Studies of advance Subalpine Fir in the Kamloops forest district.

by L. J. Herring
STUDIES OF ADVANCE SUBALPINE FIR IN
THE KAMLOOPS FOREST DISTRICT

By

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Studies of advance subalpine fir in the Kamloops Forest District.

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"A cooperative effort of the Research Division (B.C.F.S.) and the Pacific Forest Research Centre (C.F.S.)."


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ABSTRACT

The growth characteristics of advance subalpine fir (Abies lasiocarpa) beneath a mature overstory are discussed, and indicate that the age of advance growth cannot be predicted on the basis of stem size. Following logging a delay of one full year is common before diameter growth response on the advance growth released from suppression. Height growth response may be delayed for several years. Factors significant to the management of advance subalpine fir regeneration are described, including stem form, stocking and density, and growth performance. The health of advance growth in relation to logging injuries and decay are discussed. The incidence of active decay infections was low, but increased with the size of stem at the time of injury. The method of attack by the Indian paint fungus (Echinodontium tinctorium) and its potential threat to advance subalpine fir regeneration are described. The application of study results and silvicultural prescriptions for the management of advance growth are presented.
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INTRODUCTION

E.P. 754.01 was initiated in 1975 to assess the health, growth response and suitability as a restocking component of subalpine fir (Abies lasiocarpa (Hook.) Nutt.) advance regeneration in the Engelmann spruce-subalpine fir forest types of the Kamloops Forest District. The study was a co-operative effort by the Research Division (B.C.F.S.) and the Pacific Forest Research Centre (C.F.S.). Specific study objectives were:

1. To determine the growth response of advance subalpine fir regeneration following logging, and to assess such factors as size, age and competition to determine their influence on growth response.

2. To determine the susceptibility of advance subalpine fir to attack by wound parasites after release by logging, as well as its susceptibility to the Indian paint fungus (Echinodontium tinctorium) (Ell. & Ev.) Ell. & Ev.) and the significance of age and size in relation to decay hazard.

INVESTIGATION METHODS

FIELD MEASUREMENT PHASE

Field sampling was conducted in second growth subalpine fir-Engelmann spruce stands left after early logging operations above 1200 m elevation in the Kamloops Forest District. Advance subalpine fir regeneration was systematically sampled along transects using 0.0016 ha plots to determine the age, height, and diameter of the sample trees at the time logging occurred, as well as currently. Current tree heights were standardized for all areas at the termination of height growth in the fall of 1974, to eliminate the bias of sampling areas at different times throughout the 1975 growing season. Other factors such as stocking, density, competition and stem form were also assessed in the field. Basal disks were removed from each sample tree for accurate age counts and suppressed basal diameter measurement.
LABORATORY PATHOLOGICAL ANALYSIS PHASE

In conjunction with the field measurements the incidence of logging damage, type of injury and the presence or absence of hidden defect (stain or decay) were determined. The stumps of all sampled trees were also examined for the presence of root or butt rots. Culture isolations were carried out in the laboratory from all wound samples with hidden defect to identify the causal organism. The susceptibility of advance subalpine fir regeneration to the Indian paint fungus was determined by culture isolations made after dissection and systematic sampling of pith and embedded branch stubs from additional 60 cm long basal stem sections collected at each study area.

Sampling was undertaken in five study areas with widely varying logging histories. Figure 1 illustrates the location of each area. In order that the survey results be fully understood, it is necessary to describe the characteristics of each study area.

Raft Mountain

The Raft Mountain study area is located on the Candle Creek Road (Branch 43) approximately 11 km northeast of Clearwater, B.C. The site lies at 1400 m elevation with a southwest aspect and average slope of 20 percent. The original spruce-subalpine fir stand was clearcut in 1943 in an experimental logging operation. The area was divided into two sectors; one sector logged by highlead yarding machinery, the other sector by tractor skidding. The very slight difference in the second-growth stands on each sector did not justify stratified sampling, since both logging methods resulted in a very low diameter-limit clearcut with few large stems left standing.

Sock Lake

The Sock Lake study area is located on the Grizzly Mountain plateau, 1.6 km southwest of Sock Lake, and approximately 13 km northwest of Clearwater. The site lies at approximately 1,400 m elevation on a plateau landform with parallel north-south ridges and draws. This area was the site of an experimental project in 1953 which evaluated the costs of several different site preparation methods (J.D. Clark et al., 1954). The original Engelmann spruce-subalpine fir stand was logged to a high diameter limit, which left a relatively heavy residual stand. To this stand, the various site preparation treatments were applied. The 1953 treatment of interest to this project is best described as a residual tree-removal treatment. In 1953 all trees over 1.3 m in height were felled by powersaw, thus eliminating all residuals and most large advance regeneration.1 The resulting second-growth stand sampled in

1. For clarity of description, advance regeneration is defined as any stem left after logging which was less than 3.0 m in height at the time of logging, regardless of age. Residuals are defined as any stems left after logging which were greater than 3.0 m in height at the time of logging.
1975 originated entirely from small advance regeneration less than 1.3 m in height in 1953, as well as from natural regeneration which became established after 1953.

Figure-Four Lake

Figure-Four Lake study area lies approximately 1.2 km north of Figure-Four Lake, at the headwaters of Eagle Creek (latitude 51° 32'; longitude 120° 28'). The site lies at approximately 1300 m elevation on a dry, southwest-facing slope of 20 to 30 percent. The site was logged to a high diameter limit in 1966 which left scattered large sub-alpine fir residuals, many of which have now died or blown over. Slash and windfall were heavy, but patchy in distribution. The remaining small residuals and advance regeneration were sampled.
Bolean Lake

The Bolean Lake study area lies approximately 5 km north of Falkland, at an elevation of 1,550 m. The site supports an Engelmann spruce-subalpine fir forest type on a plateau with a neutral to southwest aspect and a slope of 0 to 10 percent. Bolean Lake area was the site of another experimental silvicultural project in 1952 (Smith and Clark, 1974). A small portion of the area received the same treatment applied at Sock Lake in 1953, that is, a residual tree-removal treatment which eliminated all stems over 1.3 m in height. The second-growth stand which developed within this small 2.8 hectare treatment block originated from small advance regeneration less than 1.3 m high in 1952, and was the basis of sampling for this study in 1975.

Fortune Creek

The Fortune Creek study area lies at the northern boundary of Silver Star Park, at the termination of the Ganzeveld access road from Enderby. The site lies at approximately 1,585 m elevation on a plateau with neutral aspect. The terrain is slightly rolling with a 0 to 10 percent slope. The mature Engelmann spruce-subalpine fir forest was logged in 1957 to a high diameter limit, which left trees ranging from seedling size advance regeneration to very large residuals.

RESULTS AND DISCUSSION

GROWTH CHARACTERISTICS

Table 1 presents the sample means and their standard errors for two initial-state variables (age and height at release), total height growth up to the fall of 1974, and height growth since logging (or treatment) for each study area.

As seen in Table 1, the effects of the residual-removal treatments at Sock and Bolean Lakes, and the experimental clearcut at Raft Mountain have lowered the average age and height-at-release of the surviving trees compared with the diameter-limit cutting at Figure-Four Lake and Fortune Creek. The effect on stem size distribution of the three experimental treatments can best be illustrated by Figure 2, showing the frequency and distribution of size classes in the surviving second growth stand immediately after treatment or logging in each study area. The long "tails" on the graphs of Figure-Four Lake and Fortune Creek study areas represent stocking by large advance regeneration and residuals which survived the diameter-limit logging operation.
Table 1. Sample means and standard errors for initial state and response growth variables for advance subalpine fir sampled in five study areas in the Kamloops Forest District.

<table>
<thead>
<tr>
<th>STUDY AREA AND DATE OF LOGGING</th>
<th>SAMPLE SIZE (trees)</th>
<th>AGE AT RELEASE (yrs)</th>
<th>HT. AT RELEASE (m)</th>
<th>TOTAL HT. GROWTH (to 1974) (m)</th>
<th>HT. GROWTH SINCE TREATMENT MEAN TOTAL (m)</th>
<th>MEAN ANNUAL RATE (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAFT MOUNTAIN 1943</td>
<td>220</td>
<td>37</td>
<td>1.2</td>
<td>8.17</td>
<td>7.46</td>
<td>0.24</td>
</tr>
<tr>
<td>SOCK LAKE 1953</td>
<td>108</td>
<td>37</td>
<td>2.4</td>
<td>5.80</td>
<td>5.29</td>
<td>0.24</td>
</tr>
<tr>
<td>FIGURE-FOUR LAKE 1966</td>
<td>202</td>
<td>61</td>
<td>2.4</td>
<td>2.82</td>
<td>1.29</td>
<td>0.16</td>
</tr>
<tr>
<td>BOLEAN LAKE 1957</td>
<td>58</td>
<td>25</td>
<td>2.6</td>
<td>4.19</td>
<td>3.87</td>
<td>0.18</td>
</tr>
<tr>
<td>FORTUNE CREEK 1957</td>
<td>184</td>
<td>70</td>
<td>3.9</td>
<td>5.57</td>
<td>3.37</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Results of the field survey indicate several major characteristics and factors affecting the use or management of advance subalpine fir regeneration in the Kamloops Forest District. A discussion of each of these factors follows.

1. Suppressed Growth Characteristics

Survey data indicate a wide range of size and age of advance subalpine fir within the overstory of a mature stand. The rate of suppressed growth was also found to vary tree by tree within the understory, depending on such factors as light intensity, growing medium and competition. Studies of advance amabilis fir (Herring and Etheridge, 1976) indicate that the growth rates of individual suppressed stems are also quite changeable, reflecting gradual changes in the overstory canopy cover with time. This is also true of advance subalpine fir and indicates that stem age at release cannot be accurately predicted on the basis of stem size. As a very general rule, however, the largest subalpine fir stems tend to be the oldest. For this reason the mean age of surviving stems was lowered as a result of the residual-removal treatments at Sock and Bolean Lake study areas, as seen in Table 1. The pathological significance of this particular treatment will be discussed later in this report.
2. Response Delay

Response delay is the lag period between the date of logging (commonly called the date of release for advance regeneration) and the date of diameter growth acceleration of the advance regeneration stem. Based on data from all study areas, 75 percent of the sampled advance subalpine fir regeneration responded with increased diameter growth within one full year after the year of logging. In other words, if logging of the overstory had occurred in 1976, 75 percent of the advance regeneration would have responded in increased diameter growth during (or before) the 1978 growing season. Another 23 percent of the sampled trees responded between 2 and 5 full years after the year of logging, while only 2 percent exhibited a delay of between 6 and 10 years. Studies of other
Abies species advance regeneration in Canada, the U.S.A. and Europe (Hatcher, 1964; Gordon, 1973; Bellon and Kowalski, 1968; Kotar J., 1972) indicate similar radial growth response delays after release by logging. It is generally assumed that this delay period is the result of gradual foliar adaptation to full sunlight conditions as well as root system expansion.

No attempt was made to estimate the height growth response delay period for the sampled trees. A study by Gordon (1973) indicates height growth response delays of 3 to 4 years for Red fir (Abies magnifica) and White fir (Abies concolor), even though radial response was more rapid. It is likely then, that significant height growth response would not be visible on advance subalpine fir until about 3 full years following the year of logging. Full height growth response would not likely be immediate at that time, but would gradually increase over a number of years.

Response delay is a factor which must be considered in the early management of advance subalpine fir. Assessment of growth performance shortly after logging will not provide a realistic indication of the growth potential of the advance regeneration and may lead to premature and costly decisions to employ site preparation and artificial regeneration treatments. The response delay period may be used to advantage where a decision is made to fill-plant with spruce. Prompt planting with large vigorous stock soon after logging could result in a desirable species mix with a minimum threat of suppression to the planted spruce by the larger advance regeneration.

3. Stem Form

Stem form is an important aspect of second growth management since it affects future merchantability. Prior to release by logging most advance subalpine fir stems have relatively poor form. Suppressed advance regeneration generally have small, flat-topped crowns with little or no leader dominance, as shown in Figure 3. They also commonly suffer from basal sweep, likely caused by understory winter snow load conditions. Many of these minor deformities are quickly outgrown and disappear soon after accelerated response growth. More severe deformities may not be outgrown, however, particularly those caused by logging damage.

During the field sampling procedure stem form was classified (varying number of years after logging) according to the severity of deformity. The classification ranged from class one stems with straight boles and well developed crowns, to class four stems with severe deformities such as extreme basal sweeps or crooks, or small, poorly developed crown structure. Based on the total number of sample stems (772), 57 percent were class one stems, and 30 percent were class two stems with only minor sweeps or crooks, which would eventually be outgrown. Only about 13 percent of the samples had more severe deformities which might cause utilization problems. Of this 13 percent, almost half (44 percent) were directly attributed to logging damage. Broken tops resulting in extreme crooks, and crushing by slash and logs causing extreme basal sweeps were the most common types of logging damage resulting in deformities.
Figure 3. Typical suppressed advance regeneration of subalpine fir taken from the understory of an uncut stand. Note the poor stem form and flat-topped crowns. The ages of these three stems are from left to right, 68, 78, and 63 years of age.

4. Stocking and Density

The overall stocking and density estimates for all study areas are presented in Table 2. Generally, it was observed that the stocking of advance regeneration tended to be clumpy, with high stand density and heavy competition within clumps (see Figure 4). Variable sized non-stocked openings were common where logging disturbance was severe, or where advance regeneration had never been established. The most common openings were those created by tractor skidroads. In some cases, post-logging natural regeneration had restocked these openings; however, in many cases they remain unstocked as many as 33 years after logging.

Table 2 indicates that advance subalpine fir regeneration densities ranged from a nearly satisfactorily stocked 1,200 stems/hectare at Sock Lake, to an overstocked and clumpy 3,100 stems/hectare at Bolean Lake. In all study areas, post-logging naturals increased total stocking and stand density considerably, resulting in an overstocked condition in many cases. However, the post-logging natural component of each stand was generally subordinate in crown level to the larger advance regeneration component. Nevertheless, the high density and clumpiness of stocking in all areas suggests that some form of spacing would be beneficial to the stand.
The absence of residuals in either Bolean or Sock Lake study areas reflects the treatments these areas received. Both Figure-Four Lake and Fortune Creek study areas support similar numbers of residuals, although the incidence of very large residuals was higher at Fortune Creek. By comparison, the negligible number of residuals in the Raft Mountain study area illustrates the effect of clearcutting on residual stand structure. As previously mentioned, the 1942 clearcutting at Raft Mountain left very few large residuals, and many of them have likely blown down since that time.

Although Table 2 presents only stocking data for advance subalpine fir there was, nevertheless, a variable yet sometimes significant percentage of advance Engelmann spruce regeneration in the study areas. As an example, Engelmann spruce represented 23 percent of total stocking in the advance regeneration component at Sock Lake. In contrast, Engelmann spruce at Bolean Lake represented only about 8 percent of the total advance regeneration stocking component. Obviously the percentage of

<table>
<thead>
<tr>
<th>STUDY AREA</th>
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<th>TREE SPECIES</th>
<th>Stocking Density</th>
<th>ADVANCE AND NATURAL REGEN. Stocking Density</th>
<th>RESIDUALS Stocking Density</th>
</tr>
</thead>
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<tr>
<td></td>
<td>(0.0005 ha)</td>
<td></td>
<td>Stocking %</td>
<td>Density (trees/ha)</td>
<td>Stocking % Density (trees/ha)</td>
</tr>
<tr>
<td>RAFT MOUNTAIN</td>
<td>440</td>
<td>12</td>
<td>2,056 (832)*</td>
<td>64</td>
<td>5,515 (2,732)*</td>
</tr>
<tr>
<td>SOCK LAKE</td>
<td>192</td>
<td>29</td>
<td>1,218 (693)*</td>
<td>54</td>
<td>1,153 (1,275)*</td>
</tr>
<tr>
<td>FIGURE-FOUR LAKE</td>
<td>440</td>
<td>54</td>
<td>2,705 (1,093)*</td>
<td>68</td>
<td>5,031 (2,036)*</td>
</tr>
<tr>
<td>BOLEAN LAKE</td>
<td>116</td>
<td>33</td>
<td>3,120 (1,276)*</td>
<td>75</td>
<td>5,022 (2,034)*</td>
</tr>
<tr>
<td>FORTUNE CREEK</td>
<td>352</td>
<td>24</td>
<td>86 (352)*</td>
<td>57</td>
<td>6,014 (2,634)*</td>
</tr>
</tbody>
</table>

* Density in trees/acre in parentheses

advance Engelmann spruce varies from stand to stand, but it may represent a significant and valuable understory re-stocking component in some areas.

The significantly higher proportion of subalpine fir advance regeneration found in all five study areas suggests that artificial regeneration must be relied upon if the species mix within an unburned or un-scarified area is to be more balanced. The numerous unstocked openings and skidroads mentioned previously lend themselves favourably to fill-planting to bolster the spruce component of the second-growth stand. If this post-logging silvicultural treatment was combined with an improvement cutting of the advance regeneration component promptly following logging, a superior second growth stand would develop.
Figure 4. An overstocked clump of released advance growth in the Figure-Four Lake study area.

5. Growth Performance

The mean annual height growth since release for the study areas ranged from 0.16 m/yr. to 0.24 m/yr. (see Table 1). These figures, however, considerably underestimate the current growth performance of the stems, since no consideration was given to the height growth response delays which normally precede full response growth. Current annual growth rates may best be characterized by averaging the 3 year leader growth from 1972 to 1974. As an example, the calculated mean annual height growth since release for all samples at Sock Lake was 0.24 m/yr. compared with a mean annual height growth of 0.35 m/yr. for the period 1972 to 1974. This latter growth rate further underestimates the growth potential of the advance growth since it is an average of all sample stems under all levels of competition. For instance, the 1972 to 1974 mean annual leader growth for the fastest growing 50 percent of the Sock Lake sample trees was 0.44 m/yr., and is a better estimate of the growth performance of dominant trees undergoing limited competition.

The major factors affecting growth response appear to be competition and microsite. Two types of competition were evident in the study: competition by similar size stems, and competition by large residuals.
The former was the most common type of competition and is due to the clumpy nature of advance regeneration stocking (see Figure 4). In some instances sample trees were competing with up to 30 trees within a 2 metre radius. More commonly, however, 2 or 3 immediate competitors were tallied around sample trees. While not tested statistically, the competitive effect of several closely growing sapling size stems will undoubtedly affect the growth performance of an advance regeneration tree, and make early spacing a desirable prescription.

The competitive effect of large residuals on advance regeneration was only observed in the Figure-Four Lake and Fortune Creek study areas. Depending on the density of residuals, their canopy influence can adversely affect the growth of the smaller advance regeneration by forcing them to undergo various levels of partial suppression.

Figure 5. Excellent response growth on this advance subalpine fir and Engelmann spruce regeneration after the residual tree-removal treatment at Sock Lake in 1953.

The shade and moisture depletion effect of residual trees in a partial-cut stand makes their removal advantageous. A similar suppression effect was observed where vigorous advance regeneration partially shaded out smaller post-logging naturals which became established near them. In some cases where naturals seeded in promptly, however, both types of regeneration developed at the same rate.
Generally, it was observed that microsite has less effect on the response growth of advance subalpine fir in the Kamloops Forest District than for advance amabilis fir in the coastal zone of the Vancouver Forest District. However, some trends deserve mention. Post-logging growth was poor close to swampy microsites, possibly indicating rooting and nutritional restrictions associated with high water tables and soil acidity. Growth was also poor on obviously shallow, dry microsites, which is not surprising since subalpine fir is reported to require a relatively moist habitat (Krajina, 1969).

It is significant that no direct relationship was found to exist between age at release and growth response following logging for advance subalpine fir regeneration. This indicates that stem age alone is not a reliable predictor of growth potential. Table 3 illustrates this point with an example of age and growth data from dominant advance regeneration sampled at Bolean Lake. As shown, stems with ages at release of from 8 to 87 years responded with similar growth performance since logging in 1952. Table 3 also illustrates the irregularity of the age/size ratio in advance subalpine fir, as described previously.

<table>
<thead>
<tr>
<th>AGE AT RELEASE 1952 (yrs.)</th>
<th>HEIGHT AT RELEASE 1952 (o)</th>
<th>GROWTH RESPONSE 1952-1976 (o)</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>0.45</td>
<td>5.27</td>
</tr>
<tr>
<td>79</td>
<td>0.96</td>
<td>6.19</td>
</tr>
<tr>
<td>69</td>
<td>0.97</td>
<td>5.66</td>
</tr>
<tr>
<td>54</td>
<td>0.90</td>
<td>6.30</td>
</tr>
<tr>
<td>40</td>
<td>0.69</td>
<td>5.86</td>
</tr>
<tr>
<td>30</td>
<td>0.61</td>
<td>5.61</td>
</tr>
<tr>
<td>25</td>
<td>0.37</td>
<td>5.43</td>
</tr>
<tr>
<td>18</td>
<td>0.36</td>
<td>5.47</td>
</tr>
<tr>
<td>13</td>
<td>0.12</td>
<td>4.83</td>
</tr>
<tr>
<td>8</td>
<td>0.06</td>
<td>4.91</td>
</tr>
</tbody>
</table>

A trend was observed in all study areas for the largest advance growth stem in a clump to remain the dominant tree after release. Gordon (1973) and Stettler (1958) also observed this characteristic in advance Abies species and attributed it simply to competition. In cases where competition is high (i.e. dense clumps) the larger advance growth stems are less likely to suffer post-release suppression. Stem size holds much more significance from the standpoint of pathological risk, and will be discussed later in the report.

The differences in mean annual growth rates, evident in Table 1, may be partially due to differences in the length of time since the date of logging. Trees growing on the oldest study area (Raft Mountain) have had considerably longer to respond to release, and have grown for a longer period at normal rates than those from the most recently logged
area (Figure-Four Lake). The mean annual growth rate is therefore weighted in favour of the older study area. Other possible causes of between-area growth rate differences include site specific or area specific factors such as climate, elevation and soils, although no attempt was made to statistically assess the large number and range of environmental factors involved.

Figure 6. Excellent advance regeneration growth after residual tree-removal treatment at Bolean Lake in 1952.

PATHOLOGICAL CHARACTERISTICS

1. Logging Damage and Decay

The results of the decay hazard analysis are described separately for the three clearcut study areas (Raft Mountain, Sock Lake, Bolean Lake), and the two partial-cut (diameter-limit clearcut) study areas (Figure-Four Lake, Fortune Creek).

Table 4 provides the frequency of logging damage for the three clear-cut study areas, based on stem height at release. The frequency of logging damage in the 0.0 to 1.3 m (height at release) class is 8.2 percent (avg.) for the three areas. The average frequency of logging
Table 4. The frequencies of logging damage and active decay infection in two height-at-release classes of advance regeneration, and residual subalpine fir from five study areas in the Kamloops Forest District.

<table>
<thead>
<tr>
<th>STUDY AREA</th>
<th>FREQUENCY OF LOGGING DAMAGE</th>
<th>FREQUENCY OF DECAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>advance regeneration</td>
<td>residuals</td>
</tr>
<tr>
<td></td>
<td>0-1.3 m</td>
<td>1.3-3.0 m</td>
</tr>
<tr>
<td>RAFT MOUNTAIN</td>
<td>17 trees (8.8%)*</td>
<td>3 trees (12.5%)*</td>
</tr>
<tr>
<td>SOCK LAKE</td>
<td>9 (9.0%)</td>
<td>1 (12.5%)</td>
</tr>
<tr>
<td>FIGURE-FOUR</td>
<td>28 (20.7%)</td>
<td>15 (29.4%)</td>
</tr>
<tr>
<td>LAKE</td>
<td>3 (5.2%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>BOLEAN LAKE</td>
<td>22 (19.1%)</td>
<td>4 (14.8%)</td>
</tr>
<tr>
<td>FORTUNE CREEK</td>
<td>15 (12.5%)</td>
<td>15 (14.8%)</td>
</tr>
</tbody>
</table>

* Based on the total number of sampled trees in each size class.

damage in the 1.3 to 3.0 m (height at release) class is only slightly higher at 12.5 percent. These frequencies represent a low incidence of damage to both advance regeneration classes. In particular, the smaller size class, which represents 91 percent (avg.) of the total sample, received only negligible damage. The clearcutting operation on Raft Mountain and the residual removal treatments at Sock and Bolean Lakes eliminated all but a small proportion (less than 9 percent (avg.)) of stocking in the larger height-at-release class. If more of these stems had survived logging or been left after the residual removal treatments, it is likely that the incidence of logging damage to that size class would have been higher.

Table 4 also shows the incidence of active decay infections found in advance regeneration in the three clearcut areas. Only two stems in the Sock Lake study area were found to contain active decay infections (both were *Haematostereum sanguinolentum*), both caused by logging injuries. This represents an average frequency of decay of only 0.5 percent for all samples taken in the three study areas. Interestingly, one of the Sock Lake infections resulted from a slashed top from the 1953 residual-removal treatment, after which the tree survived.

The results of the damage and decay hazard analysis for the two partially cut study areas (Figure-Four Lake, Fortune Creek) are also presented in Table 4. The average frequency of logging damage to stems in the 0.0 to 1.3 m class was 20 percent for these areas, compared with 24 percent for the larger advance growth stems in the 1.3 to 3.0 m class. No explanation can be given for the higher frequency of damage to the small size class in the partial-cut stands compared with the clearcut areas. Of consequence, however, is the higher frequency of active infection (avg. 10.2 percent) in the larger advance regeneration compared with the smaller size class (avg. 1.6 percent). This higher
frequency of decay becomes even more significant to the stand manager when it is expressed as a percentage of the injured trees. The average frequency of decay infection for injured stems in the small advance regeneration class is 8 percent compared with 42 percent for the large class stems. These figures indicate the relatively high risk of decay as a result of injury to larger advance regeneration.

The most common wound parasite (decay fungus) associated with logging injuries to advance subalpine fir regeneration was *Haematostereum sanguinolentum*, which accounted for 82 percent of all injury-caused active decay. *Amylostereum chailletii* and an unknown white rot were of minor importance, accounting for the remainder of the decay infections. The incidence of these logging injury caused decay infections in relation to the occurrence of "open" (unhealed) and "closed" (healed) wounds was significant. The frequency of active decay in "open" injuries was 26 percent compared to only 3 percent for "closed" injuries. This finding corresponds with injury and decay studies of advance amabilis fir regeneration (Herring and Etheridge, 1976) which indicated that wound parasite infections are eliminated once tree injuries are fully healed.

Several other decay infections were included in Table 4 which were not the direct result of logging injuries. These included three *Echinodontium tinctorium* and one *Haematostereum sanguinolentum* infection, all from the Fortune Creek study area. The latter infection had entered an advance regeneration stem through a pre-logging windthrow scar. Two of the three E.t.² infections were present in advance growth stems prior to logging in the form of dormant infections. The infections may have been re-activated by logging injuries which initiated the decay process. The third pre-logging E.t. infection was probably released and caused decay prior to logging. The significance and threat to subalpine fir advance regeneration of E.t. will be discussed subsequently.

Table 4 provides damage and decay frequencies for residual subalpine fir regeneration (larger than 3.0 m in height at release). The average frequency of damage to these stems was high (38 percent) for both partial-cut stands. The average incidence of active decay infections was 23 percent, and represented a considerable proportion of the total stocking of this size class.

Even more significant, however, is the extremely high infection rate of residuals injured by logging. Of the total number of residual trees from all areas injured at the time of logging, 60 percent were found to contain active decay associated with the wounds at the time of sampling in 1975. These large residual stems often sustain serious injuries, causing large wounds, which may remain unhealed for many decades and result in a high risk of infection and decay.

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2. Throughout the remainder of this report the Indian paint fungus (*Echinodontium tinctorium*) will be referred to by the abbreviation E.t.
Figure 7. Typical logging damage to the lower boles of large residual subalpine fir in the Fortune Creek study area.

Figure 8. Logging injury and associated decay (Haematostereum sanguinolentum) in a residual subalpine fir.
Besides presenting a rather low crop-tree potential themselves, residual stems (particularly large ones) pose a threat to the small, vigorous advance regeneration within a partial-cut stand. As the advance growth increases in size after release, it becomes more susceptible to serious injury and infection due to scarring from residual windthrow. Strong evidence supporting high residual mortality and windthrow after partial cutting is provided by a 1952 study at Bolean Lake, as reported by Smith and Clark (1974). The early removal of residuals will greatly reduce damage and defect to the advance regeneration which will still be small and relatively unsusceptible to serious injury. In the case of relatively dense residual stands, early removal will also more fully release the understory advance growth.

The most common wound parasite attacking subalpine fir residuals damaged by logging was *Haematostereum sanguinolentum* which accounted for 72 percent of all wound induced decay. *Amylostereum chailletii* and an unknown brown cubical rot accounted for the remaining 18 and 10 percent respectively. Three pre-logging decay infections caused by *Haematostereum sanguinolentum*, *Hericium abietis* and *Odontia bicolor* root rot were also included in the data of Table 4.

2. Threat by the Indian Paint Fungus

The analytical method used to determine the presence of E.t. infections included supplementary sampling and cultural isolations from small embedded branch stubs and stem piths from suppressed cores of advance regeneration over 60 years of age. Previous studies by Etheridge and Craig (in press) indicated that E.t. does not enter trees through large injuries as does a wound parasite such as *Haematostereum sanguinolentum*. Instead, entry courts for E.t. are very small diameter branch stubs which have broken off flush with either a main branch or the main stem of a tree. The duration of the healing process for these stubs determines their suitability as entry courts to the fungus. Long periods of suppression with the associated depressed radial increment and callus tissue development greatly increase the likelihood of infection. In the case of advance subalpine fir regeneration, the slow rate of growth in a suppressed understory and the formation of small diameter branch stubs on the main stem make these trees potential targets for E.t. infections prior to logging. The results of a study of amabilis fir (Etheridge and Craig, 1975) indicate that approximately 60 years of continuous suppression was required before suitable entry courts could form in significant numbers. Once infection takes place during suppression, however, the fungus commonly enters a dormant stage and may be overgrown by wood tissue. These pre-logging dormant infections, if present, could pose a serious threat to the management of advance subalpine fir, since logging injuries are capable of reactivating the infection and initiating the decay process.

The results of the E.t. analysis (based on 384 isolations) indicate no dormant infections were present in the stems sampled. Pre-logging infections were of some significance, however, since three E.t. infections were found in advance regeneration in the Fortune Creek study area, as
was previously mentioned. These advance growth stems were very old (avg. 128 years at release) with an average height at release of 2.6 m and contained dormant infections prior to logging. However, the accelerated radial growth of these trees following logging may seal off the infections and decay to the extent that the fungus may again revert to its dormant state (pers. comm. H. Craig).

The absence of any dormant infections in the supplementary subalpine fir samples may have been due to their relatively young age (avg. 86 years). Since a minimum suppressed age of 60 years (based on studies of amabilis fir) may be necessary before suitable entry courts are formed, these samples may have been too young to be infected by E.t. in the understory. It should be noted that in the case of the three clearcut study areas (Raft Mtn., Sock Lake, Bolean Lake), the average age of surviving regeneration had been reduced to the extent that finding a stem older than 60 years at release was extremely difficult. In contrast, the average age of survivors in the two partial-cut stands was much higher (see Table 1).

CONCLUSIONS AND RECOMMENDATIONS

Based on sampling and analysis of advance subalpine fir in the Kamloops Forest District, the major conclusions of the study are as follows:

1. Age and size of advance subalpine fir regeneration are not directly related, making accurate age prediction based on relative size impossible. As a general rule, however, the largest advance regeneration in a stand tend to be the oldest.

2. Radial growth response delays following release by logging are commonly one or two full years following the year of logging. Significant height growth response may be delayed from three to five years after the year of logging.

3. Stem form of advance subalpine fir regeneration is often poor before or immediately following release by logging. However, after growth rates accelerate, all but the most severe stem deformities are usually outgrown. Severe deformities are generally the result of logging damage.

4. Stocking and density of advance subalpine fir regeneration depends on pre-logging understory stocking and the degree of logging disturbance. Generally, stocking tends to be patchy with overstocked clumps and non-stocked, variable-sized openings.
5. Following an initial response delay period, advance subalpine fir regeneration is capable of excellent growth performance. The major factors affecting growth are tree competition and site quality.

6. There is no direct relationship between stem age at release and response-growth performance.

7. The most common wound parasites attacking subalpine fir advance regeneration and residuals injured by logging are *Haematostereum sanguinolentum* and *Amylostereum chailletii*.

8. The smaller size class (0.0-1.3 m height at release) of advance regeneration sustains less serious damage and exhibits lower decay rates than the larger size class (1.3-3.0 m). This is evidenced by the excellent pathological conditions of the study areas which received a residual-removal treatment in which all trees over 1.3 m in height-at-release were destroyed.

9. Residual stems preserved during partial cutting have poor crop-tree potential due to the incidence of serious logging damage and associated decay.

10. The threat to advance subalpine fir regeneration by the Indian paint fungus is low. However, it is likely that the threat increases with age-at-release. For this reason, treatments which tend to reduce the average age of surviving advance growth are desirable.

**APPLICATION OF STUDY RESULTS**

Caution should be exercised before extrapolating the results of this study to present-day conditions. The logging methods, degree of ground disturbance, and the size and distribution of surviving advance growth in the areas investigated during the study bear little similarity to the characteristics of currently logged-over sites in the Engelmann spruce-subalpine fir zone of the Kamloops Forest District. However, through changes in harvesting technique and silvicultural prescription, it may be possible to obtain acceptable restocking by using advance regeneration as a partial restocking component. Based on some of the findings of this report, silvicultural recommendations and theoretical site prescriptions are described below in an attempt to apply existing and new knowledge to a specific aspect of high elevation reforestation. Many assumptions are made, and no economic consideration was given to the recommendations. Nevertheless, given the high levels of understory destruction resulting from current harvesting practices, unless the following prescriptions and recommendations are given serious consideration the use of advance regeneration in reforestation is impossible, and any research into the subject merely a theoretical exercise.
Three preliminary requirements must be met if reforestation by advance regeneration is considered. These requirements are described briefly.

SUITABILITY OF SITE

Before any consideration can be given to utilizing advance subalpine fir regeneration, the site must be assessed for its suitability in supporting the growth of the species. Very dry sites having moisture deficit problems (due either to edaphic or climatic factors) will not support satisfactory subalpine fir growth and should not be selected for advance regeneration management. The presence of advance growth in the understory of such a site prior to logging is not reason enough to consider it as suited to the growth of subalpine fir after logging.

UNDERSTORY STOCKING

A suitable level of understory advance regeneration stocking prior to logging is required to ensure adequate stocking after logging and associated mortality. An intensive pre-logging advance regeneration survey is required to obtain this information. Only advance regeneration within size class 1 (0.0-1.3 m in height) should be tallied in such a survey. All but the most severely deformed or damaged stems in this size class should be considered as acceptable regeneration. Larger advance regeneration within size class 2 (1.3-3.0 m in height) should not be considered as acceptable stocking since it is doubtful that many trees of this size class would survive a close utilization logging operation. The pre-logging stocking level is presently an unknown factor and will only be determined through further study and experience.

SUITABILITY OF LOGGING METHOD

The suitability of the logging method from the standpoint of understory protection and slash-fuel control is one of the major requirements of advance regeneration management. The aspect of understory protection is particularly important. This requirement may be met by currently used skidding machinery, but only through a more sophisticated method of limited access skidroad layout. Present-day stump-to-landing tractor operation is not compatible with understory protection. Gottfried and Jones (1975) recommend pre-planning and layout of skidroads with careful tractor winching techniques. This must be coupled with rigidly enforced regulations which will ensure that machines do not traverse the between-road areas. Engineering expertise and practical experience will likely determine the optimum skidroad density and layout which will provide an acceptable level of understory protection. Consideration must be given to slash-fuel loading and fire hazard in the logging plan, since any form of post-logging mechanical site preparation for slash hazard abatement would result in severe understory destruction. Slash control must be made an integral part of the logging utilization standard.
Assuming the above requirements are met, the following recommendations for silvicultural treatment are presented:

1. Cutting Prescriptions

All residual size trees (over 3.0 m in height) are to be felled during the commercial falling operation, regardless of vigour or form. These trees are poor risk crop-trees due to their high incidence of serious logging injury and associated decay, and the possibility of dormant E.t. infection. All advance regeneration in size class 2 (1.3-3.0 m) are to be left standing during the falling operation. The survivors of this size class will be treated after logging by silvicultural prescription.

2. Post-Logging Treatment

Post-logging treatment for the management of advance regeneration should be undertaken to improve stocking and density, stem form, health, and species mix. A spacing-cleaning of the advance subalpine fir (and spruce, if present) component will greatly reduce clumpiness and competition. Removal of surviving, but badly damaged advance regeneration in size class 2 will also reduce the incidence of deformity and wound-associated decay. Spacing and crop-tree selection priorities should conform to the following format, although specific site and stocking conditions will ultimately govern the treatment applied.

i) Eliminate all of the following:
   (a) badly damaged size class 2 stems (bole injuries greater than 30 cm in length or 3 cm in width, or with broken tops)
   (b) badly deformed size class 2 stems (extreme basal sweeps or crooks, or stems flattened or deformed by slash)

ii) Space to an acceptable density (i.e. 2-3 m spacing) according to the following priority classes:
   Priority 1. undamaged size class 1 stems of good form
   Priority 2. undamaged size class 2 stems
   Priority 3. slightly damaged size class 1 stems (wounds less than 3 cm in width) of good form
   Priority 4. slightly damaged size class 2 stems (wounds less than 30 cm in length or 3 cm in width)

Spruce advance regeneration (where present) conforming to any of the above priority classes shall take priority over any subalpine fir advance regeneration in a crop-tree-selection decision. The overall species mix may be improved by fill-planting with large, high quality spruce stock, either in conjunction with the spacing-cleaning treatment, or shortly afterwards.
Obviously, the labour intensive treatments recommended for advance regeneration management will be costly. However, it will only be through operational trials and much practical experience that the relative benefits and drawbacks of this as yet untried high elevation silvicultural system will be determined.
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