Riparian Conifer Underplanting Monitoring Synthesis 2010 Cedar River Municipal Watershed

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Riparian Conifer Underplanting – Monitoring Synthesis 2010

1 Introduction

Riparian conifer underplanting is an element of the mitigation and conservation strategy for riparian and aquatic ecosystems under the Cedar River Watershed Habitat Conservation Plan (HCP Section 4.2). Since 2001, numerous riparian conifer underplanting projects have been implemented and several have included an effectiveness monitoring component to evaluate success of the project or of specific techniques. Although the ultimate success of riparian conifer underplanting projects will not be known for many decades (e.g., when planted trees are eventually recruited as large woody debris in adjacent streams), it is timely after eight years of monitoring to compile the monitoring data acquired to date and assess the results. This document brings together the current results of all riparian conifer underplanting projects that have formal monitoring and assesses the effectiveness of each project. It also draws several overall conclusions about the success of different techniques and approaches to riparian conifer underplanting that have been implemented in the Cedar River Watershed over the past nine years. The results can be used to inform future riparian underplanting projects in the best approaches to maximize success.

1.1 Projects assessed

To date, four riparian conifer underplanting projects have included a formal monitoring program (Figure 1):

(1) an experiment initiated in 2001 along Webster Creek to evaluate different underplanting techniques,

(2) a volunteer planting project implemented in 2002 in the Road 16 area of Rock Creek,

(3) a pilot project along Taylor Creek implemented in 2003, and

(4) a similar project to that of Taylor Creek along Rock Creek implemented in 2004.

The monitoring interval and data collected have varied among these projects, but all were monitored through 2009 or 2010, which allowed evaluating success of the projects over periods ranging from five to eight years after the project was completed.

A number of other riparian conifer underplanting projects have been implemented between 2001 and 2009in addition to these four projects. There has been conifer underplanting incorporated into road decommissioning projects along the 16, 33, 60, and 80 roads, and underplanting conducted following invasive plant removal in a variety of locations. None of these projects have included a formal monitoring program. Also, five sites along the Upper Cedar River were treated with conifer underplanting and release in 2008 and 2009. Because there are no quantified monitoring data for these projects or the projects are very recent, they are not discussed in this monitoring synthesis.

1.2 Format of synthesis

For each of the projects covered in this synthesis, there is a description of the project and the monitoring protocols, presentation of the monitoring results, and discussion of the results, including major conclusions drawn from each project monitoring. Following these project-specific descriptions, a synthesis and summary of the riparian underplanting monitoring is presented, with general conclusions about the effectiveness of specific techniques and approaches.

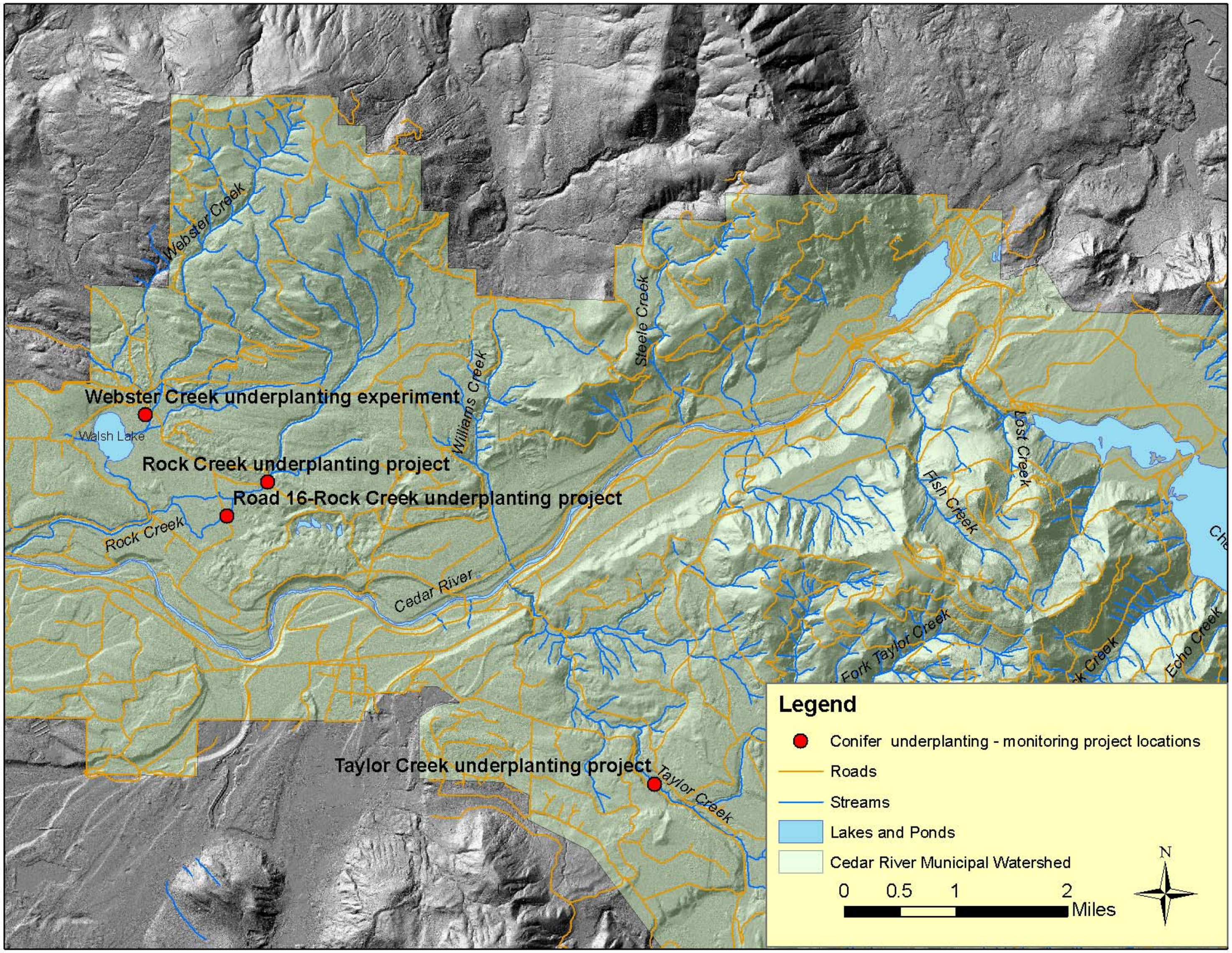


Figure 1. Map of project locations where formal monitoring of riparian conifer underplanting was implemented, 2001-2004.

2 Webster Creek Conifer Underplanting Experiment – 2001

2.1 Description of Project

This project was set up as an experiment to evaluate the effects of two different treatments on the success of conifer underplanting – understory brushing and brushing with tilling (using a rototiller), which were both compared to unbrushed controls. Two species were planted: western redcedar and Sitka spruce. Seedlings were bare root, although size and age of seedlings were not well documented (western redcedar were probably P+1 and Sitka spruce 2+0).

The experiment was set up on the right side of Webster Creek, downstream of the 10 Road crossing about 300 feet. The project area had an overstory dominated by red alder, black cottonwood, and bigleaf maple, with canopy closure varying from about 20 to 90 % across the transects. Canopy closure averaged about 60 %. Understory was dominated by salmonberry and vine maple, with red elderberry also quite common.

Seedlings were planted in transects approximately perpendicular to the stream channel, with ~15 seedlings per transect. Each transect consisted of a single species and treatment. The project was implemented in April 2001, with planting done by the ecosystems staff. Monitoring was initiated in April 2002.

Although we intended to have four transects per species for each clearing treatment (24 transects total), an error during implementation resulted in two brushed and six unbrushed Sitka spruce transects and six brushed and two unbrushed western redcedar transects. This mistake compromised the sample size and balance for statistical analysis, especially with time as mortality further reduced sample sizes. However, with the extra numbers of brushed western redcedar, we were able to evaluate the effects of rebrushing in 2003 (two years following planting), allowing us to examine another variable affecting conifer underplanting success.

In addition, three different browse protection methods were evaluated – (1) a meshed tube commonly used to protect seedlings from browse (Protex browse guard); (2) a triangular, translucent, and solid cone (Sinocast tree cone); and no protection. The three different browse control methods were alternated along each transect.

2.2 Monitoring Protocol

Seedling survival and height were measured in 2002, 2003, 2004, 2005, 2006, and 2009. Survival was considered presence of any evident live stems or branches. Height was measured from the ground to the top of the leader along a straightened stem. Monitoring measurements were made in the spring of each year monitored.

2.3 Monitoring Results

Survival data for the Webster Creek conifer underplanting experiment are shown for each species in Figure 2 for treatment type and in Figure 3 for protection type. Survival data are presented in Tables 1 and 2. Results of a chi-square analysis of survival by treatment type is shown in Table 3 and for protection type in Table 4. Height data for each species by treatment type are shown in Figure 4 and Table 5 and for species by protection type in Figure 5 and Table 6. Results of Analysis of Variance (ANOVA) on species by treatment are shown for 2003 and 2006 in Table 7. ANOVA results for treatment effects in western redcedar alone for 2006 and 2009, including the additional rebrushed treatments, are shown in Table 8. Table 8 also includes results of non-parametric tests on treatment effects in Sitka spruce for 2009 and for differences in height between species for the brushed seedlings only. ANOVA results for effects of protection type for each species in 2003, 2006, and 2009 are presented in Table 9.

2.3.1 Effects of Treatment on Seedling Survival and Growth

The most notable effect of treatment was much lower survival in both species without a clearing treatment (Figure 2, Tables 1, 2). After 8 years (2009), percent survival of seedlings in uncleared transects was 8 and 13 percent, respectively for Sitka spruce and western redcedar. Seedling survival after 8 years for the cleared treatments ranged between 27 and 43 percent. In Sitka spruce, there was significantly lower survival for seedlings in uncleared transects for every year of monitoring, while in western redcedar untreated seedlings had significantly lower survival only for years 2003 through 2006 (Table 3). There were no significant differences in survival between species comparing brushed and brushed/tilled seedlings of each species. Also, survival of the 2003 rebrushed western redcedar seedlings did not differ in any year from the seedlings brushed only once at the beginning of the experiment.

Comparing species, seedling heights among treatments were fairly similar through 2006 (not including the rebrushed treatment that was for cedar only) (Figure 4, Table 5). There were no significant differences in a species x treatment ANOVA for 2003 or 2006 (Table 7, but see below for differences within cedar treatments). Height differences became more apparent in 2009, but statistical comparisons in 2009 were compromised by small sample sizes and unequal variances. However, comparisons of means using a combination of parametric and non-parametric tests provided some basis to evaluate some differences in 2009 height.

A pronounced and significant difference in height of rebrushed western redcedar seedlings compared to other cedar treatment types became apparent in 2006 and 2009 (Table 8). A non-parametric Kruskal-Wallis test of differences among means of Sitka spruce in 2009 also showed a significant effect of treatment on height, with brushed seedlings being the tallest and brushed/tilled seedlings being the shortest. For height in 2009, a comparison of brushed seedlings between species using the non-parametric Mann-Whitney test indicated a significantly greater height of Sitka spruce compared to western redcedar seedlings.

2.3.2 Effects of Protection Type on Seedling Survival and Growth

The tree cone protection type generally had lower survival in both species, especially in Sitka spruce (Figure 3, Table 2). However, there were no significant differences in seedling survival within either species for protection type (browse guard, tree cone, or no protection) for any year (Table 4).

Because mortality through the course of the experiment resulted in small sample sizes for a given protection type and treatment, seedlings from the combined brushed, brushed/tilled, and no treatments were combined to evaluate differences in height among protection types. There were no significant differences in seedling height by species, by protection type, or by species x protection type interaction for 2003, 2006, or 2009 (Table 9).

2.4 Discussion and Conclusions

One of the most informative results of the Webster Creek underplanting experiment was the strong effect of brushing on seedling survival in Sitka spruce, and early in the experiment on western redcedar. Survival of Sitka spruce seedlings was especially sensitive to competition from competing understory plants, with salmonberry the most prominent shrub present in the transects. Although survival of cedar seedlings in 2003 and 2006 was lower in unbrushed transects, by the end of the experiment the positive effect of brushing on cedar survival was not significant (P=0.199). Effects of browsing may have eventually offset any survival benefits provided by brushing. We have no explanation why mortality rate increased from 2006 to 2009 in the brushed western redcedar, although it is possible that browsing pressure was greater during this period leading to higher mortality. Browsing pressure was typically greater in the cleared areas compared to the uncleared areas.

The effect of brushing on height was less clear than that for survival. The initial brushing treatment did not have much of an effect on height in comparison to the unbrushed or brushed/tilled treatments, except for Sitka spruce seedlings in 2009. A non-parameteric Kruskal-Wallis test indicated a significant difference among the treatment and control means for 2009 spruce seedlings, but statistical constraints prevented evaluating the significance of the brushed versus unbrushed means. The 36 cm greater mean height in brushed than in unbrushed spruce seedlings in 2009 does suggest that brushing does have a positive effect on spruce growth, but the 30 cm lower mean height of brushed/tilled spruce seedlings is perplexing (see below for further discussion of this result).

Rebrushing of cedar seedlings, however, did have a pronounced effect on height (though not on survival) in that species. It would have been useful to evaluate the effects of rebrushing on Sitka spruce, but this added treatment was an *ad hoc* modification of the experiment due to the initial error in setting out additional brushed cedar transects, and there was not a sufficient number of brushed seedlings to conduct this experiment for spruce. The greater height in rebrushed cedar seedlings suggests that maintaining a cleared understory is important in the first few years after initial clearing and planting.

Any additional benefit of tilling areas already cleared of understory competition (i.e., brushed) was not evident from the experiment. It is possible that tilling actually conferred a disadvantage to seedling growth, suggested by the significantly lower heights in 2009 of brushed/tilled versus brushed spruce seedlings. Perhaps tilling stimulated more or faster regrowth of understory, but we collected no cover data to test this hypothesis. The small sample size (n=10) of the brushed spruce treatment in 2009 may have skewed the results, if the surviving seedlings in that treatment were especially tall. (Brushed spruce had initially half as many seedlings as unbrushed, the other side of the error in laying out transects that resulted in too many brushed cedar.) That is, the surviving seedlings may have been the tallest, either by chance or because surviving spruce seedlings in brushed transects may have survived because they were tall.

The presence or type of browse protection does not appear to have a substantial effect on either seedling survival or growth. Because browse on western redcedar was very common and appeared to have a major effect on growth of cedar, it was surprising not to see evidence of this in either survival or growth data. It is possible that the tree cone, while better protecting the seedlings (i.e., branches could not be browsed at all, compared to browsing of any branches growing through the mesh in the browse guard), also suppressed growth due to lower light levels or physical constraint, resulting in no net benefit. Browse would certainly seem to reduce growth rate in cedar, as there were major differences in the amount of leaf area in browsed versus unbrowsed cedar. Although Sitka spruce is a faster growing species than western redcedar, the much greater height in brushed Sitka spruce seedlings may be partly because of the lack of any browse effects on it compared to the high amount of browse on cedar.

A general lesson from the Webster Creek underplant experiment is the importance of relatively long-term data. Although it will take decades to know the ultimate effectiveness of each species and each treatment, there were differences in 2009 that were not apparent earlier (e.g., greater height of brushed spruce seedlings), and some differences apparent early in the experiment that disappeared with time (e.g., Sitka spruce vs. western redcedar survival). In terms of monitoring efficiency, monitoring every year does not appear to be a very effective use of monitoring resources, as changes were often small from one year to the next with differences only apparent after several years. A sampling schedule of years 1, 3, 6, and 9 would have yielded results just as informative as sampling in every year. Some maintenance of the experiment was needed, however, and too great of an interval between sampling might make it difficult to track seedlings. A sampling interval of 2-3 years would seem sufficient to maintain the experiment in adequate condition to ensure good data collection.

An inherent problem with this kind of experiment is the substantial and uneven mortality of seedlings, which confounds statistical analysis. The high mortality rate argues for much higher sampling sizes than initially thought to be necessary.

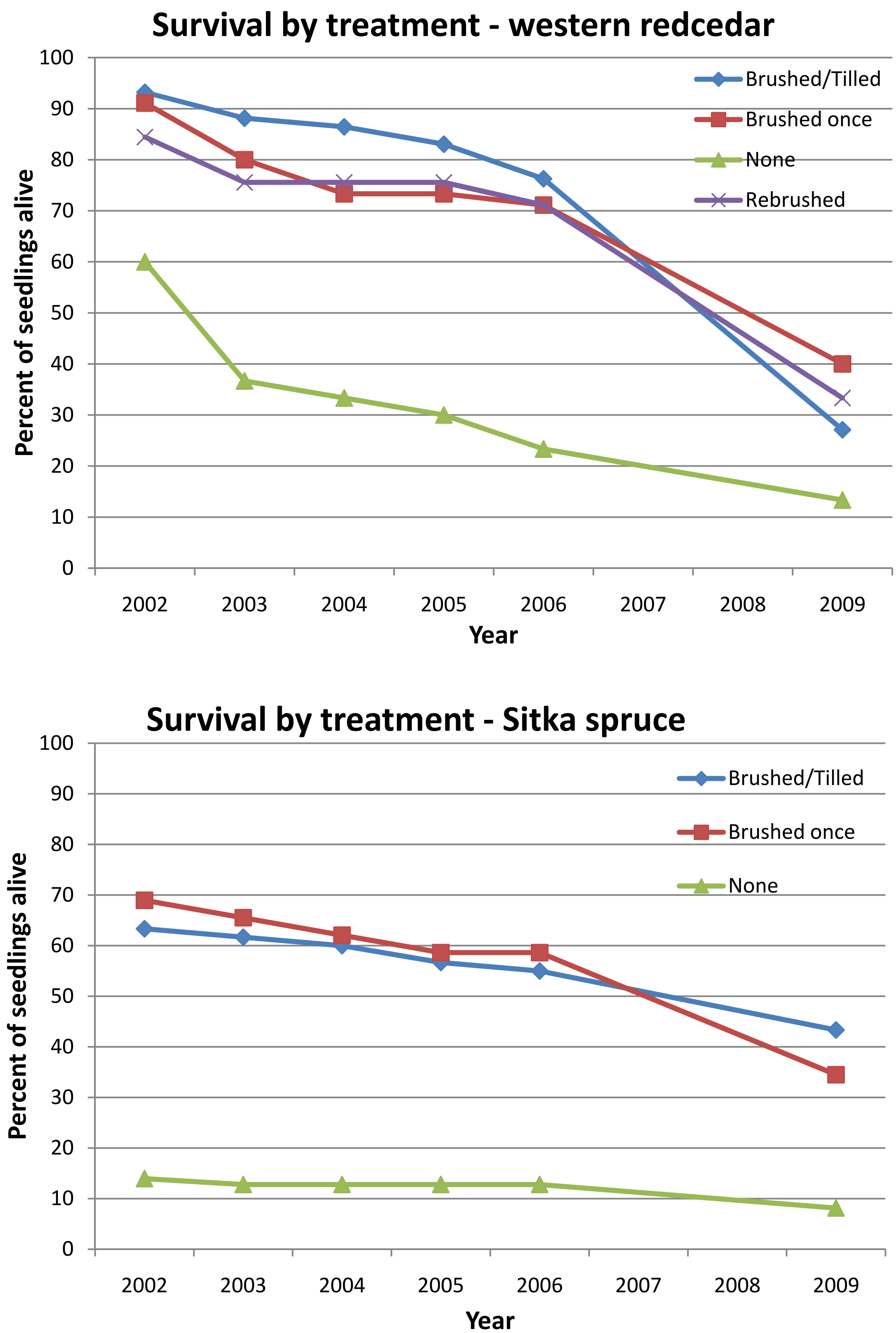
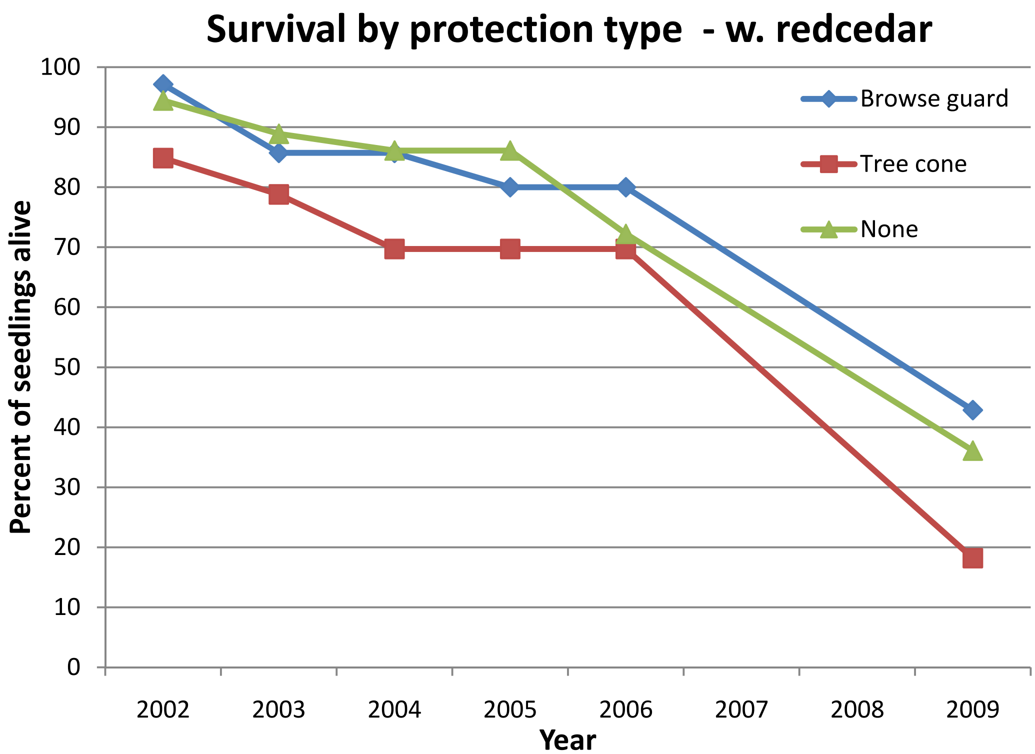


Figure 2. Percent survival of western redcedar (top) and Sitka spruce (bottom) seedlings under different treatments in Webster Creek conifer underplanting experiment.



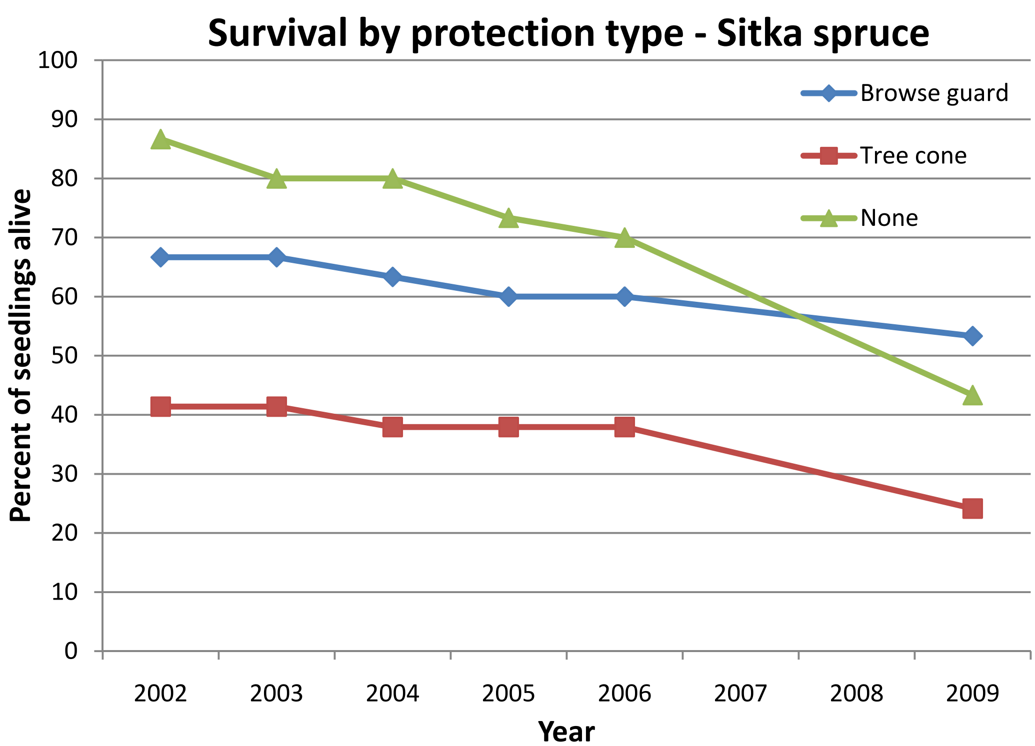


Figure 3. Percent survival of western redcedar (top) and Sitka spruce (bottom) seedlings with different types of browse protection in Webster Creek conifer underplanting experiment. Only seedlings in brushed and brushed/tilled treatments included.

Table 1. Number of surviving seedlings by year, Webster Creek conifer underplanting experiment.

		Total No. Seedlings	Number of seedlings alive					
Western red cedar		**2002**	**2002**	**2003**	**2004**	**2005**	**2006**	**2009**
Brushed/Tilled	None	20	20	20	19	19	15	6
	Browse guard	20	20	19	19	17	17	9
	Tree cone	19	15	13	13	13	13	1
	Subtotal	**59**	**55**	**52**	**51**	**49**	**45**	**16**
Brushed once	None	16	14	12	12	12	11	7
	Browse guard	15	14	11	11	11	11	6
	Tree cone	14	13	13	10	10	10	5
	Subtotal	**45**	**41**	**36**	**33**	**33**	**32**	**18**
None	None	9	7	6	6	5	3	2
	Browse guard	9	3	1	1	1	1	1
	Tree cone	12	8	4	3	3	3	1
	Subtotal	**30**	**18**	**11**	**10**	**9**	**7**	**4**
Rebrushed	None	15	15	14	14	14	12	4
	Browse guard	14	11	10	10	10	10	7
	Tree cone	16	12	10	10	10	10	4
	Subtotal	**45**	**38**	**34**	**34**	**34**	**32**	**15**
Sitka spruce								
Brushed/Tilled	None	21	19	18	18	17	16	10
	Browse guard	20	13	13	13	12	12	12
	Tree cone	19	6	6	5	5	5	4
	Subtotal	**60**	**38**	**37**	**36**	**34**	**33**	**26**
Brushed once	None	9	7	6	6	5	5	3
	Browse guard	10	7	7	6	6	6	4
	Tree cone	10	6	6	6	6	6	3
	Subtotal	**29**	**20**	**19**	**18**	**17**	**17**	**10**
None	None	26	6	6	6	6	6	4
	Browse guard	30	2	2	2	2	2	0
	Tree cone	30	4	3	3	3	3	3
	Subtotal	**86**	**12**	**11**	**11**	**11**	**11**	**7**

Table2. Percentage of surviving seedlings by year, Webster Creek conifer underplanting experiment

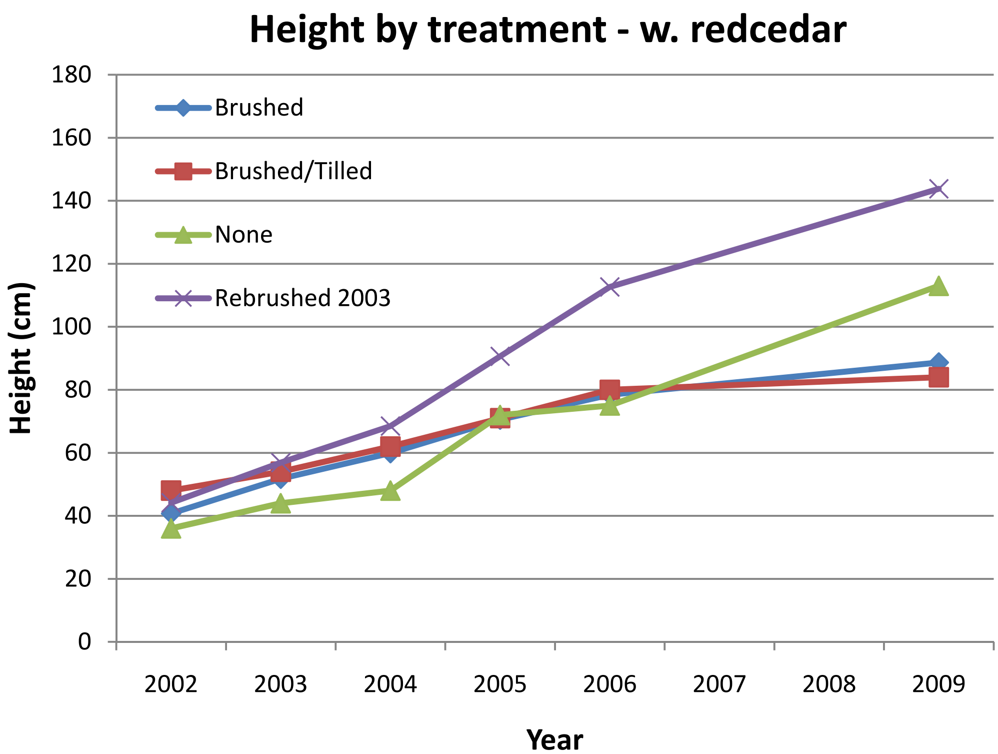
		Percentage of seedlings alive					
Western red cedar		**2002**	**2003**	**2004**	**2005**	**2006**	**2009**
Brushed/Tilled	None	100	100	95	95	75	30
	Browse guard	100	95	95	85	85	45
	Tree cone	79	68	68	63	68	5
	Subtotal	93	88	86	81	76	27
Brushed once	None	88	75	75	75	69	44
	Browse guard	93	73	73	73	73	40
	Tree cone	93	93	71	71	71	36
	Subtotal	91	80	73	73	71	40
None	None	78	67	67	56	33	22
	Browse guard	33	11	11	11	11	11
	Tree cone	67	33	25	25	25	8
	Subtotal	60	37	33	30	23	13
Rebrushed	None	100	93	93	93	80	27
	Browse guard	79	71	71	71	71	50
	Tree cone	75	63	63	63	63	25
	Subtotal	84	76	76	76	71	33
Sitka spruce							
Brushed/Tilled	None	90	86	86	81	76	48
	Browse guard	65	65	65	60	60	60
	Tree cone	32	32	26	26	26	21
	Subtotal	63	62	60	57	55	43
Brushed once	None	78	67	67	56	56	33
	Browse guard	70	70	60	60	60	40
	Tree cone	60	60	60	60	60	30
	Subtotal	69	66	62	59	59	34
None	None	23	23	23	23	23	15
	Browse guard	7	7	7	7	7	0
	Tree cone	13	10	10	10	10	10
	Subtotal	14	13	13	13	13	8

Table 3. Results of chi-square analysis of effects of treatment on survival, Webster Creek conifer underplanting experiment.

	2002	2003	2004	2005	2006	2009
Sitka spruce – all treatments compared						
df	2	2	2	2	2	2
chisquare	32.10	30.27	27.46	23.78	22.73	19.79
P	0.000	0.000	0.000	0.000	0.000	0.000
Western redcedar – all treatments compared						
df	3	3	3	3	3	3
chisquare	2.88	7.44	8.08	8.29	9.71	4.66
P	0.411	0.059	0.044	0.040	0.021	0.199
Western redcedar – brushed once and rebrushed treatments compared						
df	1	1	1	1	1	1
chisquare	0.11	0.06	0.01	0.01	0.00	0.27
P	0.736	0.811	0.903	0.903	1.000	0.602
Sitka spruce vs. western redcedar (brushed + brushed/tilled treatments)						
df	1	1	1	1	1	1
chisquare	4.43	3.03	2.71	2.97	2.32	0.80
P	0.035	0.082	0.100	0.085	0.127	0.372

Table 4. Results of chi-square analysis of effects of protection type on survival, Webster Creek conifer underplanting experiment. Data include combined survival of brushed and brushed/tilled treatments only.

	2002	2003	2004	2005	2006	2009
Western redcedar						
df	2	2	2	2	2	2
chisquare	0.31	0.22	0.73	0.87	0.27	3.36
P	0.858	0.898	0.693	0.649	0.875	0.186
Sitka spruce						
df	2	2	2	2	2	2
chisquare	4.66	3.60	4.35	3.28	2.82	3.20
P	0.097	0.166	0.113	0.194	0.245	0.202



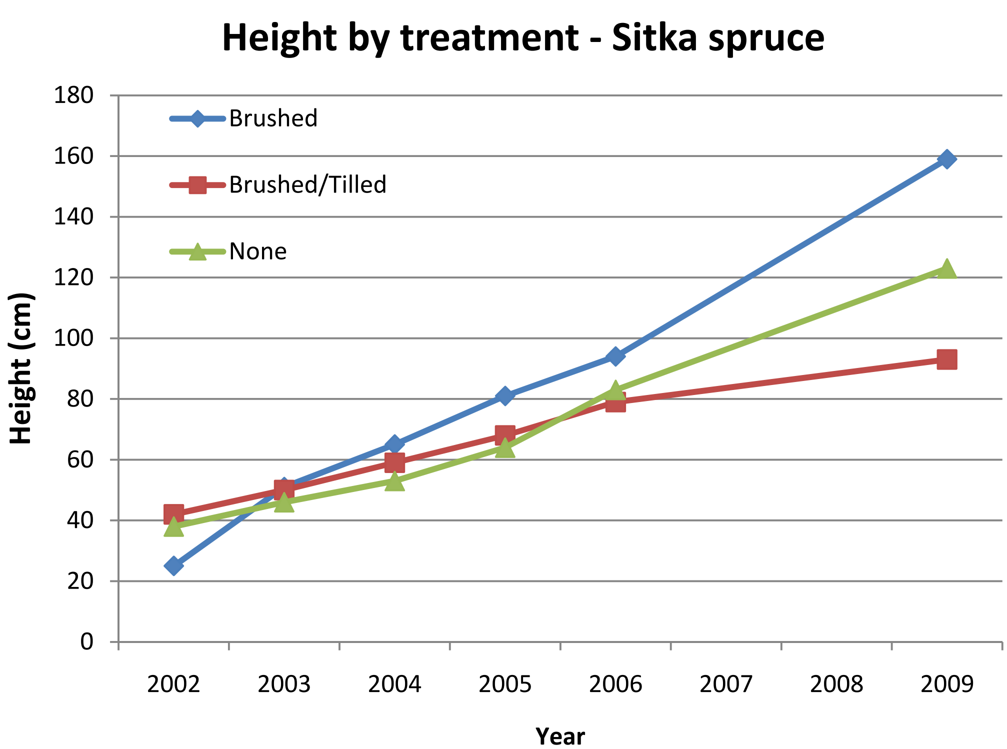
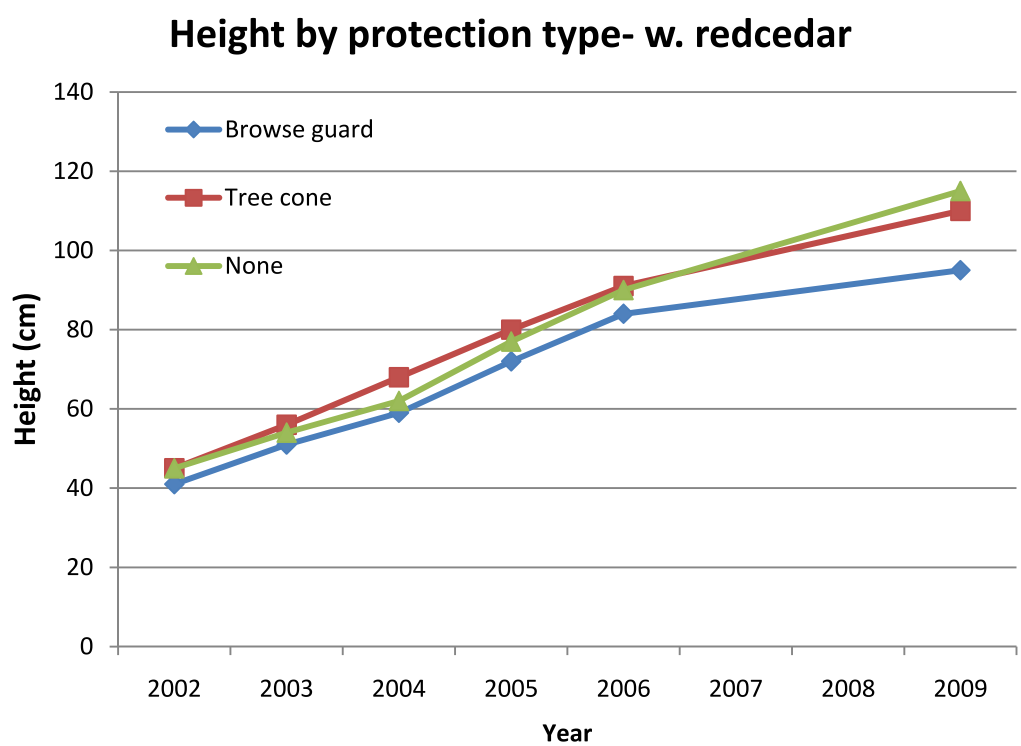


Figure 4. Mean height of western redcedar (top) and Sitka spruce (bottom) seedlings under different treatments in Webster Creek conifer underplanting experiment.



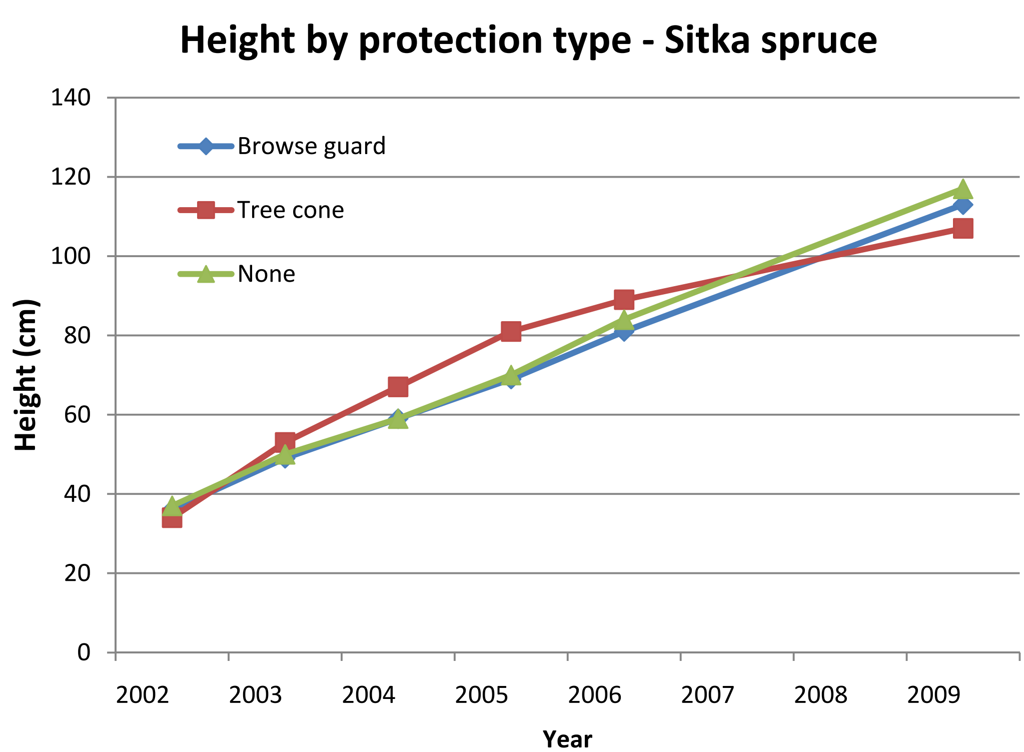


Figure 5. Mean height of western redcedar (top) and Sitka spruce (bottom) seedlings with different types of browse protection in Webster Creek conifer underplanting experiment. Only seedlings in brushed and brushed/tilled treatments included.

Table 5. Height (mean and standard deviation) of Sitka spruce and western redcedar seedlings by treatment, Webster Creek conifer underplanting experiment.

	Brushed		Brushed/Tilled		None		Rebrushed	
	Mean (cm)	SD	Mean (cm)	SD	Mean (cm)	SD	Mean (cm)	SD
Western redcedar								
2002	41	10	48	12	36	9	44	9
2003	52	13	54	14	44	11	57	14
2004	60	15	62	14	48	20	69	20
2005	71	21	71	20	72	35	91	27
2006	78	26	80	24	75	34	113	39
2009	89	26	84	17	113	26	144	56
Sitka spruce								
2002	25	14	42	11	38	18	----	----
2003	51	17	50	16	46	20	----	----
2004	65	22	59	19	53	25	----	----
2005	81	28	68	22	64	29	----	----
2006	94	35	79	29	83	43	----	----
2009	159	89	93	32	123	75	----	----

Table 6. Height of Sitka spruce and western redcedar seedlings by protection type, Webster Creek conifer underplanting experiment. Data are means (and standard deviation) of all seedlings combined in brushed and brushed/tilled treatments only.

	Browse guard		Tree Cone		None	
	Mean (cm)	SD	Mean (cm)	SD	Mean (cm)	SD
Western red cedar						
2002	41	10	45	10	45	13
2003	51	12	56	13	54	15
2004	59	16	68	16	62	18
2005	72	23	80	24	77	25
2006	84	33	91	35	90	31
2009	95	34	110	44	115	52
Sitka spruce						
2002	36	14	34	15	37	16
2003	49	15	53	13	50	19
2004	59	13	67	19	59	26
2005	69	20	81	23	70	29
2006	81	29	89	32	84	37
2009	113	71	107	57	117	60

Table 7. ANOVA results for species x treatment (brushed, brushed/tilled, none) for height of western redcedar and Sitka spruce in 2003 and 2006, Webster Creek conifer underplanting experiment

2003

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Species	11.089	1	11.089	0.051	0.821
Treatment	655.001	2	327.501	1.519	0.222
Species x Treatment	169.432	2	84.716	0.393	0.676
Error	33210.980	154	215.656		

2006

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Species	982.076	1	982.076	1.231	0.269
Treatment	1449.469	2	724.734	0.909	0.406
Species x Treatment	1827.002	2	913.501	1.145	0.321
Error	106874.083	134	797.568		

Table 8. ANOVA for treatment (brushed, brushed-tilled, rebrushed 2003, none) for height of western redcedar alone 2006 and 2009, Webster Creek conifer underplanting experiment. Results of non-parametric tests presented for Sitka spruce, 2009 and western redecedar vs. Sitka spruce (brushed treatment only) below table.

2006 – Western redcedar only

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Treatment	26557.109	3	8852.370	10.158	0.000
Error	97604.089	112	871.465		

2009– Western redcedar only

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Treatment	34227.974	3	11409.325	8.968	0.000
Error	61070.083	48	1272.293		

2009- Sitka spruce height

Sitka spruce for 2009 had unequal variances, which reduces reliability of ANOVA of both species together or of Sitka spruce alone. Non-parametric Kruskal-Wallis test of differences among means for Sitka spruce height (all three treatments) yielded a Kruskal-Wallis test statistic of 7.812 with a probability of 0.020 (2 df). Sample size (n) and ranked sums were: Brushed (10) 285, Brushed/Till (26) 433, and None (3) 62

2009 – Western redcedar vs. Sitka spruce height , brushed seedlings only

Non-parametric Mann-Whitney test of differences between means for western redcedar and Sitka spruce height (seedlings from brushed treatments only) yielded a Mann-Whtiney U test statistic of 136.50 with a probability of 0.026 (1df). Sample size (n) and ranked sums were: western redcedar (18) 214.50 and Sitka spruce (10) 191.5

Table 9. ANOVA results for effects of protection type on height, western redcedar and Sitka spruce (brushed, brushed/tilled and no treatments combined) for 2003, 2006, and 2009, Webster Creek conifer underplanting experiment.

2003- Western redcedar

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Protection type	755.492	2	377.746	2.143	0.123
Error	16741.824	95	176.230		

2006 - Western redcedar

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Protection type	1756.625	2	878.313	1.445	0.242
Error	49237.660	81	607.872		

2009 - Western redcedar

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Protection type	1235.895	2	617.947	1.109	0.341
Error	18943.295	34	557.156		

2003- Sitka spruce

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Protection type	86.423	2	43.211	0.154	0.858
Error	16574.997	59	280.932		

2006- Sitka spruce

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Protection type	395.836	2	197.918	0.181	0.835
Error	58085.146	53	1095.946		

2009- Sitka spruce

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Protection type	2477.682	2	1238.841	0.295	0.746
Error	150991.908	36	4194.220		

3 Road 16/Rock Creek Volunteer Conifer Underplanting – 2002

3.1 Description of Project

This project is located on both sides of the Rock Creek channel north of the now decommissioned Road 16. Approximately 750 cedars and 650 hemlocks were planted on April 20, 2002 by volunteers organized by Friends of the Cedar River and supervised by SPU staff. Seedlings were planted with approximately 10 ft spacing, with locations selected by planter. In addition, there were several logs and stumps on which seedlings were planted in pre-drilled holes or natural cavities.

There is no documentation of the seedling material planted, other than the seedlings were bare root. Since initial heights were generally 40 to 60 cm, they were likely 2 year transplants. A browse guard (Protex mesh tube) was placed over all of the western redcedar seedlings; hemlock seedlings were left unprotected.

The seedlings were planted in a stand dominated by bigleaf maple and red alder, with scattered western hemlock and western redcedar. Canopy closure varied from about 30% to 90% in the project area, and averaged about 70%. Understory was dominated by swordfern, salmonberry, and vine maple.

3.2 Monitoring Protocol

A subset of the planted seedlings was selected for monitoring, with the first monitoring event occurring on July 16, 2002. The start and bearing of five transects each were established along each bank of Rock Creek north of the 16 Road. For each transect, the first two seedlings near the transect start point were chosen for monitoring. Subsequent seedlings were selected by walking on the transect bearing and choosing the nearest two seedlings every fifth step, with a pin flag used to mark each monitored seedlings. When possible, a seedling of each species (hemlock or western redcedar) was selected at each spot. A total of 62 western hemlock and 80 western redcedar were measured on the five transects.

In addition to seedlings monitored on transects, four logs had seedlings planted on them in pre-drilled holes. For the seedlings on each log, an equivalent number of seedlings of the same species were selected in the immediate area to use as controls. Seedlings on and off nurse logs were measured for height. A total of 26 seedlings were measured on/off nurse logs. No browse guards were used on nurse log seedlings or controls. Two of the logs (#2 and #3) were very close to one another and counted together with controls, while the two other logs (#1 and #4) were counted separately, resulting in three sampling groups for seedlings planted on logs.

Seedling survival and height were recorded in 2002, 2003, 2004, and 2010. The 2010 monitoring differed from the previous years in that any seedling found in the planting area was measured and recorded as living. Because of the long interval since the previous monitoring, it was difficult in 2010 to find markers (pin flags) for monitored seedlings to sample the same seedlings monitored in previous years. As a result, the seedlings found in 2010 were considered as a percentage of the total number of seedlings planted, rather than as a percentage of the sample selected for monitoring during 2002 to 2004. It is possible that some surviving seedlings were not found in the 2010 monitoring, which would mean an underestimate of seedling survival.

3.3 Monitoring Results

Seedling survival was similar in both species over the entire nine year monitoring period (Figure 6, Table 10). After two years, survival was 42 and 49 percent for western hemlock and western redcedar, respectively. By 2010, the survival was only 4 percent for both species. Although sample size of seedlings on logs was very small, there was no indication that survival on logs was beneficial, as all seedlings on logs had died by 2010.

Mean height of seedlings did not change appreciably for the first two years after planting (Figure 7, Table 11). In part this was due to reduced height of many seedlings as a result of browsing, which offset increases in height of unbrowsed seedlings. By 2010, however, height of hemlock seedlings had increased substantially and was significantly higher than that of cedar seedlings (based on non-parametric Mann-Whitney U test [due to unequal variances] with $P = 0.000$). Average height of hemlock seedlings was 137 cm compared to 70 cm for cedar seedlings. Cedar seedlings in 2010 were mostly still growing within the mesh browse guards, and typically had few unbrowsed branches outside of the mesh. In addition, the mesh had often fallen or been pushed to the ground by falling debris, resulting in the seedling being forced to grow in a nearly horizontal position. No hemlock seedlings in 2010 had signs of browse.

3.4 Discussion and Conclusions

Although the 16 Road-Rock Creek conifer underplanting project was not designed or implemented as an experiment, monitoring of seedling survival provided valuable information about the project's effectiveness. First, seedling survival was very low in both species due to a variety of factors. Factors contributing to low survival included browse, potentially poor planting technique by volunteers, understory competition, blowdown, and the negative effect of browse guards (on cedar seedlings). Browse occurred in both species, but was not pervasive except in cedar seedlings in 2010. Relatively low vigor or a dead leader in many seedlings by 2003 suggests that poor planting technique may have contributed to mortality over the first year. The presence of understory and overstory competition was variable but also likely reduced growth and may have made seedlings more susceptible to stress. Some seedlings were knocked down or buried by falling branches, particularly in a severe windstorm in January 2003, contributing to seedling mortality. Falling debris and failure of the supporting wood stick caused many of the browse guards to be knocked over, which results in the enclosed cedar seedlings having reduced light levels and even more competition from understory.

With respect to the percentage of seedlings that will survive and grow to maturity, the effectiveness of the project was quite low. With respect to overall effectiveness, however, the project did result in the establishment of 26 generally healthy hemlock seedlings averaging almost 1.5 meters in height over a several acre area. I would expect that at least some of these seedlings will grow to maturity and contribute to the conifer component of the riparian area along this reach of Rock Creek. I would expect few, if any, of the cedars to eventually reach maturity, primarily due to continued browse that prevents the seedlings from ever reaching a level above the understory. Lack of maintenance of the browse protection may also have contributed to lower survival and growth, as seedlings in browse guards that were knocked over were in a lower light environment and had difficulty maintaining vertical growth. The marginal interim success of this project suggests that conifer underplanting without effective understory treatment, maintenance of browse guards, or browse control (for redcedar) for the first few years is not likely to contribute many conifer trees to a deciduous dominated riparian stand.

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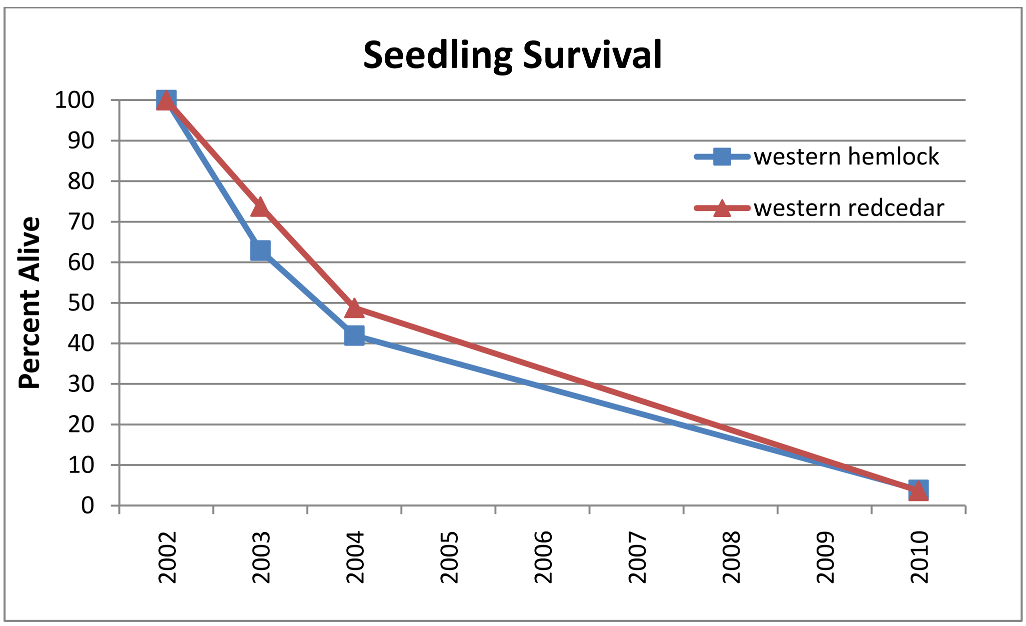

Figure 6. Percent survival of western hemlock and western redcedar seedlings, 2002-2010, 16 Road-Rock Creek conifer underplanting project.

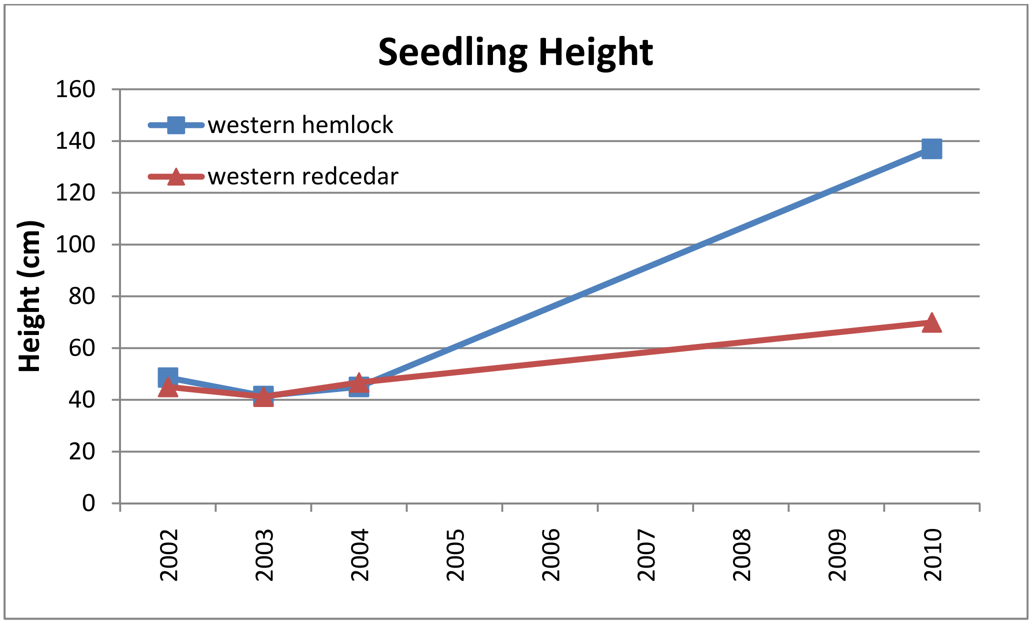

Figure 7. Mean height of western hemlock and western redcedar seedlings, 2002-2010, 16 Road-Rock Creek conifer underplanting project.

Table 10. Number and percent alive of seedlings in 2002 Road 16-Rock Creek conifer underplanting project.

	Number alive		Percent alive*	
	western hemlock	**western redcedar**	**western hemlock**	**western redcedar**
2002	62	80	100	100
2003	39	59	63	74
2004	26	39	42	49
2010	24	27	4	4

*Percent alive in 2002-2004 based on percent of monitored seedlings; percent in 2010 based on percent of total seedlings planted.

Table 11. Mean and standard deviation of seedling height, Road 16-Rock Creek conifer underplanting project.

	western hemlock		western redcedar	
	Mean (cm)	**SD**	**Mean (cm)**	**SD**
2002	48.6	11.9	45.0	8.0
2003	41.5	15.9	41.2	10.4
2004	45.0	15.4	46.7	12.5
2010	137.0	45.1	69.9	18.6

Table 12. Number of surviving seedlings planted next to (off log) and within predrilled holes in logs (on log), Road 16-Rock Creek conifer underplanting project.

	Number of surviving seedlings			
	western hemlock		**western redcedar**	
	Off log	**On log**	**Off log**	**On log**
2002	8	8	5	5
2003	4	5	3	4
2004	4	4	2	4
2010	1	0	0	0

Table 13. Height of surviving seedlings planted next to (off log) and within predrilled holes in logs (on log), Road 16-Rock Creek conifer underplanting project.

	Mean seedling height (cm)			
	western hemlock		**western redcedar**	
	Off log	**On log**	**Off log**	**On log**
2002	46	51	40	52
2003	44	48	31	39
2004	48	59	41	41
2010	140	---	---	---

4 Taylor Creek Conifer Underplanting Pilot Project – 2003

4.1 Description of Project

The Taylor Creek conifer underplanting project was one of three pilot projects in riparian areas along Taylor Creek, which also included a restoration thinning of a dense grand fir stand and conifer release within a mixed conifer/alder stand. This monitoring report addresses the underplanting project only.

The project was located on the left bank of Taylor Creek below the now decommissioned 80 Road, about 0.5 miles east of the junction of the 80 and 82 roads (See Figure 1). The area was on the Taylor Creek floodplain characterized by a fairly open stand of red alder and a dense understory consisting mostly of salmonberry, with some red elderberry, vine maple, and other species. Canopy closure was 30-40%. Four areas approximately 30 feet in diameter were cleared of understory (brushing only) and each planted with between 9 and 11 conifers. Species planted were Sitka spruce (20 seedlings), western redcedar (12 seedlings), and western hemlock (six seedlings). Seedlings used as planting stock were rooted in two gallon containers. The understory was recleared in April, 2009 (2009 monitoring occurred in August), as there was substantial understory regrowth since the initial clearing in 2003. No browse protection was used.

4.2 Monitoring Protocol

Sampling consisted of tagging each seedling and measuring its height and caliper (diameter). Height was measured to the nearest centimeter with a tape measure; caliper was measured at the base of the seedling to the nearest half millimeter with a pair of calipers. Notes about vigor, browsing, and growth were also made.

Photographs were taken in 2003 during implementation and during each monitoring. Two photographs of each of the four cleared areas were taken, one from the upstream and one from the downstream side, looking from the edge into the cleared and planted area.

4.3 Monitoring Results

Seedling survival was relatively high, with only six out of 38 seedlings dying (two for each species) (Figure 8, Table 14). Growth was substantial, with mean seedling height reaching almost 2.5 meters in western hemlock and Sitka spruce after six years of growth (Figure 9, Table 15). One Sitka spruce seedling was over 4 meters in height in 2009. Seedling caliper (the diameter of the stem at the base) did not increase much at first, but after six years increased substantially in Sitka spruce and western hemlock (Figure 10, Table 16). Increase in caliper of western redcedar, in contrast, was much less.

Growth of western hemlock for the first year was reduced due to browsing of leaders (probably by mountain beavers), but after the first year, hemlock growth rate exceeded that of the other species. After the first year, browsing of hemlock was less. In contrast, western redcedar suffered browse damage throughout the six years of monitoring. Although Sitka spruce was not browsed, several spruce seedlings were heavily damaged in 2006 by deer and/or elk rubbing their antlers on the stem, which sometimes resulted in girdling of the stem. The girdled spruce would then send up a new leader, but growth of the seedling was hampered until the leader could catch up to the previous leader height. Also, dead leaders of Sitka spruce were evident in 2009 and may be due to damage caused by Sitka spruce weevil (*Pissodes sitchensis*), which is known to cause leader death.

4.4 Discussion and Conclusions

Results through 2009 from monitoring seedling survival and growth in the 2003 Taylor Creek conifer underplanting pilot project are very encouraging. It appears that using larger, potted seedlings resulted in little seedling mortality and relatively rapid growth. After six years of growth, both western hemlock and Sitka spruce were at about the same height as the surrounding understory and less vulnerable to competitive inhibition of growth by understory shrubs. Initial larger size of the seedlings plays an important role in how rapid conifer seedlings escape understory competition. With the same relative growth rate, a seedling 1.0 meter tall when planted, for example, will reach two meters in half the time a seedling starting out at 0.5 meter tall. The relatively open canopy of the Taylor Creek site, compared to the Webster Creek and Rock Creek/Road 16 sites, may also contributed to faster seedling growth.

Regrowth of the understory in the 2003 Taylor Creek planting areas was substantial by 2008 and may have been hindering conifer seedling growth at that time. Understory was re-cleared in 2009, but probably should have been done a year to two years earlier to get maximum seedling growth. Since seedling height is approaching that of the surrounding understory, another re-clearing is not likely to be necessary. Thus, one re-clearing about four to five years after planting would seem to be appropriate for the site conditions and planting stock (two gallon seedlings) used at Taylor Creek.

Animal damage was the most significant factor causing seedling mortality and reducing growth, although a tree falling in one planting area also killed two seedlings. No browse protection was incorporated into the project design.

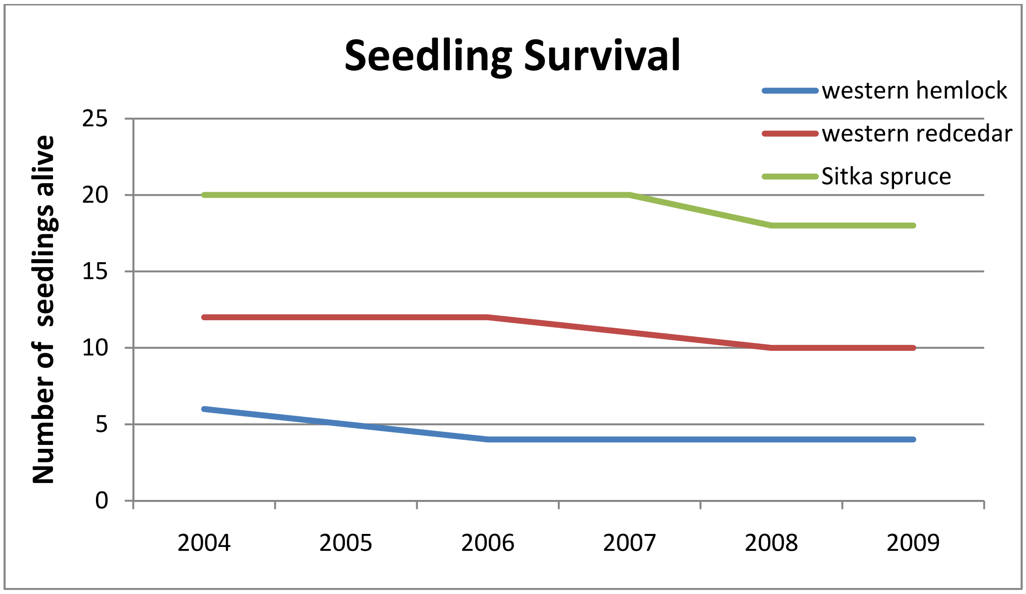

Figure 8. Percent survival of western hemlock and western redcedar seedlings 2004 -2009, 2003 Taylor Creek conifer underplanting project.

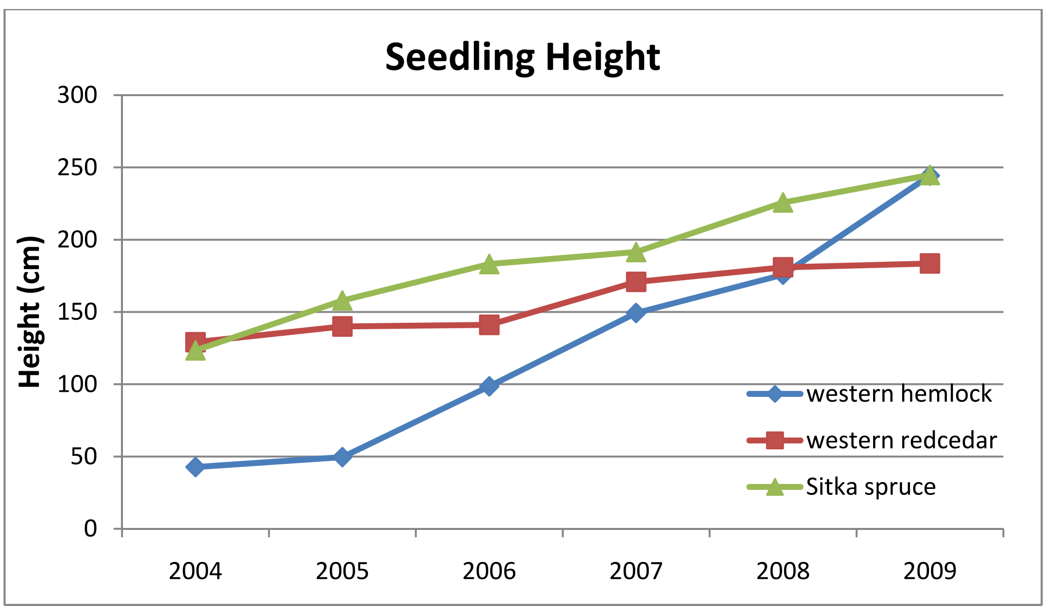

Figure 9. Mean height of western hemlock and western redcedar seedlings 2004 -2009, 2003 Taylor Creek conifer underplanting project.

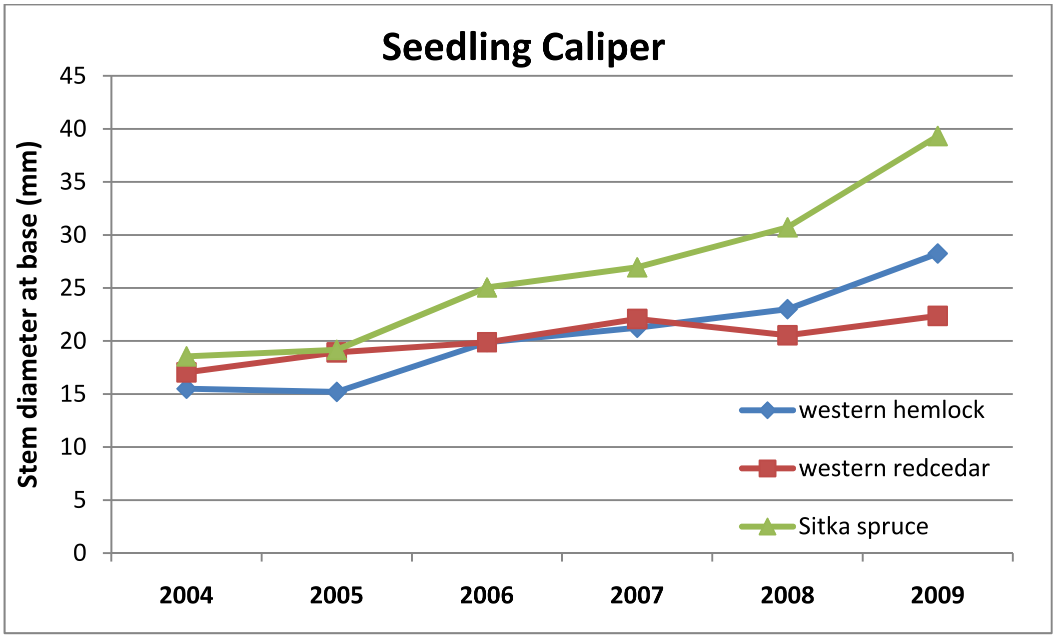

Figure 10. Mean caliper (stem diameter at base) of western hemlock and western redcedar seedlings 2004 -2009, 2003 Taylor Creek conifer underplanting project.

Table 14. Number and percent alive of seedlings in 2003 Taylor Creek conifer underplanting project.

	Number alive			Percent alive		
	western hemlock	western redcedar	Sitka spruce	western hemlock	western redcedar	Sitka spruce
2004	6	12	20	100	100	100
2005	5	12	20	83	100	100
2006	4	12	20	67	100	100
2007	4	11	20	67	92	100
2008	4	10	18	67	83	90
2009	4	10	18	67	83	90

Table 15. Mean and standard deviation of seedling height in 2003 Taylor Creek conifer underplanting project.

	western hemlock		western redcedar		Sitka spruce	
	Mean (cm)	SD	Mean (cm)	SD	Mean (cm)	SD
2004	43	23	129	13	123	8
2005	50	19	140	24	158	12
2006	99	16	141	34	183	59
2007	149	30	171	29	191	79
2008	176	45	181	43	226	86
2009	244	38	184	44	245	95

Table 16. Mean and standard deviation of seedling caliper (stem diameter at base) in 2003 Taylor Creek conifer underplanting project.

	western hemlock		western redcedar		Sitka spruce	
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD
2004	16	3	17	3	19	2
2005	15	2	19	4	19	2
2006	20	2	20	4	25	4
2007	21	2	22	4	27	4
2008	23	5	21	5	31	9
2009	28	6	22	4	39	15

5 Rock Creek Conifer Underplanting – 2004

5.1 Description of Project

The conifer underplanting at Rock Creek was implemented in conjunction with a large woody debris (LWD) addition just upstream of the 10 Road crossing (Figure 1). The site had dense understory of mostly salmonberry, with lesser amounts of red elderberry and devil's club. The overstory was dominated by alder, but the canopy was moderately open (30-40% closure). Four underplanting areas were monitored:

- An 800 ft^2 area near the stream within the floodplain that was impacted by yarding of logs for the LWD project and subsequently cleared of remaining understory;
- A 700 ft^2 area within the Rock Creek floodplain about 60 feet away from the stream that was manually cleared of all understory;
- A 2,800 ft^2 area within the Rock Creek floodplain about 90 feet away from the stream that was manually cleared of all understory; and
- A 400 ft^2 cleared area along a large down log, which had seedlings planted in holes dug into the decaying log.

Seedlings planted were from 2 gallon containers, except for the ones planted on the log, which were from 1 gallon containers, Species planted included western redcedar, Sitka spruce, grand fir, and black cottonwood. Understory vegetation in the plots was re-cleared in May 2009 (2009 monitoring in August). No browse protection was placed on any of the seedlings.

5.2 Monitoring Protocol

Seedlings to be monitored were marked with tags identifying each tree by number. Survival and height of each marked seedling were monitored during the summers of 2005 through 2009.

5.3 Monitoring Results

As in the 2003 Taylor Creek project, mortality of planted seedlings was less than 50 percent through the five year monitoring period (Figure 11, Table 17). Black cottonwood and grand fir had the lowest survival, with much of the mortality in black cottonwood due to a flood event in winter of 2006-2007. Sitka spruce and cottonwood attained the greatest height over the five years of monitoring, with mean heights of 2.8 and 3.3 meters, respectively, in 2009 (Figure 12, Table 18). Sitka spruce, however, had the greatest gain in height, as initial heights of cottonwood seedlings were much taller. Western redcedar and grand fir showed little gain in height from 2005-2009. However, the two cedar seedlings planted on the log were substantially taller (mean of 192 cm) than those in cleared plots (mean of 121 cm). Height of spruce seedlings growing on the log was somewhat lower compared to seedlings in the cleared plots (251 and 278 cm, respectively).

Western redcedar was the only species that showed significant animal damage, with nearly all seedlings heavily browsed. The only exception was that the two cedar seedlings on the log did not show browse damage. The browsed seedlings had reduced leaf area, which undoubtedly contributed to low growth rates. Although cottonwood showed substantial growth, the seedlings were generally spindly and often leaning. Most of the cottonwood trees were not adding substantial leaf area and generally did not appear vigorous until 2008 to 2009. Grand fir had relatively slow growth throughout the five year monitoring period, but did not appear unhealthy until 2008-2009, when many seedlings developed a chlorotic appearance. Sitka spruce seedlings generally looked healthy throughout the monitoring period.

5.4 Discussion and Conclusions

The relatively high survival and growth for some species in the 2004 Rock Creek conifer underplanting project indicates that the treatment at this site was generally effective in getting conifer seedlings established in a salmonberry-alder dominated sites. The level of success (and treatment design) was similar to that of the 2003 Taylor Creek project, although there were some differences in species planted in the two projects.

Except for western red cedar, the Rock Creek project had much less animal damage than the Taylor Creek project, however. As at all of the underplanting project sites, the browsed cedar seedlings led to reduced leaf area, which undoubtedly contributed to its low growth rates. The taller, unbrowsed redcedar on the logs at Rock Creek suggests that browsing does have a strong effect on height growth. Seedlings on logs benefited from being in an uncleared area where elk are less likely to enter and were also in an elevated planting location that may also contribute to less likelihood of browsing.

Sitka spruce grew well, and unlike the spruce at Taylor Creek, did not suffer debarking from deer or elk rubbing their antlers. There was also no evidence of dead leaders in the Rock Creek spruce seedlings, which resulted from possible weevil infestations at the Taylor Creek site.

Black cottonwood grew well in height, but the young trees appeared very different than those that occur from natural establishment. This difference reflects an apparent high height to diameter ratio in the planted seedlings, which could be due either to early growth pattern in the nursery or to conditions at the planting site. Since the spindly appearance of cottonwood was present early after planting, it seems likely that this growth pattern is a characteristic of the particular plant material obtained from the nursery, stemming from either genetic origin or growing conditions or both.

The reasons for the low growth rate and later unhealthy condition of the grand fir are not clear. Since it is relatively shade tolerant, the moderately open canopy where it was planted would not seem to severely limit its growth. The floodplain location had high soil moisture and likely has good nutrient status. There was no obvious insect damage in the grand fir seedlings, but it is possible that the chlorotic condition was due to stress from either insect or pathogen infection.

In summary, the results of 2004 Rock Creek conifer underplanting corroborate those of the 2003 Taylor Creek project in showing that cleared patches planted with larger conifer seedlings (and cottonwood seedlings at Rock Creek) from containers is an effective technique for getting conifer established in alder-salmonberry stands.

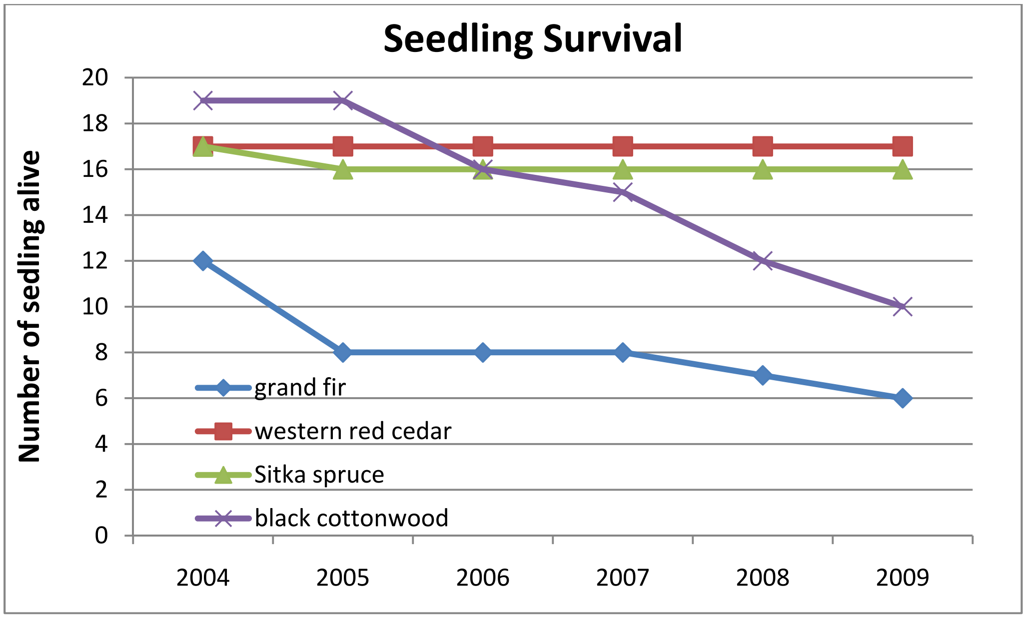

Figure 11. Number of surviving seedlings of three conifer species and one deciduous species 2005 -2009, 2004 Rock Creek conifer underplanting project.

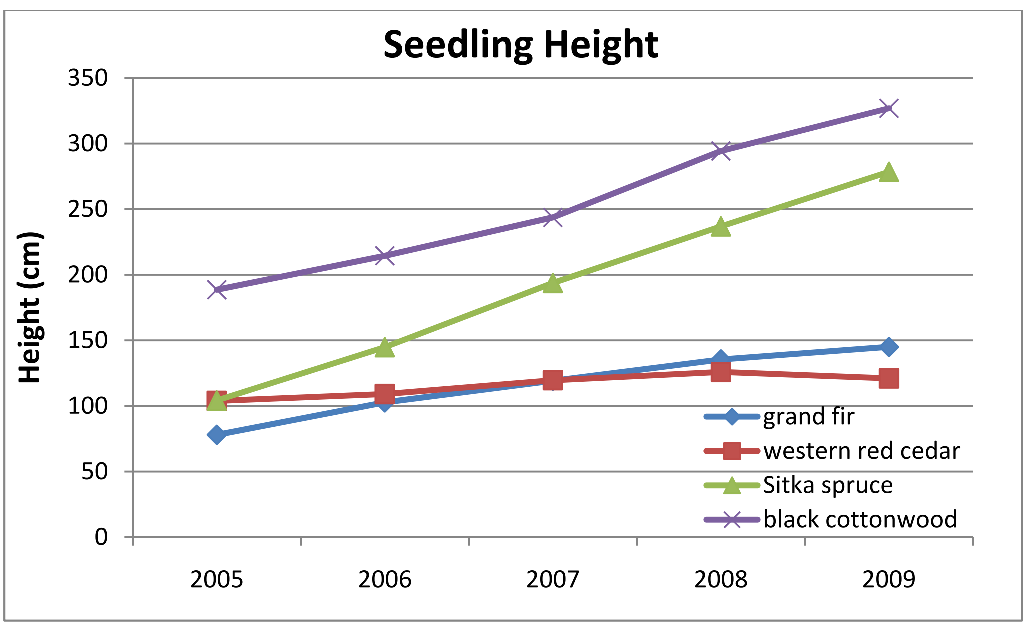

Figure 12. Mean height of seedlings of three conifer species and one deciduous species 2005 -2009,

2004 Rock Creek conifer underplanting project.

Table 17. Number and percent alive of seedlings in 2004 Rock Creek conifer underplanting project.

	Number Alive				Percent Alive			
	grand fir	western red cedar	Sitka spruce	black cottonwood	grand fir	western red cedar	Sitka spruce	black cottonwood
2004	12	17	17	19	100	100	100	100
2005	8	17	16	19	67	100	94	100
2006	8	17	16	16	67	100	94	84
2007	8	17	16	15	67	100	94	79
2008	7	17	16	12	58	100	94	63
2009	6	17	16	10	50	100	94	53

Table 18. Mean and standard deviation of seedling height in 2004 Rock Creek conifer underplanting project.

	grand fir		western red cedar		Sitka spruce		black cottonwood	
	Mean (cm)	SD	Mean (cm)	SD	Mean (cm)	SD	Mean (cm)	SD
2005	78	14	104	16	104	27	189	27
2006	103	16	109	16	145	19	215	29
2007	119	15	120	24	194	37	244	58
2008	135	20	126	29	237	56	294	106
2009	145	19	121	29	278	74	327	136

6 Conclusions and Summary

The projects summarized here included a variety of techniques and species used to establish conifer seedlings (and in some cases cottonwood seedlings) in deciduous-shrub dominated riparian stands that presently have little or no conifer component. Five interacting characteristics of riparian conifer underplanting projects appear to strongly affect outcome and success: understory clearing, overstory canopy closure, initial size of seedlings, animal damage, and species selection.

6.1 Understory Clearing and Overstory Effects

Understory clearing was part of the project design in three of the four projects. For those species that were grown in both cleared and uncleared conditions, survival was generally much higher when understory was cleared (Table 19). For example, Sitka spruce survival rates in uncleared areas ranged from 4 to 8 percent, while survival in uncleared areas ranged from 34 to 94 percent. For western redcedar, survival in uncleared areas was 4 to13 percent, compared to 33 to 100 percent in cleared areas. For western hemlock, there was 4 and 67 percent survival in uncleared and cleared areas, respectively. Although these comparisons include vastly different sample sizes and different monitoring periods, the strong and consistent differences in survival are good evidence that clearing has a major positive effect on seedling survival for both moderately shade-tolerant (e.g., Sitka spruce) and shade tolerant (e.g., western hemlock, western redcedar) species. However, one caveat is that by the end of the monitoring at Webster Creek, percent survival was not significantly different in western redcedar between uncleared and cleared treatments, which may be due to confounding effects of heavy browsing.

Clearing also had an apparent effect on growth rate for Sitka spruce and western hemlock (Table 19). Although sample size of spruce seedlings in uncleared transects was small (n=3) by the end of the monitoring period in the Webster Creek experiment, growth rate in uncleared ("unbrushed") spruce was 12 cm/year compared to 17 cm/year in spruce growing in cleared areas. Comparing hemlock in cleared (Taylor Creek) to uncleared (16 Rd-Rock Creek) areas, growth was much higher in the cleared areas (40 and 13 cm/year, respectively, in cleared and uncleared areas). The pervasive and confounding effects of browse in western redcedar obscure patterns in growth rate as a function of clearing treatment for that species. However, the significantly greater height in rebrushed cedar seedlings at Webster Creek compared to those brushed only just before planting suggests that reclearing understory is beneficial to seedling growth.

Because none of the projects included overstory clearing, shading by the overstory likely reduced growth rates of seedlings to some degree. In three of the projects, however, the planting sites were selected to be in more open locations or had substantial areas where the canopy was relatively open (< 50% closure); the 16 Road-Rock Creek project had somewhat higher canopy closure. Higher canopy closure at the 16 Road-Rock Creek site may have contributed to the overall lower survival in that project. The projects did not include overstory clearing in order to reduce costs and impacts and allow successional processes in the sites to proceed more naturally. Since the deciduous trees in the project sites tended to be older (> 50 years), the alder component of the stands were beginning to senesce, which will likely lead to more open canopy in these sites within 20 to 30 years. However, conifer underplanting projects without overstory treatment in sites where canopy closure is higher (>70%) may have only marginal success.

Reasonable conclusions regarding the effects of understory clearing and canopy closure on conifer underplanting project success include the following:

- Clearing has a substantial effect on survival for both moderately shade-tolerant species like Sitka spruce and shade tolerant species like western hemlock.
- Results suggest that clearing also increases growth rate in both moderately shade tolerant (spruce) and shade tolerant (hemlock) species, although this conclusion is based on very limited data.
- Maintenance of clearing ("rebrushing") appears to have a positive effect on growth in western red cedar.
- Without thinning of overstory trees, conifer underplanting projects should be located in sites where canopy closure is 60% or less.

Table 19. Comparison of growth rate and survival among species, sites, and treatments at four different riparian conifer underplanting projects in the Cedar River Municipal Watershed.

Species/site	Site clearing	Animal damage common	Initial height (cm)	End height (cm)	Number of years	Growth rate (cm/yr)	Percent survival
Sitka spruce							
Webster Creek-unbrushed	No	No	38	123	7	12	8
Webster Creek-brushed	Yes	No	25	159	7	19	34
Taylor Creek	Yes	Yes	123	245	5	17	90
Rock Creek	Yes	No	104	278	4	44	94
western hemlock							
16 Rd.-Rock Creek	No	Some	49	137	7	13	4
Taylor Creek	Yes	year 1 only	43	244	5	40	67
western redcedar							
Webster Creek-unbrushed	No	Yes	36	113	7	11	13
Webster Creek-brushed	Yes	Yes	41	89	7	7	40
Webster Creek-rebrushed	Yes	Yes	44	144	7	14	33
16 Rd.-Rock Creek	No	Yes	45	70	7	4	4
Taylor Creek	Yes	Yes	129	184	5	11	83
Rock Creek	Yes	Yes	104	121	4	4	100
black cottonwood							
Rock Creek	Yes	No	189	327	4	35	53
grand fir							
Rock Creek	Yes	No	78	145	4	17	50

6.2 Initial Size of Seedlings

Seedling size at time of planting appears to affect both survival and growth rate of seedlings. In cleared sites and where there was not significant animal damage, comparison of bare root versus larger container stock within a species showed higher survival in larger Sitka spruce (Webster Creek –brushed vs. Rock Creek) and western hemlock (16 Rd-Rock Creek vs. Taylor Creek) seedlings (Table 19). Survival of Sitka spruce seedlings planted from 2 gallon containers at Rock Creek was 94 percent compared to 34 percent for bare root seedlings planted at Webster Creek. Although western hemlock seedlings in two gallon containers planted at Taylor Creek were about the same height at the bare root seedlings planted at 16 Rd-Rock Creek, they had much higher survival (67 vs. 4 percent alive). Growth rate was also more than twice as great in seedlings of both spruce and hemlock planted from two gallon containers versus those planted as bare root stock.

As with examining the effects of clearing, data to make comparisons of the effects of planting stock are limited and sample sizes of some projects quite small (e.g., Taylor Creek and Rock Creek). However, the consistent and strong differences in both survival and growth suggest that seedlings from two gallon container stock do much better than those from bare root stock.

6.3 Animal Damage

Browsing clearly has a strong negative effect on growth rate of western redcedar seedlings. In every project, most of the cedar seedlings were browsed heavily at some point during and often throughout the monitoring period. However, effect of browsing on survival is not clear, as cedar survival was comparable to other species that were not browsed. Both black-tailed deer and Rocky Mountain elk are active in the project areas and are likely responsible for the browse damage observed in western redcedar seedlings. Only a few western redcedar seedlings escaped browse damage in any of the projects (e.g., those on some logs at Rock Creek). Although western redcedar is a highly desirable species in the watershed, especially in riparian areas where it has the potential to become long lasting large woody debris, the consistent lack of success in getting this species to grow indicates that more effective browse control methods are needed if this species is to be successful in riparian underplanting projects. A project to evaluate different browse control methods for western redcedar was initiated in 2010, which included a larger, more robust exclosure made out of 16 gage wire fencing. This type of browse control structure has proved to be successful in several projects in British Columbia.

Some animal damage was also present in Sitka spruce and western hemlock. As described in section 4, spruce seedlings at Taylor Creek were damaged by elk or deer rubbing their antlers on the young stems, which usually occurred when the seedlings got to be about 1.5 to 2.0 meters tall. The seedlings initiated a new leader below the girdled stem and again grew quite vigorously, despite being set back by the damage. This kind of damage on spruce has been observed elsewhere in the watershed in conifer underplanting projects, and is sometimes fatal to the seedling. The occurrence is episodic, and if the seedling is not killed, results in only a temporary reduction in seedling growth. Another potential source of animal damage for Sitka spruce seedlings is Sitka spruce weevil, which attacks the growing leader and was evident at Taylor Creek. Although the plant initiates a new leader, continued attack by the weevil will clearly reduce growth rate and lead to a bushy growth form.

Stems of several western hemlock at Taylor Creek were clipped below the leader, which is characteristic of mountain beaver. Whatever the source of the browse, most of the seedlings recovered and eventually put on substantial growth.

Browse protection used in two of the projects (Webster Creek and 16 Rd.-Rock Creek) appeared to provide little benefit to seedlings. The experiment at Webster Creek showed no advantage to using either mesh tubes (browse guard) or solid, translucent cones (Sinocast tree cone). Although branches within the mesh Protex browse guard are not subject to browse, browsing of branches outside of the mesh still reduced leaf area substantially and fallen browse guards often restricted vertical growth of seedlings. The Sinocast tree cones constrained branch growth and may have reduced light levels significantly.

6.4 Species Selection

The variety of species used in the four projects summarized here offer some insight into which species have the greatest chance of survival and growth to a size where the seedlings have escaped understory competition. With respect to potential for successful establishment and strong growth, I would rank the species in the following order: Sitka spruce, western hemlock, black cottonwood, western redcedar, and grand fir.

Of all the species planted, Sitka spruce offers the greatest likelihood of high survival and growth rate when planted from container stock and in cleared areas Although vulnerable to animal damage from deer/elk and weevils, the frequency of damage is relatively low. Western hemlock was planted in only two projects, but had high growth rate and good survival at Rock Creek when planted in cleared areas, despite some animal damage. Black cottonwood had high growth rate, but spindly stems made it susceptible to physical damage. Perhaps different planting stock would provide a stronger stem structure. Western redcedar was consistently browsed heavily, which reduced growth markedly, although survival was not always affected. Unless effective browse control methods are found, cedar does not appear to be an effective species for use in conifer underplanting projects in the watershed in riparian habitats, where deer and elk browsing pressure is high. Grand fir was only evaluated at one site (Rock Creek), but did not grow well. Although present in many riparian areas in the watershed, more trials are needed to determine an effective technique for getting it established successfully.

6.5 Summary

This report synthesized monitoring data on four riparian underplanting projects implemented in the Cedar River Municipal Watershed from 2001 through 2004. Monitoring periods for the projects ranged from five to eight years after project implementation. Species planted in the monitored projects were four conifers (Sitka spruce, western redcedar, western hemlock, grand fir) and one deciduous species (black cottonwood). Depending on the project, species were planted in uncleared or cleared areas, and in two projects browse protection was provided. Numbers of planted seedlings of a given species varied by project from less than 10 to as many as 750.

Although different project designs, sample sizes, and implementation techniques make statistical comparisons among projects problematic, several conclusions were drawn from considering the monitoring results together. First, understory clearing has a strong positive effect on survival for both moderately shade-tolerant and shade-tolerant species and a less dramatic, but still evident positive effect on growth. Second, using container stock greatly improves seedling survival and growth. Third, animal damage has a major negative effect on success of western redcedar seedlings, but less effect on other species. The species that appears to have the greatest probability of success, defined as survival and growth above the understory canopy, is Sitka spruce followed by western hemlock. Black cottonwood also provides fast growth, but problems with a weak growth form indicate that stock selection may be critical in this species. With adequate browse control, western redceda may also have a high success rate.