used. The seed density for the centre location (30 m from an edge) was averaged from the centre three traps from the four blocks.

Seeds from the previous year's crop were collected from each trap in late spring. Entire screens were removed from each trap, and, along with the remaining litter contents of a trap, placed into a paper bag. The bags and their contents were dried for several weeks then stored in a cool, dry area until the contents could be analyzed. The litter content from each screen was carefully sorted and the seeds were removed. All tree seeds were identified by species and counted.

FIGURE 2 *50 × 50 cm metal seedfall trap.*

A cutting test was performed on all mature conifer seeds to assess seed viability. The cutting test was performed as outlined by Eremko et al. (1989). The seed was assessed as nonviable if there was no embryo or if there was a deterioration of the seed contents. Seeds were assessed as viable if the cutting test revealed a moist, white megagametophyte and white to yellowish embryo.

2.5 Seedling Response to Forest Edge

The same four 1.0-ha openings used for the seedfall study were also used to investigate the effects of the forest stand edge on survival and growth of seedlings planted at set distances from the edge. The data were also used to describe the influence of orientation (along or across the contour) on seedling survival and growth. In each opening, 195 seedlings were planted into 13 rows of 15 seedlings at 2-m intervals. The rows were parallel to the long edges on either side of the opening at the following distances from the forest canopy drip line: 2, 5, 10, 15, 20, 25, and 30 m (centre). Planted Douglas-fir seedlings were as described in Section 2.2, and planting was done by a single individual.

Seedlings were measured at the time of planting (June 1998), and fall (late August–early September) in 1998, 1999, 2000, and 2002. Measurements included 5-year height, 5-year groundline diameter, 2002 height increment (leader), overall seedling condition rating, vegetation cover rating, and condition and damage codes for the stem, leader, and foliage. There were five condition ratings: dead, moribund (unlikely to survive to the next year), poor (reduced growth and undesirable form due to sparse foliage and forked stems so unlikely to become a crop tree), fair (moderate growth and minor defects), and good (vigorous growth and healthy appearance).

Seedling growth data (height, diameter, and leader) were compared between the two orientations using a mixed model (random and fixed effects) analysis of variance (Littell et al. 1996), based on a one-way, completely randomized design (two blocks nested in each orientation), regardless of distance from edge. Seedling performance at set distances from the forest edge (2, 5, 10, 15, 20, 25, and 30 m) were compared using mixed model analyses of variance based on a randomized block design for each orientation (along and across contours) (n=2 blocks) and not separated by orientation (n=4 blocks). The MIXED model procedure in SAS Version 8.2 was used (SAS Institute Inc. 2001). Approximate (pseudo) F-tests, with denominator degrees of freedom calculated with Satterthwaite's method (SAS Institute Inc. 1996), were used to determine the statistical significance of treatment effect (distance from edge). Least square means (and associated standard errors) were calculated for all groups and comparisons of interest. To account for multiple comparisons, significance levels between treatment means were adjusted using Scheffé's method. Only live trees (good, fair, and poor condition) were included in the analyses. Results were considered significant at $\alpha=0.05$.

3.1 Vegetation

3.1.1 Plant community and potentially competitive species Harvesting affected plant layer cover, shifted the dominant species, and introduced new species, regardless of opening size and site preparation. Variation between openings within treatment groupings was high, but there appeared to be no trends in treatment effects on the percentage cover and heights of shrubs and herbs 5 years after harvest (Table 4). Harvesting reduced the pre-harvest cover and height of tall shrubs (>1.3 m) and increased the cover of the short shrub layer. The 3% reduction in the tall shrub layer was offset by a 16% increase in the cover of short shrubs, while the herb layer changed little, and the moss layer was substantially reduced from 23 to 2% (Table 5). Harvesting did not eliminate species, but it reduced the cover of plants such as falsebox and red-stemmed feathermoss (*Pleurozium schreberi*) to less than 3%. Compared to pre-harvest, at 5 years after harvest, there were 33 new species present (data not shown). These included the appearance of several grass species (Table 5), trembling aspen, and black cottonwood. A few species, such as timothy, were introduced when the skidtrails were seeded with an agricultural mix of seed.

TABLE 4 *Mean (±S.D.) of modal height and percent cover of tall and short shrubs and herbaceous vegetation with and without site preparation, and by opening size, prior to logging and 5 years after harvest*

			Pre-harvest		5 Years post-harvest	
Treatment	Plant layer	n	Cover (%)	Height (cm)	Cover (%)	Height (cm)
Site prep	Tall shrubs					
Y		11	8 ± 7	270 ± 42	2 ± 2	181 ± 42
N		8	9 ± 4	308 ± 65	1 ± 0.4	259 ± 148
	Short shrubs					
Y		11	30 ± 10	54 ± 31	45 ± 18	63 ± 31
N		8	33 ± 5	43 ± 21	43 ± 19	55 ± 37
	Herbs					
Y		11	30 ± 19	31 ± 7	36 ± 13	34 ± 21
N		8	33 ± 11	25 ± 13	27 ± 14	25 ± 16
Opening size	Tall shrubs					
0.25		4	8 ± 3	317 ± 76	1 ± 0.5	211 ± 69
0.5		4	12 ± 7	283 ± 29	1 ± 0	285 ± 214
1.0		9	4 ± 5	262 ± 50	3 ± 2	184 ± 49
2.0		2	14 ± 2	275 ± 35	1 ± 0	215 ± 7
	Short shrubs					
0.25		4	36 ± 5	59 ± 20	41 ± 21	88 ± 13
0.5		4	31 ± 8	39 ± 21	52 ± 19	52 ± 56
1.0		9	27 ± 12	52 ± 37	40 ± 17	50 ± 22
2.0		2	33 ± 4	48 ± 32	54 ± 16	60 ± 35
	Herbs					
0.25		4	36 ± 3	26 ± 11	44 ± 17	38 ± 20
0.5		4	25 ± 12	32 ± 9	30 ± 7	11 ± 1
1.0		9	32 ± 25	29 ± 11	28 ± 14	30 ± 16
2.0		2	33 ± 11	28 ± 4	35 ± 2	58 ± 4

TABLE 5 *Mean (±S.D.) percent cover values for plant layers, (n= 19 openings), and the prominent species (>3% cover), prior to logging and 5 years after harvest*

Plant layer	Totals or species	Pre-harvest cover (%)	5 Years post-harvest
Tall Shrubs	Total	5 ± 4	2 ± 2
	ALNUVIR	3	-
Short shrubs	Total	26 ± 7	42 ± 16
	LINNBOR	3	8
	PACHMYR	3	-
	SHEPCAN	3	-
	RUBUIDA	-	12
	SPIRBET	-	5
	RUBUPAR	-	3
Herbs and Grasses	Total	26 ± 14	31 ± 14
	CORNCAN	6	6
	ASTECON	-	6
	FRAGVES	-	6
	ELYMGLA	-	3
	POA PRA	-	3
Mosses	Total	23 ± 14	2 ± 2
	PLEUSCH	7	-
	PTILCRI	4	-
	HYLOSPL	3	-

The largest species shift in the shrub layer was the increase in red raspberry, followed by an increase in twinflower (*Linnaea borealis*), birch-leaved spirea (*Spirea betufolia*), and thimbleberry (Table 5). Red raspberry and thimbleberry have been identified as potential competing species in the ICH (Davis 1998; Simard et al. 2001), along with Sitka alder, willow, birch, trembling aspen, and cottonwood. Sitka alder was still present 5 years post-harvest, but reduced in cover and height (Table 5), while willow remains <0.5% cover across all openings. Birch cover was ≤2% post-harvest and both poplar species were <1% cover 5 years after harvest and are discussed in Section 3.3 in relation to the performance of the planted Douglas-fir seedlings. Three moss species common prior to harvest (≥3%) are virtually absent, while four herb and grass species have become common (Table 5).

3.1.2 Forage species Table 6 lists 19 shrub and tree species, plus grasses, herbs, and lichens, identified as important mule deer forage in early winter (Waterhouse et al. 1994). On the Horsefly winter range (location of this study), mule deer forage mainly on Douglas-fir (from large, older trees), western redcedar regeneration, and tall Oregon-grape (*Mahonia aquifolium*). The pre-harvest presence of the forage species was similar among the openings with and without site preparation, except that openings to be treated had no willow, but did have highbush-cranberry (Table 7). The pre-harvest presence of the forage species was also similar among the four opening sizes, except that the two smaller sizes had no birch; the 0.5-ha openings had no red-osier dogwood; the 1.0-and 2.0-ha openings had no raspberry; there was no willow in the 0.5- and 2.0-ha openings; and only the smallest opening size

TABLE 6 *The species listed occur in mule deer diets in the central interior of British Columbia (Waterhouse et al. 1994). Percentage in the diet are data collected from the same elevational range as the research trial in the Horsefly winter range during 1999 and 2002 winters (extracted from Trask 2004).*

Plant layer	Common name	Plant code	% in diet (n=6)
Trees	subalpine fir	ABIELAS	0.1
	paper birch	BETUPAP	0.1
	Douglas-fir	PSEUMEN	38.4
	lodgepole pine	PINUCON	2.8
	western redcedar	THUJPLI	25.6
Shrubs	Douglas maple	ACERGLA	1.2
	saskatoon	AMELALN	0.5
	red-osier dogwood	CORNSTO	0.1
	tall Oregon-grape	MAHOAQU	15.9
	falsebox	PACHMYR	0.1
	prickly rose	ROSAACI	-
	red raspberry	RUBUIDA	0.1
	thimbleberry	RUBUPAR	0.1
	willow	SALIX	-
	soopolallie	SHEPCAN	0.1
	birch-leaved spirea	SPIRBET	-
	common snowberry	SYMPALB	-
	black huckleberry	VACCMEM	0.1
	highbush-cranberry	VIBUEDU	-
Grasses			0.8
Herbs			0.7
Lichens			2.3

had highbush-cranberry (Table 8). There was no understory lodgepole pine pre-harvest in any of the openings.

All forage species were present 5 years after harvest, and there were no apparent site preparation or opening size effects on presence (Tables 7 and 8). Five years after harvest, willow and dogwood were present in more of the openings, and all openings had Oregon-grape, prickly rose, thimbleberry, and red raspberry (Table 7). The biggest increase was for red raspberry, present pre-harvest in only four openings. Several grass species were lumped together because their percent covers were low (Tables 7 and 8). Except for timothy (*Phleum pratense*), grasses are slowly making an appearance; they occurred in fewer than half of the openings. Redtop (*Agrostis stolonifera*) was only in opening 1 which was partially seeded along with the adjacent skidtrail. Timothy was present 5 years post-harvest in all opening sizes, but western fescue (*Festuca occidentalis*) was present only in the larger size openings, and nodding wood-reed (*Cinna latifolia*) only in the smaller openings. Bluejoint (*Calamagrostis canadensis*) was present (<1%) in the 0.25-ha and 1.0-ha openings.

Besides changes in presence, there have been changes in percent cover and modal height with harvesting. Douglas maple, Oregon-grape, rose, and black huckleberry remained similar in percent cover or modal height between

TABLE 7 *Mean (±S.D.) of percent cover and modal height of forage species by site preparation both pre-harvest and 5 years post-harvest (n=11 openings site-prepared and n=8 for openings not site-prepared) (na = not applicable as there was only one sample)*

		Pre-harvest				5 Years post-harvest			
		Site-prepared		Not site-prepared		Site-prepared		Not site-prepared	
Plant code		Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)
ABIELAS		1.5±0.9	82±59	1.4±1.2	105±88	1.3±0.0	105±62	0.6±0.8	71±42
ACERGLA	Tall	0.1±0.2	155±37	0.2±0.3	221±162	0.2±0.3	160±32	0.1±0.1	216±123
	Short	0.4±0.4	104±45	0.5±0.3	95±25	0.5±0.4	99±19	0.5±0.2	9227
AMELALN	Tall	0.3±0.3	200±49	0	-	0.2±0.2	143±12	0.2±0.3	175±64
	Short	0.7±0.4	93±21	0.8±0.2	96±44	1.3±1.2	89±13	1.2±0.5	77±22
BETUPAP		0.3±0.0	80±51	0.4±0.0	153±58	2.0±1.0	75±47	1.3±0.8	160±170
CORNSTO	Tall	0	-	0	-	0.0±0.1	131±na	0	-
	Short	0.1±0.2	55±9	0.0±0.1	50±na	0.4±0.3	75±13	0.3±0.3	84±15
GRASSES		0.08±0.0	54±20	0.09±0.0	46±22	2.6±1.7	94±46	1.6±1.8	81±46
MAHOAQU		0.6±0.3	30±7	0.7±0.3	25±5	0.6±0.3	23±5	0.9±0.5	34±14
PACHMYR		2.8±3.7	24±7	3.7±2.9	19±6	1.8±2.8	23±9	2.8±5.5	16±5
PINUCON		0	-	0	-	1.2±0.6	33±15	0.9±0.3	26±17
PSEUMEN*		1.6±1.4	46±38	1.8±0.4	55±70	2.1±0.3	60±35	3.0±0.8	62±39
ROSACCI	Tall	0	-	0	-	0.0±0.1	165±na	0	-
	Short	1.0±0.7	57±12	0.8±0.4	54±20	1.7±1.0	65±13	1.1±0.4	59±12
RUBUIDA	Tall	0	-	0	-	0.3±0.4	146±13	0.1±0.2	136±6
	Short	0.0±0.1	56±na	0.1±0.2	33±15	14.0±9.8	76±19	11.3±11.2	78±28
RUBUPAR	Tall	0	-	0	-	0	-	0.0±0.1	132±na
	Short	2.3±2.3	64±13	1.5±1.6	62±23	2.7±4.0	62±15	3.4±4.9	53±19
SALIX	Tall	0	-	0.0±0.1	230±na	0.1±0.1	145±15	0.0±0.1	220±na
	Short	0	-	0.1±0.3	70±na	0.3±0.3	104±14	0.2±0.2	59±24
SHEPCAN	Tall	0.1±0.2	156±0.7	0.4±0.6	156±40	0.0±0.1	150±na	0.1±0.2	145±na
	Short	3.1±4.5	114±11	1.9±1.7	105±10	0.3±0.4	57±15	0.8±0.3	70±19
SPIRBET		1.4±1.0	37±9	1.0±0.1	37±7	6.4±6.1	46±7	4.9±7.3	47±5
SYMPALB		0.2±0.3	53±8	0.4±0.7	75±24	0.6±0.8	71±16	1.3±2.1	61±8
THUJPLI		9.6±6.1	173±121	9.4±8.0	168±141	1.4±1.3	115±91	3.9±1.1	128±95
VACCMEM		1.0±1.0	48±11	1.2±0.4	48±10	0.8±1.1	37±10	1.0±0.4	40±14
VIBUEDU		0.0±0.1	55±na	0	-	0.1±0.1	57±20	0.1±0.2	35±7

* Includes planted and natural regeneration.

pre-harvest and 5 years post-harvest when openings were grouped by site preparation treatment (Table 7). Saskatoon, thimbleberry, and highbush-cranberry showed a slight increase (1%) in cover (Table 7). The increase for thimbleberry was more dramatic in the 0.25- and 0.5-ha openings (Table 8). Willow, a species not present pre-harvest in openings that were site-prepared, was similar in cover for both site-prepared and not-site-prepared openings 5 years after harvest (0.3%). Raspberry increased in cover from 0.3% up to 14% in site-prepared openings and 11.3% in openings not site-prepared, in the 5 years since harvest, although variability among openings was high. Birch-leaved spirea also increased substantially (5%) from the pre-harvest cover of about 1%. Soopolallie decreased (about 2%) in cover with harvesting.

TABLE 8 *Mean (±S.D.) of percent cover and modal height of forage species by opening size both pre-harvest and 5 years post-harvest (na = not applicable because there was only one sample)*

		Pre-harvest							
		0.25 ha (n=4)		0.5 ha (n=4)		1.0 ha (n=9)		2.0 ha (n=2)	
Plant code		Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)
ABIELAS		1.4±0.7	123±91	0.9±1.0	92±74	1.7±1.2	85±61	1.4±0.8	49±26
ACERGLA	Tall	0.1±0.1	167±47	0.1±0.1	145±7	0.2±0.3	223±163	0.3±0.4	138±4
	Short	0.4±0.2	76±19	0.4±0.3	93±12	0.6±0.4	129±41	0.3±0.4	58±18
AMELALN	Tall	0.4±0.3	223±55	0.1±0.3	135±92	0	-	0.4±0.5	200±na
	Short	1.0±0.0	95±25	0.9±0.3	85±13	0.8±0.3	95±49	0.3±0.0	115±na
BETUPAP		0	-	0	-	0.3±0.0	125±72	0.4±0.0	93±52
CORNSTO		0.1±0.1	50±na	0	-	0.1±0.2	58±11	0.3±0.4	50±na
GRASSES		0.2±0	57±26	0.1±0	45±21	0.1±0	47±17	0.5±na	40±na
MAHOAQU		0.8±0.2	29±5	0.5±0.2	24±4	0.6±0.4	29±9	0.6±0.2	27±4
PACHMYR		0.9±0.1	18±6	5.3±5.6	25±8	3.2±2.7	22±5	3.3±3.2	30±7
PINUCON		0	-	0	-	0	-	0	-
PSEUMEN*		1.7±2.0	58±61	1.7±0.8	57±77	1.5±0.5	47±49	2.1±1.0	43±18
ROSACCI		1.0±0.0	53±12	1.0±0.0	67±12	0.9±0.9	53±17	0.8±0.4	54±23
RUBUIDA		0.2±0.1	35±19	0.1±0.3	50±na	0	-	0	-
RUBUPAR		2.1±1.9	64±13	1.6±1.7	83±4	2.1±2.5	56±18	1.8±1.8	64±23
SALIX	Tall	0	-	0	-	0.0±0.1	230±na	0	-
	Short	0.2±0.4	70±na	0	-	0	-	0	-
SHEPCAN	Tall	0	-	0.3±0.4	139±18	0.3±0.6	173±45	0.1±0.2	155±na
	Short	1.4±1.9	107±12	2.7±1.4	113±12	3.1±5.0	108±11	3.0±0.4	123±4
SPIRBET		1.4±1.0	36±9	1.0 ±0.0	41±8	0.9±0.5	35±8	2.6±0.9	41±11
SYMPALB		0.4±0.4	57±13	0.6±0.5	54±5	0.2±0.3	68±29	0.3±0.4	63±na
THUJPLI		11.3±8.9	148±97	10.3±3.3	166±130	9.7±4.7	178±138	4.3±0.0	185±159
VACCMEM		0.9±0.1	50±8	1.6±1.5	43±14	0.9±0.7	46±10	1.0±0.0	57±9
VIBUEDU		0.1±0.1	55±na	0	-	0	-	0	-

Western redcedar, most likely from the regeneration layer, is an important diet item for mule deer. By 2002 it had decreased by approximately 7% cover from pre-harvest measurements (9.5%), and the decrease seemed to be greater in site-prepared openings (Table 7). Lodgepole pine is eaten sporadically in small portions and has appeared in all openings except for some of those 0.25 ha in area (Table 8). Although Douglas-fir is not commonly eaten by deer in the regeneration layer, this species modestly increased in presence and cover post-harvest due in part to planting.

TABLE 8 *Continued*

		5-year post-harvest							
		0.25 ha (n=4)		0.5 ha (n=4)		1.0 ha (n=9)		2.0 ha (n=2)	
Plant code		Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)
ABIELAS		0	-	0	-	0.8±0.7	88±54	0	-
ACERGLA	Tall	0.1±0.1	270±184	0.1±0.1	153±18	0.2±0.3	166±33	0.3±0.4	150±na
	Short	0.5±0.5	122±3	0.3±0.2	82±32	0.6±0.3	90±18	0.4±0.2	105±21
AMELALN	Tall	0.4±0.3	168±45	0.1±0.1	135±na	0.2±0.3	145±18	0.1±0.2	131±na
	Short	1.0±0.0	88±10	0.6±0.3	84±25	1.5±1.1	75±15	1.9±1.2	108±4
BETUPAP		1.0±0	77±22	1.4±1.0	207±202	1.8±0	71±45	2.2±1.7	118±49
CORNSTO	Tall	0.1±0.1	131±na	0.6±0.2	68±4	0	-	0	-
	Short	0.4±0.2	89±17	0	-	0.3±0.4	73±7	0.4±0.2	78±18
GRASSES		4.9±2.1	91±49	0.9±1.4	98±48	2.0±1.8	84±44	0.9±1.2	91±50
MAHOAQU		0.7±0.3	30±17	1.0±0.8	33±16	0.6±0.3	24±6	0.9±0.2	28±4
PACHMYR		0.8±0.4	16±6	6.9±7.6	16±5	0.7±0.4	22±9	2.5±2.1	25±14
PINUCON		0.3±na	16±na	1.0±0.1	19±13	0.8±0.3	34±17	2.1±0.5	31±14
PSEUMEN		2.1±0.9	69±40	2.5±0.2	53±34	2.6±0.7	62±36	3.0±0.3	57±37
ROSACCI	Tall	0	-	0.1±0.1	165±na	0	-	0	-
	Short	1.5±0.6	61±3	1.8±1.5	55±15	1.3±0.8	69±12	1.5±0.7	50±14
RUBUIDA	Tall	0.6±0.4	140±0	0.2±0.2	136±6	0	-	0.3±0.4	165±na
	Short	14.3±8.1	100±15	22.2±7.6	83±22	6.8±9.6	65±19	16.3±5.3	73±18
RUBUPAR	Tall	0	-	0.1±0.1	132±na	0	-	0	-
	Short	6.5±5.9	65±11	4.4±6.6	58±27	1.2±0.7	58±15	1.0±0.0	45±7
SALIX	Tall	0	-	0.1±0.1	146±21	0.1±0.1	183±53	0	-
	Short	0.1±0.3	50±na	0.3±0.3	105±30	0.3±0.3	80±28	0.1±0.2	100±na
SHEPCAN	Tall	0	-	0.2±0.2	148±4	0	-	0	-
	Short	0.5±0.3	55±11	0.4±0.4	67±33	0.6±0.5	75±4	0.8±0.4	53±18
SPIRBET		7.6±10.2	48±3	5.3±3.3	50±8	3.1±3.6	44±6	15.4±6.5	46±6
SYMPALB		0.9±0.9	68±16	1.7±3.0	67±21	0.7±0.9	69±7	0.3±0.4	43±na
THUJPLI		3.9±0.9	138±84	2.9±0.0	92±132	1.9±1.5	143±61	1.0±0.0	59±90
VACCMEM		0.8±0.5	50±17	1.6±1.6	31±10	0.6±0.4	39±10	0.9±0.2	38±4
VIBUEDU		0	-	0	-	0.2±0.2	48±19	0	-

* Includes planted and natural regeneration.

3.2 Natural Regeneration

Seed viability varied from year to year for all conifer species (Table 9). Except for spruce, all species had a healthy seed set (≥80% viable) at least once within the first 6 years after harvest. Conifers can produce empty seeds as a result of a lack of pollination, lack of fertilization, or insects and disease during seed development. Additionally, seeds in the traps were subject to months of fluctuating temperature and moisture; therefore, the timing of when the seeds became non-viable cannot be determined from this study.

Douglas-fir produced the most viable seed (60%) out of the three primary species listed in the stocking guidelines for the ICHmk3-01 site series (B.C. Ministry of Forests 2002) (Table 10). Lodgepole pine and spruce made up 11 and 29%, respectively. A small amount of subalpine fir was collected, but there was prolific production of western redcedar and paper birch seed in most years. In 2 of the years (1999 and 2003) since harvest, Douglas-fir seed

TABLE 9 *Annual percentage of viable seed, by species, collected each spring from traps (n=60) in the four 1.0-ha openings (no site preparation)*

Seed year	Douglas-fir	Pine	Spruce	Subalpine fir
2003	44	49	48	no seed to test
2002	39	59	66	6
2001	50	100	no seed to test	100
2000	12	100	50	82
1999	77	78	20	48
1998	80	78	71	100

production rates exceeded the recommended aerial seeding rates of 50 000 to 70 000 seeds per ha (Mitchell et al. 1990).

Seed production was variable among blocks, and among traps within blocks, with standard deviations often large (Table 10). For Douglas-fir, the general trend over the 6 years was for fewer seeds in the traps in the centre of the openings (30 m from the forest edge), and on the south edges of the openings (15 m) (Figure 3). This is most strongly illustrated for 1999, the year with the heaviest seedfall.

Ingress has resulted in an increase in stems per ha for the five conifer species assessed (Table 11). The mean sph includes germinants, seedlings (<1.3 m tall) (natural and planted), and saplings (>1.3 m tall but <7.5 cm dbh) present at each assessment in the 1.0-ha, not-site-prepared openings (same ones with seed traps). In the interval between the initial post-harvest assessment (fall 1998) and the 5th-year tally (2002), Douglas-fir increased by 85%, from 1500 to 2675 sph. The 1998 assessment included Douglas-fir seedlings planted at 1200 sph. Given the high survival rates of the planted Douglas-fir stock, the net increase in the 2002 tallies reflects successful seedling survival from seeds produced from 1998 to 2001. The other species of interest, western redcedar, increased by 47%, from 533 to 783 sph. The net number does not provide information on germination success or mortality from year to year.

Openings with no mechanical site preparation had greater mean sph for all conifer species, but variation between openings was high (Table 12). Over the whole site in 2002, Douglas-fir (2708 ± 2199 sph) (natural and planted) and lodgepole pine (2074 ± 5199 sph) were the dominant regeneration species. Some opening sizes have no spruce (0.5 ha), subalpine fir (0.25, 0.5, and 2.0 ha), or western hemlock (0.25 and 2.0 ha). This may simply reflect the species composition of reproductive conifers in the surrounding stand at each opening that varied pre-harvest (Table 1).

TABLE 10 *Mean (±S.D.) of viable Douglas-fir, pine, spruce, and subalpine fir seeds per hectare, and all western redcedar and birch seeds (n=4 blocks). The total viable seed crop is summed over all years for each species.*

Species	Seed year	Mean	S.D.
Douglas-fir	2003	92 714	88 771
	2002	10 857	9 863
	2001	46 143	50 117
	2000	4 667	14 897
	1999	152 000	113 000
	1998	42 000	39 000
	1998–2003	**348 381**	
Pine	2003	10 143	9 548
	2002	2 000	7 209
	2001	1 334	5 164
	2000	1 334	7 241
	1999	4 700	15 000
	1998	42 000	19 000
	1998–2003	**61 511**	
Spruce	2003	97 762	63 462
	2002	7 619	18 815
	2001	0	0
	2000	1 333	10 328
	1999	54 000	90 000
	1998	10 750	20 000
	1998–2003	**171 464**	
Subalpine fir	2003	0	0
	2002	667	5 164
	2001	2 000	7 746
	2000	30 000	64 044
	1999	1 300	7 200
	1998	1 000	5 100
	1998–2003	**34 967**	
Western redcedar*	2003	13 190	25 151
	2002	676 857	504 528
	2001	163 476	202 821
	2000	30 500	79 900
	1999	295 750	429 327
	1998	-	-
	1999–2003	**1,179,773**	
Paper birch	2003	596 429	323 683
	2002	866 905	449 601
	2001	287 810	290 510
	2000	193 200	172 300
	1999	1 699 250	2,009 000
	1998	331 000	314 000
	1998–2003	**3 974 594**	

* Seed not collected in 1998.

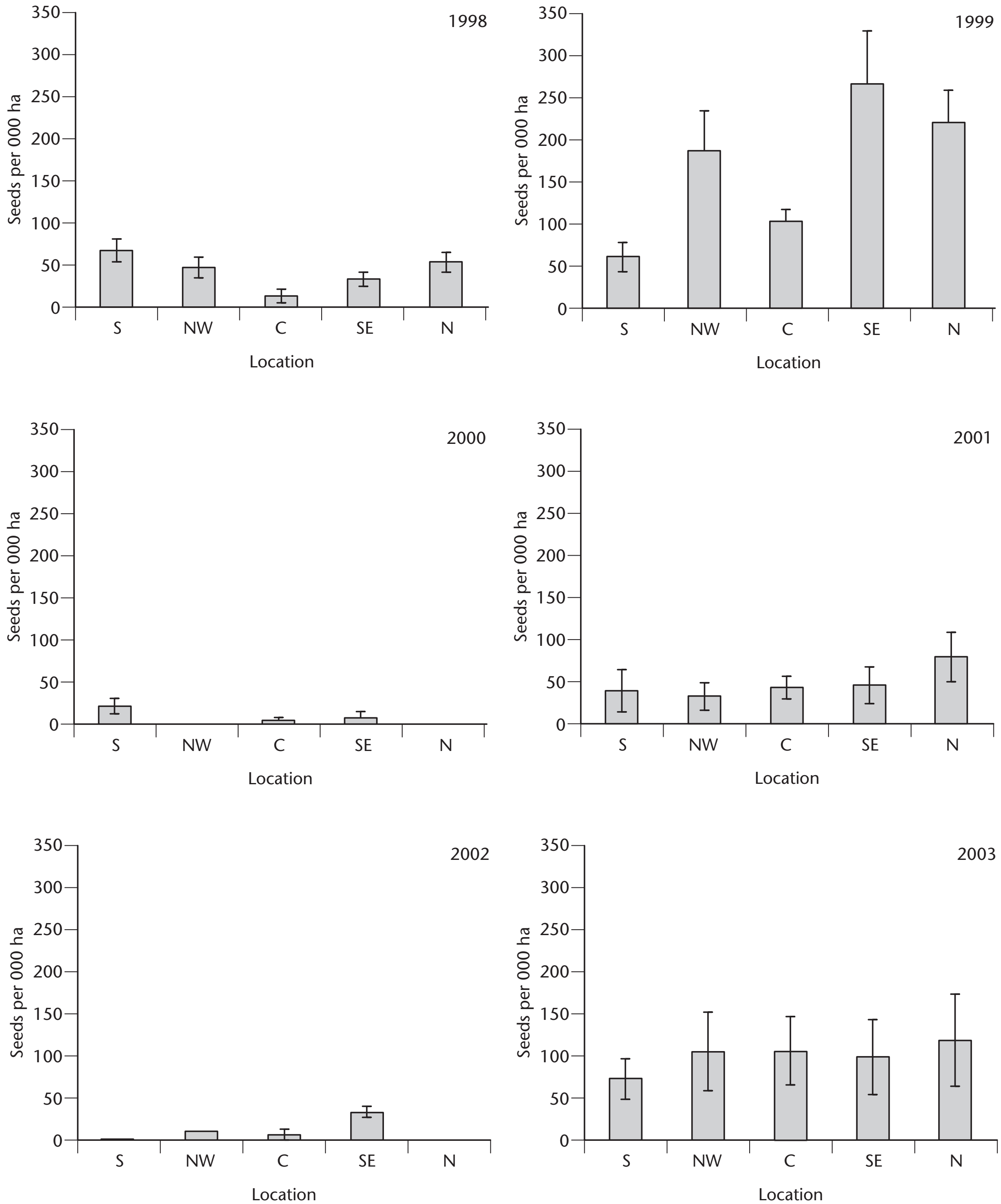

FIGURE 3 *Mean and standard error of density of viable Douglas-fir seed relative to distance from edge (15 m at N, S, SE, or SW locations or 30 m at centre [C]) for each year of the study (n=6 traps per edge and n=12 traps at centre).*

TABLE 11 *Mean (±S.D.) stems per hectare (sph) for the same conifer species as found in seedfall traps, all 1.0-ha openings with no site preparation (n=4). Data were collected on four sample plots within each TRENDS plot.*

Species	**Measurement year**	**Mean ± S.D. sph**
Douglas-fir	2002	2675 ± 1258
	1998	1500 ± 534
Pine	2002	575 ± 260
	1998	0
Spruce	2002	200 ± 100
	1998	75 ± 35
Subalpine fir	2002	167 ± 161
	1998	100 ± 87
Western redcedar	2002	783 ± 486
	1998	533 ± 501

TABLE 12 *Year 5 post-harvest mean (±S.D.) stems per hectare of conifer species by site preparation and opening size treatments*

Species	**Mean ± S.D. stems per hectare**			
site preparation	**Y (n=11)**	**N (n=8)**	**Totals for site**	
Douglas-fir	2030 ± 1956	3461 ± 2316	2708 ± 2199	
Pine	775 ± 1406	3517 ± 7357	2074 ± 5199	
Spruce	70 ± 125	333 ± 476	195 ± 356	
Subalpine fir	45 ± 142	56 ± 116	50 ± 127	
Western redcedar	405 ± 926	2128 ± 3500	1221 ± 2579	
Western hemlock	15 ± 34	178 ± 515	92 ± 354	
Opening size	**0.25 ha (n=4)**	**0.5 ha (n=4)**	**1.0 ha (n=9)**	**2.0 ha (n=2)**
Douglas-fir	2125 ± 1863	4025 ± 3494	1983 ± 1254	4500 ± 2828
Pine	188 ± 375	6013 ± 11012	483 ± 617	5125 ± 1237
Spruce	250 ± 265	0	122 ± 135	800 ± 990
Subalpine fir	0	0	106 ± 172	0
Western redcedar	475 ± 403	3375 ± 4956	311 ± 444	2500 ± 3536
Western hemlock	0	388 ± 775	22 ± 36	0

3.3 Planted Regeneration Performance

Survival of the planted Douglas-fir seedlings from the monitoring plots has been high in all openings on this study site. The greatest annual mortality occurred after the first winter, but survival was still 96%. Some trees have died each year since, with an overall 92% survival 5 years after planting. Mortality is spread evenly across opening sizes and site preparation treatments.

There were statistically significant differences ($p \leq 0.001$) in 5th-year seedling height, annual increment, and stem diameter among opening sizes (Table 13). Seedling performance decreased in the smallest openings (Figure 4). The seedlings in the 0.25-ha openings were 23% shorter on average, and had reduced stem diameters, and new growth was 65% of that put on by the seedlings in the larger openings. There was a slight trend for larger seedlings in the site-prepared openings (Figure 5), but none of the growth variables were significant (α=0.05) (Table 13).

Frost damage to planted seedlings was unrelated to site preparation or opening size (Table 14). Seedlings recorded as having mottled foliage had Cooley spruce gall adelgid, but the insects were no longer present. The frequency of adelgid was higher in the larger (1.0- and 2.0-ha) openings, but has been decreasing over time (Table 14).

Overtopping vegetation surrounding the planted seedlings averaged 91 cm in height versus 35 cm where the seedling was not overtopped (Table 15). This resulted in the overtopped seedlings showing less height growth (22% shorter), narrower crowns, and smaller diameters. Seedling condition was good for all seedlings, but more of the overtopped seedlings had multiple leaders. This condition may have been the direct result of physical damage from the competing vegetation, or the heavy cover may have predisposed the seedlings to damage from other agents. These two populations of seedlings have been on different growth curves since the first growing season, as illustrated in Figure 6.

Red raspberry overtopped most of the 194 seedlings with over-topping vegetation (Figure 7). Fifty-five percent of the seedlings were competing with red raspberry, 11% with thimbleberry, and 9% with black twinberry. Some planted seedlings had more than one overtopping competitor. Although alder decreased in cover since harvesting (Table 5), it represented 7% of the overtopping species. Trembling aspen, black cottonwood, and birch together represented almost 12% of overtopping species, while competition from another conifer species, western redcedar, accounted for 4%.

There were vegetation species taller than the modal height in both groups, and these were often hardwood (birch, aspen, and cottonwood) or alder species. Planted seedling height was compared between the not-overtopped and overtopped groups for those seedlings where one of three hardwood species or alder were growing in close proximity (<1 m) to the planted seedlings. The height growth should be the same in both groups, if the species of interest are the only competitors. However, there was a consistent trend for Douglas-fir seedlings in the not-overtopped group to be taller than their overtopped counterparts (Figure 8). This suggests that the early and continued competition from the shrub species, especially red raspberry, has had a bigger negative effect on seedling performance than the hardwood or alder species.

Size of opening has had an impact on stocking (Table 16). The smallest openings had fewer well-spaced stems per ha 5 years after planting compared to the larger openings, even though they were originally planted to the same density. Silviculture labels showed that the planted Douglas-fir composed

TABLE 13 *Results from analysis of variance using factorial model with three opening sizes (2.0 ha excluded), and with or without site preparation, for height increment, height, and stem diameter of planted Douglas-fir seedlings 5 years after harvest. Significant results in bold. Least square means within the same row, with the same superscript letter, are not significantly different at α=0.05.*

Source	Variable	Df (num, den)	F	*p*	Least square means 0.25 ha	0.5 ha	1.0 ha
Opening size (OS)	Height increment (cm)	2, 11.4	12.68	**0.001**	9.7[a]	15.2[b]	14.7[b]
	Height (cm)	2, 11.0	19.31	**<0.0001**	54.0[a]	71.0[b]	73.0[b]
	Stem diameter (mm)	2, 11.2	14.72	**<0.0001**	8.9[a]	12.3[b]	14[b]
Site preparation (SP)	Height increment (cm)	1, 11.4	0.9	0.36			
	Height (cm)	1, 11.0	0.78	0.39			
	Stem diameter (mm)	1, 11.1	0.34	0.57			
OS × SP	Height increment (cm)	2, 11.4	1.17	0.35			
	Height (cm)	2, 11.0	0.12	0.89			
	Stem diameter (mm)	2, 11.2	0.28	0.76			

TABLE 14 *Percentage of seedlings affected by frost, Cooley spruce gall adelgid, and foliar mottling 3 and 5 years after harvest by main treatments*

	Sample size		Frost (%)		Cooley spruce gall adelgid (%)		Foliar mottling (%)	
	2000	**2002**	**2000**	**2002**	**2000**	**2002**	**2000**	**2002**
Site prep								
N	275	257	20	9	18	16	53	20
Y	370	286	26	10	22	6	52	17
Opening size								
0.25 ha	135	123	16	15	8	1	22	18
0.5 ha	142	137	35	3	7	9	44	6
1ha	297	283	17	12	32	15	65	27
2 ha	71	70	37	0	23	9	78	7

TABLE 15 *Fifth-year post-harvest mean (±S.D.) morphological parameters of planted Douglas-fir, and percent cover and height of competing vegetation, for seedlings that were over-topped or not overtopped by competing vegetation in 2002*

Seedling height (cm)	2001 height increment (cm)	2002 height increment (cm)	Crown radius (cm)	Diameter (mm)	Competing cover (%)	Vegetation height (cm)
Not overtopping competing vegetation						
73 ± 21	14.7 ± 7	15.1 ± 7	23 ± 7	14 ± 4	57 ± 22	35 ± 23
Overtopping competing vegetation						
57 ± 18	10.4 ± 6	11.3 ± 6	18 ± 6	11 ± 3	65 ± 22	91 ± 40

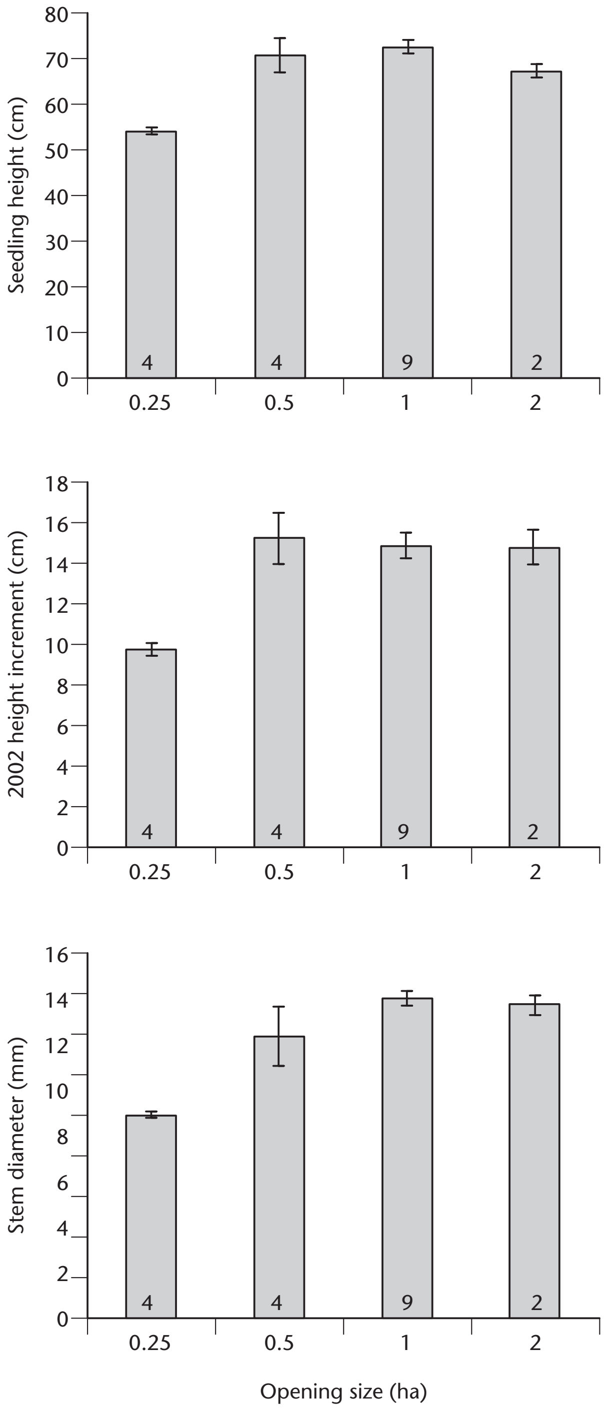

FIGURE 4 *Mean height, 5th-year height increment, and stem diameter at ground level for planted Douglas-fir seedlings 5 years after planting by opening size. Bars represent unadjusted mean values, and n values within bars represent the number of TRENDS plots used to calculate the mean and standard error.*

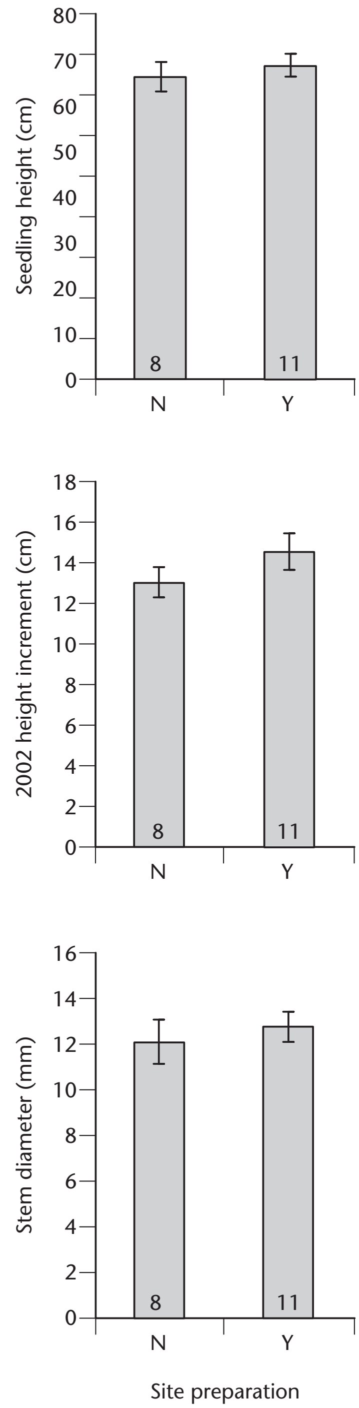

FIGURE 5 *Mean height, 5th-year height increment, and stem diameter at ground level for planted Douglas-fir seedlings 5 years after planting with (Y) or without (N) mechanical site preparation. Bars represent unadjusted mean values, and n values within the bars represent the number of TRENDS plots used to calculate the mean and standard error.*

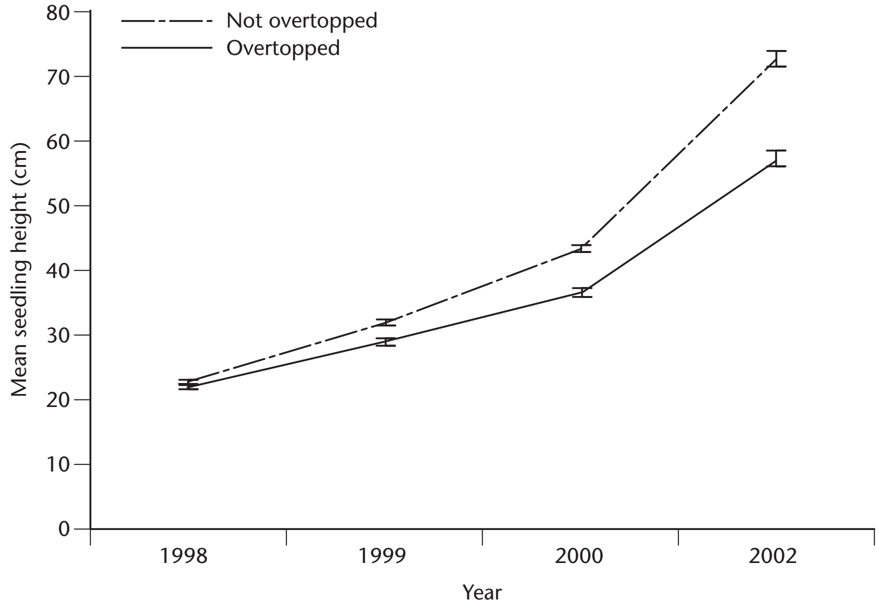

FIGURE 6 *Mean and standard error for height of planted Douglas-fir seedlings for the first 5 years of growth separated by seedlings not overtopped or over-topped by competing vegetation at the 2002 assessment. There were 419 seedlings in the not overtopped group and 194 seedlings in the overtopped.*

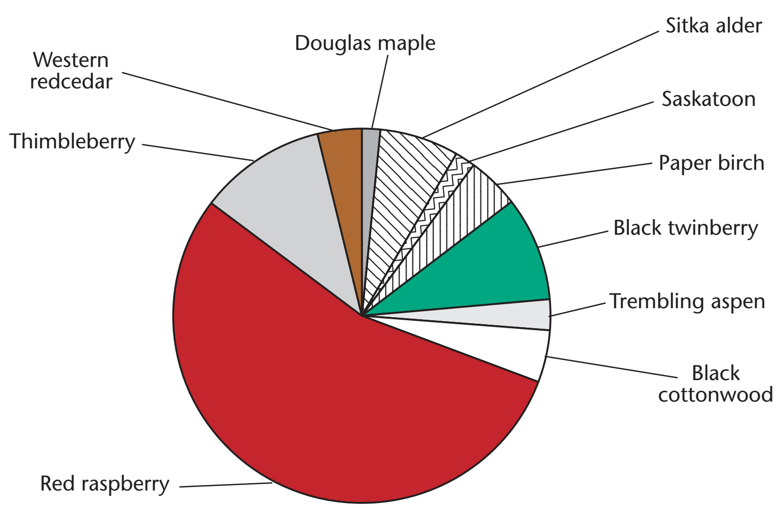

FIGURE 7 *Species composition, 5 years after harvest, of overtopping vegetation measured on 1 m radius, tree-centred plots of planted Douglas-fir seedlings, all* TRENDS *plots combined.*

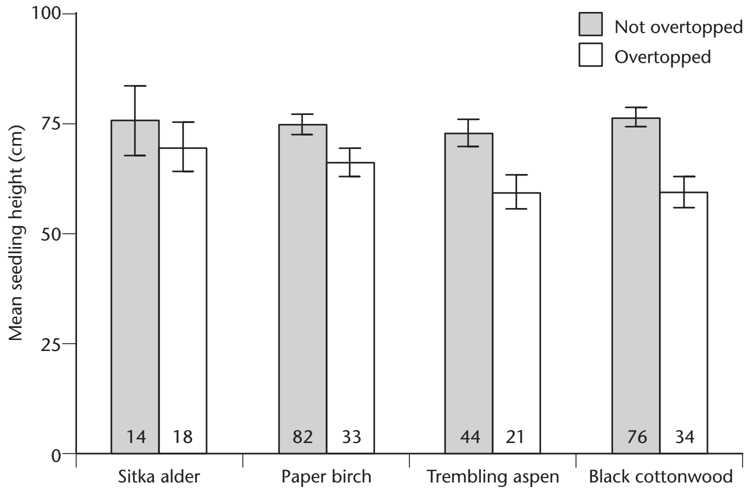

FIGURE 8 *Mean height of planted Douglas-fir seedlings, 5 years after harvest, with one or more of the four species growing within 1 m distance from the measured seedlings. Bars are the mean heights for the two populations of seedlings, not overtopped or overtopped, by competing vegetation at the 2002 assessment, based on the modal height of all surrounding vegetation. The values within the bars are the number of planted seedlings in each category used to calculate the mean and standard error.*

TABLE 16 *Stocking survey results at planting and 5 years later, plus 5th-year species composition*

Opening number	Site preparation	Total well-spaced sph ± S.D.		5th-year species composition
		at planting	5th year	
Opening: 0.25 ha (15 × 165 m)				
17	Y	1200 ± 0[a]	550 ± 252	$Fdi_{90}Cw_{10}$
18	Y	1200 ± 0	500 ± 115	Fdi_{100}
19	N	1050 ± 192	1150 ± 444	$Fdi_{83}Cw_{13}Sx_4$
20	N	1150 ± 100	1050 ± 300	Fdi_{100}
Opening: 0.50 ha (30 × 165 m)				
13	Y	1200 ± 0	950 ± 100	Fdi_{100}
15	Y	1200 ± 0	1200 ± 0	Fdi_{100}
14	N	1000 ± 163	950 ± 379	Fdi_{100}
16	N	1200 ± 0	900 ± 757	Fdi_{100}
Opening: 1.0 ha (60 × 165 m) along contour				
4	Y	1200 ± 0	1300 ± 577	$Fdi_{80}Bl_8Sx_8Hw_4$
11	Y	1050 ± 192	550 ± 192	$Fdi_{90}Bl_{10}$
8 (wet)	Y	1200 ± 0	not done	not done
5	N	1100 ± 115	2100 ± 872	$Fdi_{74}Cw_{17}Pli_7Sx_2$
10	N	1100 ± 115	1000 ± 163	Fdi75Pli1$_5$Bl$_5$Sx$_5$
Opening: 1.0 ha (60 × 165 m) across contour				
7	Y	1200 ± 0	1150 ± 412	Fdi_{100}
12	Y	1100 ± 200	1450 ± 412	$Pli_{55}Fdi_{45}$
6	N	1200 ± 0	1850 ± 680	$Fdi_{68}Sx_{17}Bl_5Cw_5$ Pli_5
9	N	1150 ± 100	1350 ± 252	$Fdi_{85}Pli_{11}Sx_4$
Opening: 2.0 ha				
2 (60 × 330 m)	Y	1150 ± 100	1250 ± 100	$Fdi_{96}Pli_4$
1 (140 × 140 m)	Y	1200 ± 0	1200 ± 0	$Fdi_{92}Pli_8$

a Standard deviation of zero means all four subplots of a plot had the same number of counted trees; common at planting because planted to full-stocking target.

most of the well-spaced trees at the time of the survey, except for opening 12, which had pine leading. Advanced regeneration of the other primary and secondary species also contributed to stocking (B.C. Ministry of Forests 2002).

3.4 Opening Orientation and Stand Edge Effects

Blocks 6 and 10 run east–west along the elevation contours, while blocks 5 and 9 run approximately northeast–southwest, perpendicular to the contours. Based on the seedlings planted in each block of the edge study, the orientation of the blocks did not affect overall seedling 5th-year height, 2002 annual increment, or 5th-year diameter (Table 17). Overall survival ranged from 80 to 92%, and most of the trees (71–87%) were in either good or fair condition (potential crop trees).

When data from the four blocks were pooled, there was lower survival (73%) of seedlings 2 m from the forest canopy edge compared to other distances into the openings (>89%). Also, seedling vigour (condition) improved as the distance from the edge increased. In the 2-m position, 33% of the sample (n=119) were rated as poor. The portion of the sample rated as poor was reduced in the 5-m location (13%), and for those rows further into the opening, fewer than 8% were rated as poor.

Based on data from the four blocks (ignoring aspect), surviving seedlings have much smaller height and diameters at 2 m from the drip line of the forest canopy than those growing further into the openings (Table 18). When the 5th-year data were separated by aspect, diameter growth in the 2 m position on south and southeast edges (shadier, cooler) was significantly smaller. It then increased with distance from the forest edge up to 10 m (Figure 9). This pattern was similar but not quite as strong for the height and leader variables (Table 18). On the north and northwest edges (warmer, sunnier exposures) there was a trend for less growth in the 2-m position, but it was not significantly (α=0.05) different from other locations.

TABLE 17 *Comparison of planted Douglas-fir seedlings (5-year height, 2002 annual height increment, and 5-year diameter) between blocks that run across and along contours using analysis of variance (num df=1; den df=2), based on a completely randomized design*

Variable	Along contour LS mean	Across contour LS mean	F	*p*
5-year height (cm)	71.9	70.2	0.06	0.82
2002 height increment (cm)	14.8	13.3	0.25	0.66
5-year diameter (mm)	13.8	13.7	0.01	0.93

LS = least square

TABLE 18 *Results from analysis of variance (randomized block design) for height and diameter of planted Douglas-fir seedlings 5 years after harvest, by distance from forest edge on different exposures and all exposures combined. Significant results are in bold. Least square means within the same row, with the same superscript letter, are not significantly different at* α*=0.05.*

Location	Variable	Least square means 2 m	5 m	10 m	15 m	20 m	25 m	30 m	Df (num, den)	F	*p*
All edges	5-year height (cm)	44^{b}	66^{a}	77^{a}	79^{a}	83^{a}	71^{a}	75^{a}	6, 17.8	10.33	**<0.0001**
(n=4)	2002 height increment (cm)	6^{b}	13^{ab}	16^{a}	16^{a}	16^{a}	14^{a}	16^{a}	6, 17.8	6.41	**0.0010**
	5-year diameter (mm)	7.4^{c}	11.8^{b}	14.7^{ab}	15.9^{ab}	16.1^{a}	14.8^{ab}	15.2^{ab}	6, 17.7	16.94	**<0.0001**
North edge	5-year height (cm)	36	69	77	81	88	80	75	6, 7.06	1.27	0.3750
(n=2)	2002 height increment (cm)	5	14	15	19	19	18	16	6, 6.01	0.83	0.5865
	5-year diameter (mm)	6.2	11.7	15.4	16.3	16.6	16.4	15.3	6, 5.99	2.52	0.1425
South edge	5-year height (cm)	45^{a}	64^{a}	79^{a}	83^{a}	82^{a}	61^{a}	75^{a}	6, 5.82	6.61	**0.0199**
(n=2)	2002 height increment (cm)	6	13	17	18	15	13	16	6, 5.89	2.76	0.1226
	5-year diameter (mm)	7.1^{b}	11.1^{ab}	14.5^{a}	16.2^{a}	16.0^{a}	13.5^{ab}	15.4^{a}	6, 5.91	10.63	**0.0058**
Southeast edge	5-year height (cm)	43^{c}	$55b^{c}$	79^{ab}	81^{a}	84^{a}	75^{ab}	75^{ab}	6, 6.00	16.49	**0.0017**
(n=2)	2002 height increment (cm)	5^{b}	11^{ab}	16^{a}	17^{a}	16^{a}	14^{a}	16^{a}	6, 6.00	12.56	**0.0036**
	5-year diameter (mm)	7.5^{c}	10.9^{bc}	14.8^{ab}	16.6^{a}	16.2^{a}	14.9^{ab}	15.0^{ab}	6, 5.99	21.03	**0.0009**
Northwest edge	5-year height (cm)	49	76	72	70	78	67	75	6, 5.85	2.56	0.1418
(n=2)	2002 height increment (cm)	7	16	16	11	14	13	16	6, 5.88	3.93	0.0618
	5-year diameter (mm)	8.3	13.4	14.1	14.4	15.7	14.3	15.0	6, 5.83	3.39	0.0842

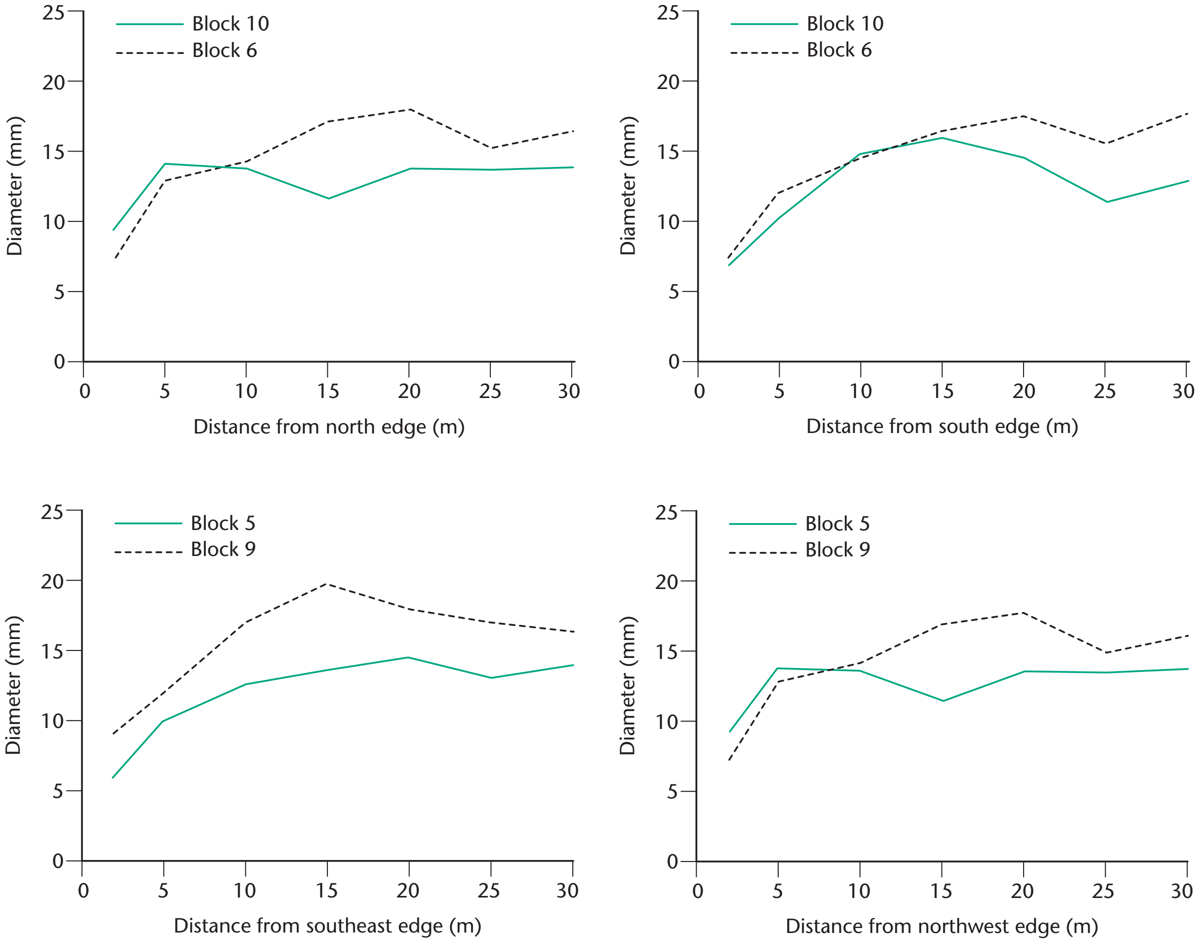

FIGURE 9 *Mean ground-level diameter with distance from the mature forest edge on different aspects (n=15 trees per row [distance]) in each block).*

4 DISCUSSION

4.1 Forage

Several plant species were identified as important winter forage for mule deer from pellets collected during two winters on the Horsefly winter range (Trask 2004) and diet analysis from other winter ranges in the SBS biogeoclimatic zone (Waterhouse et al. 1994). Douglas-fir litterfall from larger, older trees was the single most important diet item. This was followed by western redcedar commonly growing in the understory of the mature and older forest. Shrubs, such as tall Oregon-grape, were a smaller part of the diet, and the amount varied due to preference and availability. Herbs and grasses made up a very minor part of the diet.

The winter snowpack, especially on deep-snowfall winter ranges in the ICHmk3, strongly affects availability of understory diet items. As the snowpack builds, the abundance of preferred species decreases. This is accentuated in the openings, where the snowpack can be up to 40% deeper than found in the forest, based on data collected on this study site. As shrubs become buried, diet shifts to more available species, such as advanced western redcedar regeneration, Douglas-fir litterfall, and arboreal lichens (Waterhouse et al. 1994). Even if forage is available, the snowpack determines the energy required by deer to utilize it. For example, during one heavy-snowfall winter, rather than expending a lot of energy to access forage at the highest elevations in the Horsefly winter range (snowpack >50 cm), deer moved down-slope to where the snowpack was significantly shallower.

Harvesting small openings between 0.25 and 2.0 ha on this ICHmk3 study site appears to have had no effect on the presence of most shrub species identified as important for mule deer forage. After 5 years, the abundance of most species remained close to the pre-harvest amount. Notably, two shrub species, red raspberry and birch-leaved spirea, increased 5 years after harvest; however, these species are not very abundant (<1%) in mule deer diets from the Horsefly winter range or other SBS winter ranges in the central interior of British Columbia (Waterhouse et al. 1994).

In contrast, tree species used as forage have changed in response to harvesting. The immediate effect of harvesting is removal of a portion (about 20%) of the stand that produces Douglas-fir litterfall (about 38% of the mule deer diet). Also, after 5 years, regardless of opening size, understory western redcedar cover was substantially reduced from about 9.5% cover pre-harvest to 1.4% in site-prepared openings and 3.9% in not-site-prepared openings. This species is a major diet component (26%) on the Horsefly Lake winter range. It is similarly an important diet species for coastal black-tailed deer because of its high digestibility (Nyberg and Janz 1990). The overall impact of harvesting is not very serious because overstory Douglas-fir and understory western redcedar continue to be available in the residual forest (about 80% of the original stand). Also, western redcedar produces prolific numbers of seeds most years and the stems per ha of regeneration have increased between the 1st and 5th year post-harvest, so it is expected that cover will increase as the seedlings mature. Subalpine fir and paper birch occurred in trace amounts in the pellets collected on this winter range. Subalpine fir is consumed in large amounts on some winter ranges (Waterhouse et al. 1994), and is available on this winter range in the forest understory and openings. It may be a less preferred species, given the availability of western redcedar, Douglas-fir, and other shrubs. Paper birch has been found in small amounts in diets from other winter ranges and is increasing in the openings, but, as with shrubs, availability is limited by snowpack.

At 5 years post-harvest, mechanical site preparation has not substantially changed the shrub and herb communities in openings from those not site-prepared. Low-intensity mechanical treatments, including disc trenching, in replicated trials in the boreal and sub-boreal regions of northern British Columbia, caused little change to plant communities (Haeussler et al. 1999). The data from this trial indicate that site preparation does reduce the amount of western redcedar, but these data need to be confirmed in a replicated study design.

Caution must be exercised when interpreting vegetation percent cover data collected in the summer. Estimates were made when species were in full leaf, but only the stems of the non-evergreen shrubs and herbs are available during the winter months. We also have no data on the palatability and nutrient value of those available stems from this site.

4.2 Natural Regeneration

In a group selection silvicultural system, natural regeneration of openings is a reasonable expectation. However, full stocking within a set timeframe depends on seed supply, seedbed, microclimate of the opening, and shade tolerance of the species.

Seed production fluctuates from year to year in response to weather conditions. For, example, hot and dry springs stimulate flowering. In the 6 years since harvest, there were 2 years (1999 and 2003) where a large quantity (>50 000 seeds/ha) of viable Douglas-fir seed was produced. Greater viability in bigger seed crop years is consistent with other reported studies (Burton et al. 2000).

The relative amounts of seed from each species reflects the composition of the surrounding stands, which are leading in Douglas-fir, with smaller amounts of lodgepole pine and spruce, and a very small amount of subalpine fir. The stands contain a minor amount of western redcedar, but this species is a prolific seed producer. The amount of seed also reflects the reproductive strategy of each species (Environment Canada 1982). Pine has a 2-year reproductive cycle and serotinous cones, compared to the other species, and so is not comparable to the other tree species in a calendar year (McDonald and Abbott 1994). Subalpine fir generally has some annual seed production, and less frequent heavy cone crops compared to spruce or Douglas-fir.

The variability from year to year in the spatial distribution of seed within the openings was probably due to the direction of the prevailing winds during dissemination, and which edge trees were producing seed in each year (Heineman et al. 2002). Seeds are wind-dispersed, and usually fewer seed are found with increasing distance from a forest edge, especially past a distance of 50 m. The centre seed traps, at 30 m from the stand edge, still had more than 200 000 seeds/ha over the first 4 years since harvest—a critical time for establishing a new stand, although recruitment could be gradual and cumulative with a continuous seed source (McCaughey et al. 1991).

Seedfall has successfully produced surviving seedlings of all conifer species. The result of lower recruitment of stems per ha of all conifer species in the site-prepared openings is contrary to expectations, since exposure of mineral soil should promote germination and survival (Kozlowski 2002). The site preparation itself may have eliminated small seedlings present after harvest, thereby decreasing total numbers of conifers 5 years later.

Five years after harvest there has been an 85 and 47% increase in sph for Douglas-fir and western redcedar, respectively. In the ICHmc near Hazelton, B.C., emergence and sur- vival of conifers was strongly affected by position in the gap (Wright et al. 1998). Direct seeding at different positions within replicated gaps resulted in the highest survival on the shaded side of the gap with the highest soil moisture and approximately 20% full sunlight. A similar trend was found in the ICHmw near Salmon Arm, B.C., in a study (not replicated) with five different opening sizes (Heineman et al. 2002). There, generally, regeneration of conifers was greater in openings <2.0 ha in area, in the shaded portions of each gap, and <10 m away from the forest edge.

4.3 Planted Stock

The performance of planted Douglas-fir seedlings was influenced by opening width and distance from the forest edge. In the three wider, larger openings (0.5 ha, 1.0 ha, and 2.0 ha), the 5th-year survival and height results from the TRENDS plots in this trial were similar to those reported elsewhere in British Columbia. Jull et al. (1999) reported 93% survival and an average of 71 cm height for the 4th year from the ICHmk3 near McBride, B.C., and DeLong et al. (2000) found 3rd-year height for Douglas-fir was about 71 cm in an ICHmw2 trial near Nakusp, B.C.

Additionally, information from the TRENDS silviculture monitoring program of NIVMA provides a baseline for planted Douglas-fir for comparison. An average 5-year-old Douglas-fir seedling in the ICH was 74 cm in height, 17 mm in stem diameter, and 18 cm in annual increment. The planted Douglas-fir in the three larger opening sizes have grown a little slower than those in the TRENDS database. The difference in performance between the seedlings in this study and the population in the TRENDS dataset could be due to genetics (seedlot), site factors such as elevation and aspect, and the timing and kind of vegetation management used.

The larger openings will most likely meet stocking and free to grow standards before year 15 (B.C. Ministry of Forests 2002). Based on a minimum of 700 well-spaced stems per ha, all the larger openings except 11 exceed this standard at year 5 and if the seedlings continue at their current growth rate, they will exceed the 140 cm height requirement for Douglas-fir by year 10.

On the other hand, the seedlings in the smallest opening size are less likely to achieve these silvicultural targets. Survival of planted Douglas-fir was not adversely affected by the opening width, but growth was reduced by about one-third in the 15-m openings compared to the wider openings. If the current growth rate continues, the projected Douglas-fir height (155 cm) will marginally exceed the required height by year 15.

Stocking levels of well-spaced seedlings were reduced in two of the four openings below 700 stems per ha. The TRENDS plots in the narrowest openings go from edge to edge (15 × 60 m) so they include many trees very close to the residual forest. In the widest openings (60 m), the 30 × 30 m plots were placed somewhat randomly and may not have been overlapping the ground most subject to edge effect. In other silvicultural system studies, Engelmann spruce and subalpine fir in 0.2-ha openings were significantly ($p<0.05$) smaller compared to seedlings in a clearcut (Lajzerowicz et al. 2004). The cause of the smaller seedlings in smaller openings was attributed to lower soil temperature and light (Lajzerowicz et al. 2004). In the ICHmc (Coates 2000), growth increased for western redcedar, western hemlock, subalpine fir, hybrid spruce, and lodgepole pine with increasing gap size up to 0.1 ha in area and little change from 0.1 to 0.5 ha.

Surrounding residual canopies cause variable shading into the opening depending on aspect, and the large edge trees compete for moisture and nutrients below ground into the openings. The orientation of the 1.0-ha openings appeared not to have an impact on planted seedling performance up to 5 years after harvest. The overall size of the seedlings, in both orientations, is only slightly smaller than the size reported in the TRENDS database (mostly from clearcuts). We expected the seedlings planted into the openings running east–west (along contours) to be smaller than those planted across contours, due to less light. The non-significant outcome may be a result of the small sample size; however, there was not even an indication of a pattern. These results suggest that, despite edge effects, most of the opening has reasonable seedling growth.

In our seedling-edge study, established in the 1.0-ha openings, the overall lower survival and growth rates at 2 m from the canopy drip line imply that the residual forest is probably influencing light, moisture, and nutrients. Hansen et al. (1993) report smaller planted Douglas-fir within 20 m of a forest edge than further into the opening. Similarly, DeLong et al. (2000) found 70% less height growth for Douglas-fir seedlings on edges abutting the forest than in the middle of 50 m wide openings. Coates (2000) found the poorest seedling performance for shade-intolerant species on the edges of gaps greater than 0.03 ha. In this study, growth (2 and 5 m positions) on the shadier edges was reduced more than on the sunnier aspects, implying that light is the strongest factor. Coates (2000) found that aspects were equally affected, so he speculated that competition for moisture and nitrogen was probably more important than for light.

We found no relationship between seedling survival and site preparation; however, there was a slight increase in growth on the site-prepared openings. This may be due to a combination of factors, including reduced vegetation competition, increased soil warming, and increased nitrogen availability (Piatek et al. 2003). Most of the openings in our trial were disc trenched, which is rated as a low-severity treatment compared to other mechanical site-preparation techniques (Haeussler et al. 1999). The use of disc trenching to control competing vegetation and improve tree growth has variable success (Coates and Haeussler 1988) and may largely depend on site and tree species. For example, Haeussler et al. (1999), after 10 years, found much larger lodgepole pine seedlings on disc-trenched treatment units compared to untreated controls in a nutrient-poor, sub-boreal study, but, in a boreal trial site, white spruce seedlings were only marginally larger on treated units. Also, on dry, frosty sites in the SBSdw2 in the central interior, more aggressive site preparation treatments than disc trenching appeared to improve diameter growth, but not height growth, of Douglas-fir. Height growth was lost due to frost damage to terminal buds (Daintith and Newsome 1996).

Given the limited available literature and this non-replicated study, more information is needed to determine the value of disc trenching. Openings 1 and 8 were aggressively site prepared. In opening 8 (wet), which was mounded to create elevated planting sites, both growth and survival were comparable to that in the other openings. Opening 1 was used as part of a larger study (multiple sites) to compare the use of stumping and biological control fungus (*Hypholoma fasiculare*) to treat *Armillaria* root disease. Chapman et al. (2004) report lower mortality of planted stock when using the biological control treatment compared to stumping or no treatment.

Before establishment, the frost hazard rating for the trial site was low, so there was an expectation of limited mortality and moderate damage to the Douglas-fir (Steen et al. 1990). Although the evidence of frost was up to 35% (2000) in some openings, it has not caused mortality or deformities in the seedlings. Damage was not lessened in the narrowest openings, where there would be maximum frost protection from the residual forest. The moderate amounts of birch, aspen, and cottonwood in the openings could be providing protection from frost damage (Simard et al. 2001). The mottling of the foliage caused by Cooley spruce gall adelgid has not limited growth.

Shrubs appear to be the greatest competitor for the planted Douglas-fir; however, hardwoods have increased in presence and cover post-harvest. Both groups appear to be independent of opening size or site preparation. Competition from red raspberry and thimbleberry has negatively affected more of the planted seedlings than all other species combined. Rapid invasion by shrub species after harvest has been well studied. These shrubs are considered hazardous for newly planted conifers due to light competition, and management treatments are recommended 1–5 years after planting to reduce growth losses (Simard et al. 2001). Most openings with low stocking at year 5 had more than half their seedlings affected by shrubs (mainly red raspberry) competition. These Douglas-fir seedlings may be permanently lost from the crop, although mortality may not occur for a long time.

Hardwood tree species have not been a major competitor on this site up to 5 years post-harvest. Birch has increased in cover in all openings, but the cover of <2% averaged over the study site is well below what is considered competition for planted Douglas-fir (Simard et al. 2001). Aspen and cottonwood have appeared post-harvest in some openings. However, these hardwood species could increase rapidly in cover in years 5–10 (Simard et al. 2001). In our study, planted Douglas-fir seedlings growing with one or more broadleaves or alder in close proximity had average or better height, leader, crown width, and stem diameter growth if not overtopped by shrubs within the first 2 years after planting. Documented benefits from the presence of birch to planted Douglas-fir include cycling of nutrients, rhizosphere nutrient additions, increased ectomycorrhizal diversity, reduced spread of *Armillaria* root disease, frost protection, reduced ungulate browsing, and increased vertical structure in young stands (Simard et al. 2001). In the Simard et al. (2001) study plots, the individual planted seedlings with the poorest growth were those overtopped by more than two of the broadleaf species present on the study site. Scattered manual brushing of birch provided improved Douglas-fir tree condition and total height 5 years after treatment in the ICHmk (01), although resprouting occurred (Simard et al. 2001).

4.4 Limitations of this study

Data were collected on replicate openings, but only from one site. This means that care must be taken not to over-generalize the conclusions and extrapolate results to other sites. Also, there is limited replication on-site because of the eight combinations of opening size and site preparation. There was poor replication (n=2) of some combinations of treatments, and, in the case of the 2.0-ha openings, no treatment units without site preparation. The site preparation factor is also somewhat confounded by lumping all types of site preparation together, although most openings were disc trenched. There are also limitations with the block shape selected. The responses of vegetation and regeneration are more likely related to opening width rather than to block size. Since the 1.0- and 2.0-ha blocks are the same width, they may actually be the same treatment. Although results generally agree with those reported from the literature, the next logical step in this study would be to implement silvicultural systems, developed from knowledge gained from this trial, on several sites, and monitor the results.

4.5 Management Implications

In this study, the group selection silvicultural system has been used to successfully regenerate Douglas-fir. The width of an opening in a group selection system generally does not exceed twice the tree height (Smith 1986), and the opening is less than 1.0 ha in area. In our study site, the taller trees are about 35 m tall and will continue to grow; therefore, the maximum width of the opening would be about 70 m. Openings wider than this may be acceptable for Douglas-fir regeneration on sites with low frost risk but not for deer management. As the openings become smaller, deer habitat (mature forest) becomes more contiguous between the openings, resulting in less energy expended in accessing resources. The minimum opening width (15 m) tested was unacceptable for Douglas-fir survival and growth. The regeneration data from the TRENDS plots and seedling edge study point to at least

30 m wide openings, regardless of orientation. Even at this minimum, about one-third of an opening will experience reduced survival and growth.

In this study, the openings were very long (165 m), to maximize opening size, but this increased the amount of edge. From a silvicultural perspective, it is preferable to reduce the amount of edge per given area. Also, the longer openings could result in more energy expenditure by deer moving around them. We observed that deer regularly avoided crossing even the narrow openings. Hunting success may also improve because of the long sight distances for several years after harvest. Longer edges, especially when laid out perpendicular to the prevailing wind, are subject to more windthrow, especially as openings become wider (M.J. Waterhouse, unpublished data, 1998–2003, B.C. Ministry of Forests, Williams Lake). Smith (1986) also warns it is very difficult to create this type of strip group selection.

The results of this study support the operational harvesting recommendations in the *Management Strategy for Mule Deer Winter Ranges in the Cariboo–Chilcotin* (Dawson et al. 2005). The recommended range of opening sizes on warm-aspect sites (>10% slope and 135–270° aspect) is between 0.1 and 0.4 ha, with an average of 0.3 ha. On cooler aspects, openings range from 0.1 to 1.0 ha, and average 0.6 ha. This flexibility in opening size should enable planning foresters to minimize opening sizes for deer while retaining reasonable growth and survival of Douglas-fir. Opening size is only one ingredient for implementing a silvicultural system. To achieve three habitat types for mule deer through time and space, a 40-year cutting cycle in combination with area removal of 20, 25, or 33% is recommended (Dawson et al. 2005).

There may be situations where the patch cut silvicultural system can be prescribed for small salvage areas (e.g., bark beetle–killed trees or windthrow mortality). The opening sizes are also under 1.0 ha, but each opening is treated as an even-aged stand.

After 5 years, our data indicate that the openings will regenerate with a mix of species representative of the surrounding stand. On the other hand, planting and stand tending substantially reduce the risk of not meeting stocking and free-to-grow requirements (B.C. Ministry of Forests 2002) and gives greater control over the species mix. The species recommendation for deep-snowpack, mule deer winter range is to achieve at least 80% Douglas-fir by basal area in stand components over 40 years old for sites capable of growing Douglas-fir (Dawson et al. 2005). The survival and growth of planted Douglas-fir has been good in the 30-m and wider openings. There appears to be no better growth or survival of planted stock in the disc-trenched openings, so it probably is not required for mesic to drier site units similar to our study area in the ICHmk3. We would not recommend planting within 2 m of the mature forest canopy drip line, and on the shadier edges it may not be prudent to plant within 2–5 m. The density of planted and natural ingress across the whole opening will more than satisfy stocking requirements.

Vegetation competition issues for the regeneration appear to have been related to shrubs, and management (e.g., herbicide) of these species past the 5th post-harvest year may not improve the performance of affected seedlings. It is most likely that the trees, once they have grown through the shrub layer, will have acceptable growth rates. Overall, for openings 0.5 ha and larger, stocking and rate of growth are good, so legislated requirements will be easily met. The hardwood species (especially paper birch, aspen, and cottonwood) on the site could become problematic and may warrant brushing. Brushing of these species in this trial should be scattered and aimed at seedlings with multiple competitors. Trade-offs may exist in balancing the retention of hardwoods for habitat benefits in general and the performance of planted seedlings to meet silvicultural targets (Kie et al. 2002).

On deep-snow, mule deer winter ranges, it is very important to retain a large portion of the stand with trees that will maximize snow interception. The stands on this study area (about 100 years old) are providing adequate interception but the amount of time to replace such trees in the openings is unknown. The winter range must also provide an adequate amount of palatable forage items. After 5 years, there has not been a huge increase in preferred forage species in the openings. The only species to increase appreciably were red raspberry and birch-leaved spirea, which are consumed in small amounts. On the other hand, western redcedar, a desirable forage item, was substantially reduced.

The results of this study may also apply where visual quality is a concern. A significant part of the ICHmk3 is visible from large recreational lakes. Orientation of openings up to 60 m wide along contours will reduce the negative visual impact.

5 CONCLUSIONS

Based on 5th-year data, the group selection silvicultural system should maintain deer habitat while regenerating Douglas-fir. The opening widths of 30–60 m provide enough light, moisture, and nutrients to establish and grow Douglas-fir. Natural regeneration through seeding from the adjacent stand is possible given sufficient time. Planted Douglas-fir has high survival, good growth, and low frost damage. The surrounding forest canopy affects survival and growth in the openings, but this can be reduced by decreasing the edge to opening area ratio. Disc trenching is probably not necessary on mesic and drier sites. The growth of some seedlings was inhibited by other vegetation species, particularly red raspberry and deciduous trees. Site-specific brushing of deciduous trees may improve performance of some conifers. Western redcedar, an important forage species, was reduced in the openings but is expected to recover over time. Two forage species, red raspberry and birch-leaved spirea, have increased substantially but are probably of limited dietary value. It is important to continue collecting data on the trial site to document changes over the long term.

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