Development of a Residual Stand of Interior Spruce-Alpine Fir during the First Twenty-eight Years Following Cutting to a 12-inch-diameter Limit

By

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DEPARTMENT OF LANDS AND FORESTS
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TABLE 1--Residual Stand, 1929 (Stems-per-acre)

<table>
<thead>
<tr>
<th></th>
<th>Regeneration</th>
<th>Poles</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>d, b, h</td>
<td>0-3.9&quot;</td>
<td>4.0-7.9&quot;</td>
<td>8.0-11.9&quot;</td>
</tr>
<tr>
<td>Spruce</td>
<td>407</td>
<td>22</td>
<td>44</td>
</tr>
<tr>
<td>Others*</td>
<td>2,681</td>
<td>110</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>3,088</td>
<td>132</td>
<td>90</td>
</tr>
</tbody>
</table>

* Almost entirely alpine fir.

Age of trees and poles ranged from 198 to 288 years for spruce and from 150 to 220 years for alpine fir. Spruce poles were, in general, long and slender and belonged to the upper canopy, while alpine fir poles mainly occupied the understorey. Numerous residuals, particularly alpine fir, were infected by Echonodontium tinctorium. Advance reproduction, composed of relatively stunted individuals, occurred in dense clusters. While little soil disturbance resulted from the logging process itself, slash piling and burning had created a pattern of well distributed patches of exposed mineral soil, about 30-40 per acre.

EXPERIMENTAL LAY-OUT

In the early summer of 1929, nine permanent sub-plots, totalling 1.2 acres, were distributed over about 75 acres of the residual stand. Diameters of all residuals down to 0.5" were tallied. Obvious defects of individuals were recorded and each stem was tagged. A tally was made on each sub-plot, giving species and diameter of all stumps. Re-examinations were carried out in 1930, 1932, 1936, and 1957. The final examination was completed with a count of all established reproduction, down to 3-year-old seedlings.

Within these sub-plots, six 1/200-acre plots were laid out for studying establishment of regeneration following hand-scarification. In 1957, it was realized these sub-plots were too small, and since, in the interim, various other projects had been carried out to study the influence of seed-bed upon regeneration, it was decided not to re-measure them. The results on one sub-plot, however, are illustrated.

A second group of sub-plots consisted of eight permanent reproduction-strips randomly located in the residual stand. In 1929, 1930,
In 1930, one permanent sub-plot (1/200-acre) was placed in a
cluster of advance reproduction to determine survival and rate of height
growth. Heights of 102 tagged stems, predominantly alpine fir, were
recorded in 1930, 1936, and 1957. The final examination was completed
and included age-determination of each individual stem.

In 1957, a reproduction sample of 202 spruce was taken at
random from the nine permanent sub-plots described above. The age of
each individual and its height were determined.

In 1957, one hundred and fifty-seven stems were randomly
selected from the residual stand. Age as well as diameter-growth dur-
ing the past 56 years (28 years before release plus 28 years after re-
lease) were determined for each individual. Diameters and distances
of all competitors, stumps, and wind-falls were recorded within a 15-
foot radius of each sample stem. As a control, the same data were
collected from 50 stems in the adjacent virgin stand.

DEVELOPMENT OF RESIDUAL STAND 1929-57

A. TREES AND POLES

TABLE 2--Rate of Mortality 1929-57 in Stems

<table>
<thead>
<tr>
<th></th>
<th>1929</th>
<th>1930</th>
<th>1932</th>
<th>1936</th>
<th>1957</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Weighted Average 51</td>
</tr>
<tr>
<td>Date</td>
<td>Per cent of stems left in 1929</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1929</td>
<td>1930</td>
<td>1932</td>
<td>1936</td>
<td>1957</td>
</tr>
<tr>
<td>Spruce</td>
<td>0</td>
<td>17</td>
<td>39</td>
<td>58</td>
<td>72</td>
</tr>
<tr>
<td>Alpine Fir</td>
<td>0</td>
<td>11</td>
<td>15</td>
<td>34</td>
<td>42</td>
</tr>
</tbody>
</table>

1. Number of Stems. As can be seen from Table 2, the original num-
ber of residual stems was severely reduced during the past 28 years.
This is chiefly attributable to the destructive effects of wind in the
study area. Mainly affected by wind disturbance were the tall and
slender spruce poles, while alpine fir showed higher resistance.
Mortality varied among the different plots but, in an individual case,
DEVELOPMENT OF A RESIDUAL STAND OF INTERIOR SPRUCE-ALPINE FIR DURING THE FIRST 28 YEARS FOLLOWING CUTTING TO A 12-INCH DIAMETER-LIMIT

INTRODUCTION

The majority of spruce-alpine fir forests in the Interior of British Columbia have a characteristic vertical structure of various layers. Conventional cutting methods (diameter-limit, single-tree selection, marking for residual seed trees or blocks, strip-cuts, as well as commercial clear-cuts) all have in common the removal of part of the main canopy and the leaving of the bulk of the understorey. Conditions in these residual stands are of great significance from the standpoint of a second crop. Yet there is uncertainty as to whether or not residual elements are apt to develop into merchantable stems or whether—and under what circumstances—they interfere with the establishment of a more promising new generation.

In 1928, plans were made to keep track of the development of a residual stand following cutting to a 12-inch diameter limit and, in particular, to investigate (a) survival and growth of residual stems, and (b) the rate of subsequent seedling establishment. In 1929, a study area was selected, and permanent plots were established. Re-examinations of the area were carried out in 1930, 1932, 1936, and 1957. The final examination, in 1957, was supplemented by an investigation into some factors responsible for the radial-release growth of residual stems.

It should be pointed out that between the date this study was initiated and the present time there have been progressive changes in forest management practices. Carte blanche Timber Sales to a 12-inch diameter limit are giving way to Sales requiring specific cutting methods and treatments. These changes are based on experience gained from observation and changing economic conditions. Their effectiveness can only be judged in retrospect. This study is a careful analysis of a residual stand resulting from cutting an over-mature spruce-alpine fir forest to a 12-inch diameter limit, 28 years ago.

DESCRIPTION OF STUDY AREA

The study area is situated in the Similkameen Land District, about 13 miles SE of Kelowna and 5 miles SW of McCulloch. It is part of the Little White Mountain Provincial Forest. The stand is located at an elevation of 4,700 feet, close to the top of a west-exposed ridge.

*Abstract of a full report on E.P.'s 160 and 503.
Climatic data are available for McCulloch which is in the immediate vicinity of the stand in question. They are characterized by low yearly average temperature (37°F) and precipitation (27 ins.). Winters are fairly long, first snow falling in October and break-up starting in May. Rain falls mainly in the Spring, but sufficient moisture is provided throughout the growing season by melting snow and frequent thunderstorms during the Summer. At the peak of the season, daily maximum temperatures rarely exceed 90°F and frost at nights is not uncommon. Winds, from the west in particular, are a serious factor for the stands on this exposed ridge. Soils are rather shallow and, thus, contribute to the wind-susceptibility of the stands.

The merchantable volume of the original stand on the study area was estimated to be 13,500 F.B.M. per acre, 87 per cent being spruce, the remainder alpine fir and lodgepole pine. This stand was cut in late 1928 as part of a normal Timber Sale. The major contract conditions are summarized as follows:

1. Trees to be cut comprised all trees, regardless of species, containing 50% or more of the total volume suitable for lumber manufacture, with the exception of spruce trees below 12" d.b.h.; trees to be cut as well as trees to be left might also be designated by the Forest Officer.

2. Unnecessary damage to reserved trees or to young growth was to be paid for at the rate of $5.00 per tree.

3. Slash was to be piled compactly, away from live trees and reproduction. All unmerchantable alpine fir down to 4" d.b.h., within 10 feet of slash piles, had to be cut and piled with slash. Slash had then to be burned at the expense of the operator.

4. Snags, considered as a hazard by the Forest Officer, had to be felled at the expense of the operator.

Close supervision as well as a co-operative attitude on the part of the operator provided that contract clauses were well observed. Cutting and horse-skidding were active on the study area from September to December, 1928, while slash disposal was completed by March, 1929.

Cutting of the merchantable elements left a variety of residual stand conditions, ranging from almost undisturbed patches to excessively opened-up areas. The average acre, immediately after logging, supported the following stand:
went as high as 100 per cent. The study area is located in what has come to be recognized as a region that is subject to heavy wind-throw and this dominant influence of wind lasted for about seven to nine years, after which time the majority of wind-susceptible elements had been weeded out of the stand. In subsequent years, mortality decreased gradually, concentrating on those stems which had been weakened by previous disturbance.

2. Basal Area. Mortality affected the weighted average of spruce and alpine fir basal area at a higher level (71 per cent, Table 3) than it did number of stems (51 per cent, Table 1). On a total stand basis, accelerated rate of growth of residuals did not compensate for the reduction suffered due to mortality. Positive net growth, as shown by Table 3, was only realized in alpine fir trees, being the result of higher wind resistance and stronger release-response of previously suppressed individuals.

TABLE 3--Development of Basal Area (sq. ft.) 1929-57 in Stems 4"-d.b.h. and Over (based on 9 sub-plots, 1.2 acre)

<table>
<thead>
<tr>
<th></th>
<th>Mortality 1929-57</th>
<th>Ingrowth 1929-57</th>
<th>Net Growth 1929-57</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spruce</td>
<td>Alpine Fir</td>
<td>Spruce</td>
</tr>
<tr>
<td>Poles</td>
<td>26.4</td>
<td>77</td>
<td>28.5</td>
</tr>
<tr>
<td>Trees</td>
<td>12.6</td>
<td>96</td>
<td>14.1</td>
</tr>
<tr>
<td>Total</td>
<td>39.0</td>
<td>82</td>
<td>42.6</td>
</tr>
</tbody>
</table>

* in percentage of residual stand, 1929.

Marked differences were observed between the reactions to various cutting intensities on the nine sub-plots. Correlation analysis showed a high degree of association between cutting intensity and mortality, correlation coefficients being:

\[ r_1 = +0.96; \text{significant at 0.1\% level} \]
\[ r_2 = +0.88; \text{significant at 1.0\% level} \]

This demonstrates that excessive opening up in parts of the stand, decreased the resistance of residuals against wind disturbance.

\( \dagger \) Cutting intensity = \( x = \frac{b.a.}{b.a.} \) of stumps in per cent of b.a. of original stand

Mortality 1929-36 = \( Y_1 = \frac{b.a.}{b.a.} \) of stems killed until 1936 in per cent of b.a. of residual stand 1929

Mortality 1929-57 = \( Y_2 = \text{analogous} \)
3. Quality. In following the development of three quality-classes (1-Good, 2- and 3-Cull, based on increasing evidence of disease and/or injury) throughout the past 28 years (see Fig. 1), it was noticed that mortality was higher for initially poor quality stems and vice versa. This trend was less evident in the initial phases (until 1932) but later became more pronounced. By 1957, all individuals of the poorer quality class (3) had died, while a considerable proportion of originally good stems had suffered damage through wind disturbance. Only 25 per cent of the original sample stems have been left in more-or-less good growing condition.

4. Release-Response of Individual Stems. Analysis of the radial growth during the past 56 years revealed a striking difference between sample stems on the cut-over and those in the adjacent virgin stand (see Figs. 2 and 3). In undisturbed conditions, individual growth lines showed a slight decline, probably attributable to gradual stagnation due to dense stocking. On the cut-over, a marked increase in radial growth was noticeable in most of the residual stems. Expressing diameter growth 1929-57 (after release) in per cent of diameter growth 1901-29 (prior to release), D per cent values were calculated which, for alpine fir, averaged 373 per cent. Individual values went as high as 1115 per cent. In general, the first five years after release were recognized as an adaptation period, radial growth being equal or slightly above the previous five years. Maximum D per cent values were then reached about 10 to 15 years following release, while they gradually declined after 20 years.

Among factors assessed for their importance in determining the release response, diameter at time of release, as well as the number of competitors left after release, were found to be of relatively high significance (correl. coeff. being $r_1 = -0.36$ and $r_2 = -0.59$; both significant at the 0.1 per cent level). Smaller sized stems reacted more vigorously than larger ones, and growth response increased with decreasing number of competitors. There was some indication that the release reaction increased with the degree of suppression prior to release. By contrast, age seemed to be of little importance to the intensity of response. None of the individual factors assessed were associated intimately enough to allow a reasonably accurate prediction of D per cent.

Due to the high mortality of spruce, only a few stems of this species were left for analysis of radial growth. Stems sampled showed a more or less distinct release-reaction which, however, was lower than that of alpine fir (217 per cent). Individuals with well-developed crowns had definitely superior release-growth than those with poor crowns.
Absolute release growth was markedly higher in residual alpine fir than in spruce. Being particularly interested in the prospects of good quality residuals (i.e. possible aspirants of a future crop), individual growth lines of such stems were extrapolated to 1969, forty years after cutting. Results showed that only three spruce and 24 alpine fir would be available in merchantable size (12" d.b.h.*) and quality on the average acre at that date. This demonstrates clearly that the bulk of release growth has, thus, been wasted on poor-quality stems. Remarkable as this growth response was, it has not materially improved the prospects of the residual stand in terms of a second crop.

B. ADVANCE REPRODUCTION

As shown in Table 1, a good portion of advance reproduction was left after the cut in 1929. It consisted mainly of dense patches of stunted alpine fir which suffered from heavy mutual competition. The development of such a cluster of 102 stems was followed from 1930 to 1957. Results show a 69 per cent mortality for spruce as compared to a 29 per cent mortality for alpine fir over the 27-year period. The rate of mortality was higher in initially short stems and vice versa. Height growth of surviving stems was very slow, averaging 0.6-inch per year. As demonstrated in Table 4, height growth increased with initial height of the stem. Most of the tall individuals, however, were older than their inferior associates, so that age accounts for part of the effect.

TABLE 4--Height Growth 1930-57 in Three Height Classes of Advance Alpine Fir Reproduction.

<table>
<thead>
<tr>
<th>Height-Class, 1930</th>
<th>Number of Stems</th>
<th>Av. Age, 1930</th>
<th>Av. Height, 1930</th>
<th>Av. Height-Growth 1930-57</th>
<th>Av. Height 1957</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (0-1.9 ft.)</td>
<td>27</td>
<td>30</td>
<td>1.25</td>
<td>0.83</td>
<td>2.08</td>
</tr>
<tr>
<td>II (2.0-3.9 ft.)</td>
<td>20</td>
<td>56</td>
<td>2.65</td>
<td>1.47</td>
<td>4.12</td>
</tr>
<tr>
<td>III (4.0 ft. +)</td>
<td>6</td>
<td>81</td>
<td>4.90</td>
<td>3.63</td>
<td>8.53</td>
</tr>
</tbody>
</table>

Prospects for even the tallest stems, having reached 8.5 feet at an age of 108 years, are not such that they could be considered as aspirants for future crop trees.

More rapid growth was observed in advance reproduction outside clusters.
C. ESTABLISHMENT OF REPRODUCTION AFTER 1929

Mortality and stagnation in advance reproduction were largely compensated for by a high rate of subsequent seedling establishment on the cut-over. After a reduction to about 40 per cent of the original 3,000 stems (0-3.9" d.b.h.) by 1936, the number of seedlings increased rapidly and reached the level of 5,500, by 1957. At the same time, the species-ratio, alpine fir/spruce, changed from 6:1 to 3:1.

This unusual trend on a spruce-alpine fir cut-over is directly attributable to the creation of a favourable seed-bed through slash piling and burning. The majority of young spruces were found to stock on burned patches. Most of them were in vigorous growing condition, forming a marked contrast to stagnating clumps of advance reproduction. Considering that the participation of spruce in the overstorey followed a steady decline, its proportional increase in the reproduction layer is remarkable. It would appear, therefore, that under the conditions encountered, the small number of residual spruce trees and poles showed a distinctively higher reproductive ability than the large number of alpine fir.

SUMMARY

The development of a residual stand of spruce-alpine fir was studied during the first 28-year period after cutting an over-mature spruce-alpine fir stand. The following results were obtained:

1. High mortality related to wind disturbance caused a severe reduction in residual stems. Chiefly affected were remnants of the upper canopy, slender spruce poles in particular. Death-toll was higher for poor-quality stems than for good ones and was high enough to offset gross growth in basal area over the 28-year period.

2. Mortality increased with cutting intensity.

3. Surviving poles and trees showed significantly higher radial growth (release growth) than corresponding control stems from the adjacent virgin stand. Release reaction, as well as absolute release growth, were higher in alpine fir than in spruce. The bulk of this release growth, however, was built up by poor-quality stems.

4. Among factors assessed, number of competitors and d.b.h. proved to be the most significant in determining radial-release
growth. Less important were factors such as the degree of suppression prior to release, and age. Three distinct periods were recognized in the release reaction: adaptation, maximum response, and decline.

5. Advance reproduction suffered a considerable reduction, spruce in particular. Height-growth of surviving stems was extremely slow. Initial height was found to be an important factor in affecting survival and height-growth of individuals.

6. Subsequent establishment of regeneration was obviously facilitated by seed-bed preparation through piling and burning of slash. Spruce seedlings showed a definite preference for spots of exposed mineral soil. The species ratio of alpine fir/spruce in the regeneration layer changed from 6:1, in 1929, to 3:1, in 1957.

CONCLUSIONS

1. Under the wind-exposed conditions prevailing on the cutting area, the careful preservation of spruce poles during the logging process proved to be of little value to the next crop.

2. Residual elements in general (trees, poles, and advance reproduction) contributed but indirectly to the potential future of the stand. Their main value may have consisted in providing seed as well as some shade for succulent seedlings, and in hindering the formation of excessive brush.

3. The next harvest will be recruited largely from stems having established after the 1929 cutting.
FIG. 1  DEVELOPMENT 1929-57 OF 3 QUALITY CLASSES
in stems 4" d.b.h. and over (9 sub-plots, 1.2 acres)
SPECIES COMBINED

LEGEND:
- GOOD
- CULL
- WINDFALL
- SNAGS

Note: width of columns indicates weight of quality classes
Development of residual stand on subplot 15 from 1929 (1) to 1932 (2) until 1957 (3). While none of the residual spruce poles survived, dense clusters of spruce reproduction and some scattered lodgepole pine became established.
Experimental scarification on subplot 13 carried out in 1929 (4) resulted in promising spruce reproduction by 1957 (6). Practically the entire residual stand was blown down by 1932 (5).
Portion of subplot 13 in 1929 (7) and 1957 (8). Note re-established brush thicket of Rhododendron and Menziesia, also multi-layered structure of residual stand in background.