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## Recovery of Douglas-fir Seedlings from Logging Damage in Southwestern Oregon: Preliminary Evidence

### Abstract

Two studies involving overstory removal in shelterwood stands of southwest Oregon indicate that Douglas-fir understory reproduction up to 4.5 m tall can recover from substantial logging-related injuries. In these studies, such injuries included breakage of stems or terminal leaders, as well as wounds covering up to half the stem circumference. In one study, remeasurement 3 growing seasons after overstory removal indicated that at least 75 percent of the damaged seedlings that were initially 60 cm tall or taller could be classified as crop trees. At that time, annual height growth did not differ significantly between undamaged trees and those with small stem wounds or stem breakage near the top of the tree. Only when logging damage had been severe, with seedlings pushed over and sometimes still pinned to the ground, was height growth significantly less. In a second study, seedlings less than 30 cm tall recovered poorly from logging injuries and died more often than larger seedlings.

The present database is limited and caution should be exercised in using it to predict seedling recovery after other harvesting operations; however, it appears that a classification system based on seedling damage sustained during logging can be useful in predicting subsequent recovery.

### Introduction

In the western United States, forest stands are often regenerated by the shelterwood system, which involves removal of mature timber in a series of cuttings so that seedlings can become established under the partial shelter of overstory trees. Today, shelterwood stands in this region cover hundreds of thousands of hectares, and many are ready for overstory removal (U.S. Department of Agriculture 1979, Lysne *et al.* 1982). The challenge in harvesting these stands varies greatly, depending on terrain, management history, number of overstory trees to be removed, and number of seedlings established in the understory (Mann and Tesch 1985). Furthermore, overstory removal in shelterwood stands always causes some damage and mortality to seedlings. If a site is excessively stocked, seedling mortality caused by logging can result in beneficial thinning (Barrett *et al.* 1976). However, if stocking is barely adequate before overstory removal, maintaining an adequate number and distribution of seedlings can be critical. Unfortunately, little information is available to help forest managers predict recovery potential of conifer seedlings damaged during overstory removal.

When stocking is marginal after logging, foresters could make better decisions if they knew the number of damaged seedlings that will re-

cover to crop tree status, length of the recovery period, and growth rate of damaged seedlings in comparison with that of undamaged ones. Reliable prediction of seedling recovery could assure managers that stands meet minimum targets for stocking and that replanting is unnecessary.

This paper reports on two studies dealing with survival and recovery of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) seedlings after overstory removal in shelterwood stands of southwest Oregon, focusing specifically on the fate of regeneration beyond direct harvesting-related mortality. The Grub Gulch (GG) case study was begun in 1980 to identify seedlings characteristics and logging factors that influence seedling survival during overstory removal (Tesch *et al.* 1986a). While the original study was not designed to measure recovery, understory seedlings were permanently marked prior to overstory removal, allowing remeasurement of the survivors in 1984. These remeasurements enabled us to relate seedling recovery (crop tree status and growth rate) to severity of logging injury and seedling size before logging. A longer-term study on Douglas-fir seedling recovery (DFSR) was subsequently started in 1984 across a broader range of sites in southwest Oregon; its objective was to test trends observed

in the GG study. Four-year results of the DFSR study are presented, relating recovery to seedling size before logging.

## Grub Gulch Study

### Study Area and Methods

The GG study was begun in 1980 on a north-facing, 65 percent slope, cutting unit in the Siskiyou Mountains near Medford, Oregon. The site was on land managed by the U.S. Department of Interior, Bureau of Land Management. Ranging between 900 and 1140 m in elevation, the area is considered to be site class IV (McArdle *et al.* 1961) and to have a Douglas-fir/dwarf Oregon grape (*Berberis nervosa*) plant association (Atzet and Wheeler 1984). Average annual precipitation in the area is 889 mm (Froehlich *et al.* 1982), with less than 127 mm typically falling between May and September (McNabb *et al.* 1982). The area had been skyline- and tractor-logged in 1977 as part of the preparatory/seed cut in a 2-stage shelterwood system. Understory reproduction at the time of overstory removal was a combination of natural and planted Douglas-fir seedlings. The shelterwood overstory was removed in July and August of 1980 by logging with a running skyline system using a slackpulling carriage for lateral yarding (Tesch *et al.* 1986a).

*Classification of Seedling Damage After Logging.* Before overstory removal, a 4.3- by 4.3-m grid was established over the entire area to be logged. Each intersection point on this grid marked the center of a 1-m-radius circular plot. If more than one seedling was present in a plot,

the one with the best appearance was selected and tagged for future observation. All sample plots were revisited after overstory removal to determine the amount of seedling injury or mortality resulting from logging. Surviving seedlings were assigned to one of four damage classes (Table 1).

Information on seedlings that were killed during logging has been reported elsewhere (Lysne *et al.* 1982, Tesch *et al.* 1986b) and is not included in this article.

*Classification of Seedling Recovery.* In April 1984, 3 growing seasons after overstory removal, plots were revisited again to observe whether the damaged seedlings had recovered from injuries sustained during logging. Surviving seedlings were classified as crop or non-crop trees according to the following criteria:

#### Crop-tree criteria—

1. Previous damage insignificant or no longer evident; seedlings did not fit any of the following crop-tree criteria.
2. Broken terminal leader; lateral branch had assumed dominance.
3. Healed stem wound; crown healthy.
4. Healing stem wound; crown healthy.

#### Non-crop-tree criteria—

5. Debris pinning seedling to the ground.
6. Serious stem breakage below terminal leader, resulting in forked tree.
7. General lack of vigor, as shown by chlorotic needles or declining height growth.
8. Serious sweep in stem, likely to produce unstable tree.

TABLE 1. Classification of seedling damage after shelterwood overstory removal in the Grub Gulch and Douglas-fir Seedling Recovery studies.

Grub Gulch study—damage classification	Douglas-fir Seedling Recovery study—damage classification
1. No visible damage.	1. No visible damage.
2. Slight damage; broken terminal leader or small stem wound.	2. Top damaged—broken terminal leader.
3. Moderate damage; seedlings broken off below terminal leader or stem wound covering up to half of seedling circumference.	3. Stem breakage below terminal leader.
4. Severe damage; usually pushed over during logging, often half the branches missing or with large portion of stem wounded.	4. Stem wound.
	5. Tree pushed to ground but not pinned by debris (free to grow); probable root damage.
	6. Tree pinned to ground by logging slash.
	7. Lateral branches missing.
	8. Tree chlorotic; poor vigor with no obvious damage.

Evaluation of crop-tree status was based on current appearance; no consideration was given to competitive position because that could be altered by silvicultural treatments. We assumed stem damage on released Douglas-fir regeneration would not lead to significant decay if wounds healed within 10 years (Gravelle 1977). Stain and decay losses are usually negligible in trees less than 2.3 cm dbh because rapid healing compartmentalizes any defect to the wood present at the time of wounding (J. Hadfield, Forest Pest Management, USDA Forest Service, R-6, pers. comm.). We also assumed that minor flaws in tree form as a result of lateral branches expressing dominance would not lead to a significant decrease in wood quality.

Finally, we measured annual height growth for the 3-year period by observing internodal growth on either the terminal leader or on lateral branches that assumed dominance after breakage of the leader.

*Statistical Analyses.* T-tests were conducted to compare annual seedling growth among the GG damage classification criteria. Because plots were not replicated, ANOVA with multiple comparisons was not done. Differences between means were compared using t-tests with a 0.05 probability level.

## Results and Discussion

*Crop-Tree Classification and Mortality.* The damage survey conducted in 1980 immediately after logging showed that the smallest seedlings had suffered the most mortality (Tesch *et al.* 1986a, b), but that surviving small seedlings had relatively few visible injuries (Table 2). The amount of moderate and severe damage increased with seedling size.

Three growing seasons after logging, the proportion of seedlings that had survived logging and that could be classified as crop trees was lowest in the 0- to 20-cm pre-harvest height class (55%) (Figure 1), the class in which surviving seedlings had the least visible damage immediately after logging. The proportion of crop trees increased through the 61- to 80-cm height class (86%), then generally leveled off.

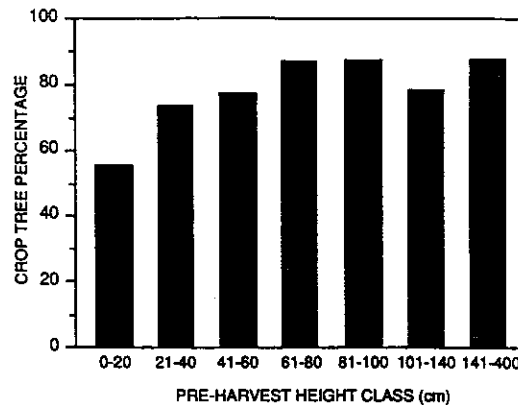


Figure 1. Percentage of Grub Gulch seedlings, by pre-harvest height class, that survived logging in 1980 and were classified as crop trees in 1984.

Of the seedlings that appeared undamaged immediately after logging, only 62 percent in the 0- to 20-cm pre-harvest height class were classified as crop trees in 1984 (Table 3), but nearly 100 percent in the 60-cm or taller pre-harvest height classes were so classified at that time. Except for seedlings in the severe damage class, the percentage that attained crop-tree status was greatest among taller individuals. Recovery of severely damaged seedlings was

TABLE 2. Seedling damage immediately after shelterwood overstory removal at Grub Gulch, by preharvest height class (n = number of seedlings in each height class).

Damage class	Preharvest height class (cm)						
	0-20 (n = 82)	21-40 (n = 278)	41-60 (n = 187)	61-80 (n = 111)	81-100 (n = 79)	101-140 (n = 94)	141-400 (n = 65)
	----- % of seedlings (n) in each damage class -----						
None	73	61	54	40	53	22	28
Slight	11	20	19	31	22	30	34
Moderate	5	9	16	18	15	30	25
Severe	11	10	11	11	10	18	14

TABLE 3. Crop tree status of seedlings at Grub Gulch in 1984, by preharvest height class and damage class just after overstory removal (n = number of seedlings in each height class).

1980 damage class just after logging & 1984 crop-tree status	Preharvest height class (cm)						
	0-20	21-40	41-60	61-80	81-100	101-140	141-400
	----- % of seedlings (n) in each damage class -----						
No damage	(n = 60)	(n = 168)	(n = 101)	(n = 45)	(n = 42)	(n = 21)	(n = 18)
Crop tree	62	84	92	98	100	100	100
Dead	28	8	5	0	0	0	0
Non-crop tree	10	8	3	2	0	0	0
Slight damage	(n = 9)	(n = 56)	(n = 36)	(n = 34)	(n = 17)	(n = 28)	(n = 22)
Crop tree	56	75	78	91	82	100	100
Dead	11	12	14	9	6	0	0
Non-crop tree	33	12	8	0	12	0	0
Moderate damage	(n = 4)	(n = 26)	(n = 29)	(n = 20)	(n = 12)	(n = 28)	(n = 16)
Crop tree	50	58	48	75	75	71	81
Dead	25	31	17	5	8	4	12
Non-crop tree	25	12	34	20	17	25	6
Severe damage	(n = 9)	(n = 27)	(n = 21)	(n = 12)	(n = 8)	(n = 17)	(n = 9)
Crop tree	11	18	43	42	38	18	33
Dead	56	59	24	42	25	12	11
Non-crop tree	33	22	33	17	38	71	56

greatest in the 40- to 100-cm height classes; in each of these, approximately 40 percent were considered crop trees in our judgment.

By 1984, there was some mortality among seedlings in all four damage classes and in each class some survivors could not be classified as crop trees (Table 3). Of the seedlings that appeared undamaged when examined immediately after overstory removal, 28 percent in the 0-to 20-cm height class died between 1980 and 1984. Within this undamaged class, most seedlings recorded as non-crop trees in 1984 were originally 40 cm tall or less. The percentage of non-crop trees in larger size classes increased with the level of logging damage, perhaps because the damage resulted in more unacceptable tree form in these size classes.

*Height Growth of Recovering Seedlings.* Except for those classified as non-crop trees because of poor vigor, seedlings that survived overstory removal clearly showed accelerated height growth over the 3-year period (Table 4). Generally, undamaged trees with poor vigor were chlorotic, lacked vigorous dark green color, had small buds, and had declined in growth since logging. In the

third year, average growth of crop trees was more than twice that of non-crop trees. In that year, height growth did not differ significantly among seedlings meeting the various crop tree criteria; seedlings that recovered from terminal leader or stem damage grew at the same rate as those without these injuries.

After the 1983 growing season, no growth differences were observed among crop trees originally classified as having no, slight, or moderate damage, but all of these trees had significantly greater growth than did those originally classified as severely damaged (Table 5). Crop trees that were growing vigorously and had healthy crowns when sampled after the 1983 growing season had received a wide range of logging injuries in 1980. For example, breakage of a lateral branch was recorded as slight damage in 1980, but it may no longer have been visible after 3 growing seasons. A few seedlings classified as severely damaged after logging in 1980 also showed no evidence of injury after the 1983 growing season. Some trees pinned to the ground during logging may have been uncovered and returned to an upright position after logging debris decomposed

TABLE 4. Mean annual height growth of surviving seedlings at Grub Gulch by criteria for crop and non-crop trees ( $\pm$  S.E.).<sup>1</sup>

Crop-tree & non-crop-tree criteria in 1984	Mean annual height growth (cm)			n <sup>2</sup>
	1981	1982	1983	
<b>Crop trees</b>				
Insignificant damage	12.0 (0.4)a	16.2 (0.5)a	22.2 (0.7)a	374
Broken terminal leader (healed)	8.7 (0.7)bc	15.7 (1.0)a	20.8 (1.2)a	86
Stem wound (healed)	11.9 (0.6)ab	16.1 (0.9)a	22.4 (0.9)a	173
Stem wound (not healed)	13.6 (1.8)ab	18.1 (1.9)a	29.2 (3.3)a	8
Mean, all crop trees	11.5 (0.3)	16.1 (0.4)	22.1 (0.5)	641
<b>Non-crop trees</b>				
Seedling pinned to ground by debris	6.4 (0.6)cd	8.6 (0.8)b	11.0 (0.8)b	42
Stem broken below terminal leader	7.3 (1.0)cd	9.3 (0.9)b	12.5 (1.8)b	13
Lack of vigor	5.1 (0.9)d	5.0 (1.0)b	5.4 (0.9)b	16
Extreme stem sweep	6.8 (1.0)cd	6.6 (0.8)b	9.9 (1.6)b	10
Mean, all non-crop trees	6.4 (0.4)	7.8 (0.5)	10.1 (0.6)	81

<sup>1</sup>In each data column, means identified by the same letter are not significantly different from one another at the 5 percent level according to t-tests.

<sup>2</sup>Number of trees with a single type of damage only; individuals with multiple injuries are deleted.

TABLE 5. Mean annual height growth of crop-tree seedlings at Grub Gulch by damage class just after overstory removal in 1980 ( $\pm$  S.E.).<sup>1</sup> (n = number of trees in each damage class.)

Damage class	Mean annual height growth (cm)			n
	1981	1982	1983	
None	11.6 (0.4)a	15.6 (0.5)a	21.6 (0.6)a	389
Slight	12.0 (0.6)a	16.6 (0.8)a	23.2 (1.0)a	157
Moderate	11.2 (1.0)ab	18.2 (1.3)a	24.6 (1.4)a	73
Severe	8.4 (1.3)b	15.3 (3.9)a	16.6 (2.2)b	22

<sup>1</sup>In each data column, means identified by the same letter are not significantly different from one another at the 5 percent level according to t-tests.

or moved down the slope. Most stem wounds on these relatively small trees had healed within 3 years.

### Summary

Observations at Grub Gulch suggest that seedlings at least 60 cm tall are best at recovering from logging damage and becoming crop trees; 75 percent or more recovered from slight or moderate injuries. Seedlings less than 20 cm tall appear to be at greatest risk, regardless of whether damage is visible immediately after log-

ging. Logging damage did not appear to retard height growth of trees unless they were partially uprooted or pinned down by slash throughout the observation period.

Rate of recovery from logging damage is undoubtedly a function of the environment. This site is on a northerly aspect and is characterized by Atzet and Wheeler (1984) as having the most productive plant association in the "dry end" of the Douglas-fir series. During the 3 years after overstory removal, precipitation was normal to slightly above normal, with 1983 the wettest year. At the time of remeasurement, reconnaissance

indicated a fairly dense cover of herbaceous vegetation and scattered deciduous shrubs which were typically less than a meter tall. Numerous seedlings were found within clumps of regeneration and undoubtedly suffered somewhat from interspecific competition.

## Douglas-fir Seedling Recovery Study

### Study Area and Methods

The DFSR study was designed to observe recovery of Douglas-fir reproduction (up to 4.6 m tall) damaged by logging on hot, dry sites in southwestern Oregon. Between September 1983 and April 1984, overstory removal was completed on 6 Bureau of Land Management timber sales in the Siskiyou and Cascade Mountains near Medford, Oregon (Table 6). All sites were logged similarly with skyline systems using slackpulling carriages for lateral yarding. Understory reproduction was a mixture of planted and natural seedlings.

During early summer of 1984, 15 permanent transects were installed within the 6 timber sales and 539 seedlings were selected for long-term observation; 92 were not visibly damaged and were selected as controls. The remaining 447 were assigned to one of eight damage categories (Table 1), and detailed measurements and

damage characteristics were recorded to aid in tracking recovery over time. Most damage occurred as stem wounds, broken tops, or seedlings pushed to the ground during logging. All transects have been monitored annually so that mortality and recovery could be related to seedling size and type of injury at the time of overstory removal. Fourth-year results are presented here. Data on growth and crop-tree status will be collected after 5 years and are not yet available.

### Results and Discussion

In the long-term DFSR study, cumulative mortality after the 1987 growing season (4 years after overstory removal) was greatest for those seedlings that had been 0- to 30-cm tall right after logging; among them, mortality rate was about 40 percent for both damaged and undamaged seedlings (Figure 2). Nearly two-thirds of the mortality of damaged seedlings in this smallest size class occurred in the first growing season, and almost all mortality had occurred by the end of the second. Most of the damaged seedlings that died had been pinned to the ground or pushed over. Stem wounds, broken terminal leaders, or missing lateral branches did not commonly lead to mortality. Mortality of undamaged seedlings in this size class occurred throughout the 4-year period.

TABLE 6. Site descriptions for Douglas-fir Seedling Recovery study.

Site	Number of transects	Percent slope	Aspect	Elevation (m)	Precipitation (mm)		Plant association <sup>3</sup>	Mountain range
					Annual <sup>1</sup>	Dry season <sup>2</sup>		
1	1	50	W	1010	864	114	Douglas-fir - ponderosa pine	Siskiyou
2	5	25-50	N,NE,S	775	1041	135	Douglas-fir - white fir/ ocean spray; Douglas-fir - depauperate	Siskiyou
3	2	40	NE	940	1270	165	Douglas-fir - jeffrey pine	Siskiyou
4	4	60	N,NW,S	850	860	120	Douglas-fir - white fir/ ocean spray	Siskiyou
5	1	60	W	1070	1270	160	Douglas-fir/ dwarf Oregon grape	Cascade
6	2	65	SE	700	1270	160	Douglas-fir/ poison oak - Piper's Oregon grape	Cascade

<sup>1</sup>Source: Froehlich *et al.* 1982.

<sup>2</sup>Source: McNabb *et al.* 1982. Dry season = May through September.

<sup>3</sup>Source: Atzet and Wheeler 1984.

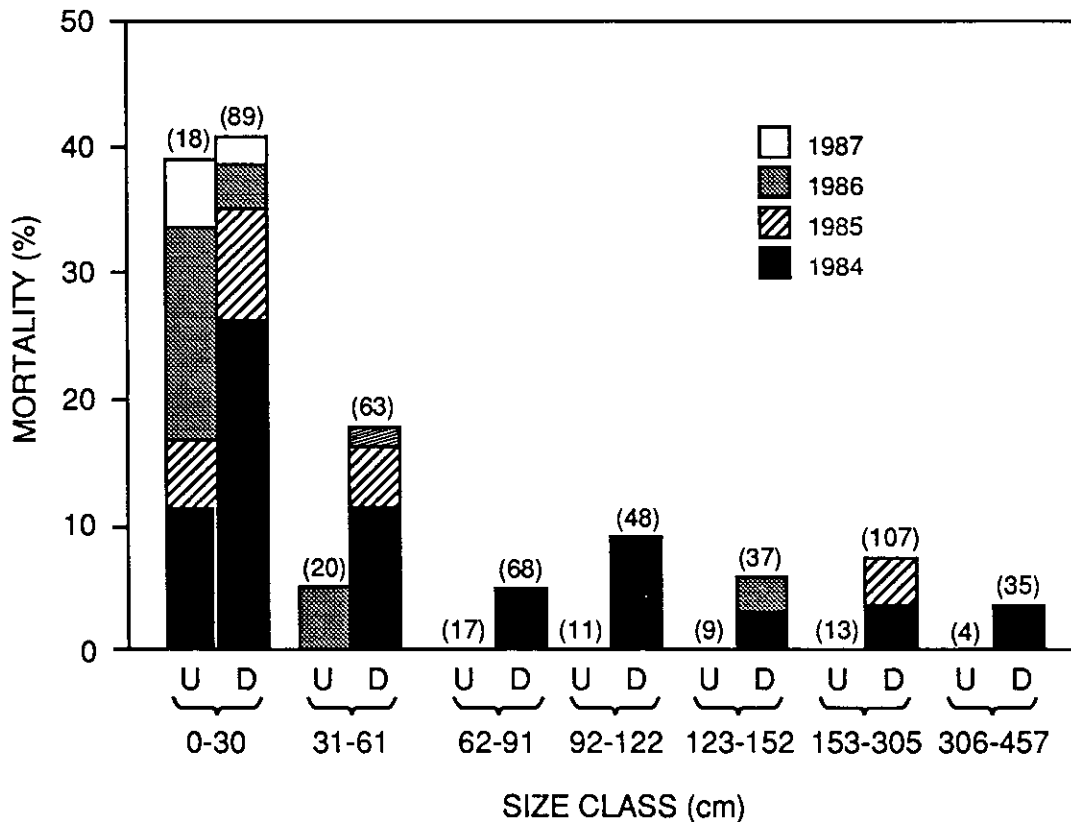


Figure 2. Mortality of undamaged (U) and damaged (D) trees on transects installed in 1984 as part of the DFRS study. Numbers above bars represent initial numbers of seedlings in each column. Data from all transects have been pooled.

At the end of 1987, cumulative mortality of damaged seedlings in the 31- to 61-cm size class was 17 percent, less than half that of corresponding seedlings in the smaller size class. As with the smaller class, most mortality occurred in the first 2 years after logging. Mortality of damaged trees in larger size classes was less than 10 percent, most of which occurred in the first year. Only a small number of undamaged seedlings greater than 30 cm tall suffered mortality. While survival of larger, damaged seedlings has been good, crop-tree status is not yet available.

We were intrigued that mortality of apparently undamaged 0- to 30-cm tall seedlings continued throughout the 4-year period, especially in the third year (1986), even though mortality of damaged seedlings of similar size was low after the first 2 years. Mortality in 1986 for apparently undamaged seedlings was 17 percent compared to

only 3 percent for damaged seedlings. Adverse environmental conditions or competition are likely causes for mortality of these small seedlings, but we were surprised that mortality was not more similar between the two groups in 1986. The fact that many damaged seedlings died quickly in the first 2 years would not seem to preclude susceptibility of remaining seedlings to environmental- or competition-related mortality. Typically, mortality declines over time as seedlings become established, unless some other factor is weakening them. We offer an alternative hypothesis that when logs roll over small, flexible seedlings, invisible root and stem damage may occur that predisposes seedlings to mortality over time. While we have no direct evidence to support this hypothesis, we feel further study is warranted because of the common notion that very small flexible seedlings suffer less logging damage.

## Summary

The key finding to date from this study is that seedlings larger than about 60 cm tall suffered the least mortality after being damaged during logging. While crop-tree status has not been determined, 90 percent of damaged trees above this size are alive after 4 years. Most mortality is related to seedlings being partially uprooted or pinned to the ground.

The transects are all located on sites judged to be at least moderately hot and dry (Atzet and Wheeler 1984), thereby making competing vegetation a potentially important influence on recovery. Competing vegetation was not controlled in any of the harvest areas and reconnaissance indicated that herbaceous plants rapidly occupied the transects after overstory removal. Shrubs and hardwood sprouts are beginning to dominate most sites after 4 years. Precipitation during the recovery period has been normal to below normal, with annual precipitation for 2 years at least 20 percent less than normal.

## Synthesis and Conclusions

Evaluation of crop-tree status at Grub Gulch demonstrated that Douglas-fir seedlings damaged during shelterwood overstory removal can recover within 3 years. Even among seedlings originally classified as severely damaged, nearly 40 percent of those between 41 and 100 cm tall were judged to be crop trees 3 years later. Recovery of less severely damaged trees was much better. Only among severely damaged seedlings was annual height growth significantly reduced 3 years after harvest.

In both studies, damaged seedlings in the smallest size classes (less than 31 cm tall) suffered the greatest mortality. Of those that survived, many at Grub Gulch were not judged to be crop trees at the end of the observation period.

For both studies, nearly 40 percent of the undamaged seedlings in the smallest size classes

either died or, in the case of Grub Gulch, were classified as non-crop trees. While poor planting, competition, and adverse environmental conditions are likely the main causes, some invisible damage to roots and stems of these highly flexible seedlings is hypothesized.

Survival and recovery of damaged Douglas-fir seedlings in both studies were much higher when seedlings were at least 40 to 60 cm tall at the time of overstory removal. This limited evidence might encourage timber sale planners to consider scheduling shelterwood overstory removal when Douglas-fir reproduction, planted seedlings in particular, is at least 40 cm tall.

These studies document that understory reproduction can recover from substantial logging-related injuries. Our database is limited at this time and caution should be exercised in extrapolating our results, but it does appear that a classification system based on damage incurred during logging can be developed and become a useful tool in predicting subsequent recovery.

## Acknowledgments

These studies were conducted as cooperative research projects between Oregon State University's Southwest Oregon Forestry Intensified Research Program (FIR) and the Bureau of Land Management, Medford District. FIR, established in October 1978, is a cooperative effort involving Oregon State University, the Bureau of Land Management, the USDA Forest Service, and southwest Oregon counties and timber industries. It is designed to help foresters and other specialists solve complex biological and management problems important to southwest Oregon, and represents a determined effort by the southwest Oregon forestry community and county governments to find practical solutions to those problems. This is paper 2389, Forest Research Laboratory, Oregon State University, Corvallis.

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