THE EFFECTS OF OPERATIONAL APPLICATION OF HERBICIDE GLYPHOSATE ON TARGET BRUSH SPECIES AND CONIFER CROP - SX TRIAL 87711R
Final Report and Four Years After Application

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THE EFFECTS OF OPERATIONAL APPLICATION
OF THE HERBICIDE GLYPHOSATE ON TARGET BRUSH SPECIES,
SELECTED BROWSE SPECIES AND CONIFER CROP TREES

SX TRIAL 87711R

4. Final Report and Four Years After Application

Prepared for the
British Columbia Ministry of Forests
Prince Rupert Forest Region

by

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Mountainview Ecological Services
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November 1991
EXECUTIVE SUMMARY

The effect of operational application of glyphosate on target brush, conifer crop trees, and selected browse species - SX trial 87711R.

The trial was established in 1987 and the final measurements were taken in 1991. Permanent plots and transects were placed in 8 clearcut blocks in the Prince Rupert Forest Region. Six blocks were treated aerially, two by back pack sprayers, all at a rate of 1.76 - 2.00 kg a.i./ha glyphosate (5-6 litres/ha).

Measurements were made before, and 1 and 2 years after treatment. A subjective "walk through" assessment of the sites was carried out 4 years after treatment.* The effect of glyphosate on the growth and recovery of selected browse species (i.e. willows, red-osier dogwood, Douglas maple and mountain ash) was observed.

1. Effect on Target Brush On six sites, the volume/hectare of all tallest target brush was reduced by between 60 and 90% one year after treatment with a 40-50% reduction on the other two sites. The vol/ha of the major target competing brush species was reduced by over 80% on six sites and by over 40% on the remaining two sites.

Two years after treatment, the volume of all tallest target brush was increasing due to a shift from shrubs and fireweed to largely grasses and other forbs as the major competing target brush species.

By the fourth year after treatment, there was a decline in the quantity of grasses and forbs on all sites (except the North Babine site) with a concomitant increase in the volume of some of the original target brush species.

2. Effects on Conifers Glyphosate application was effective for conifer release scenarios. Conifers planted after the treatment were being shaded out due to a species shift to a heavy increase of grasses and other vegetation that occurred in the first three years after treatment.

Crop trees were present on five of the sites before treatment. The rate of annual growth increased after treatment with increases varying from 25-70% of the original leader length and was apparently not affected much by increasing brush cover in year two. By year 4 after treatment, conifers originally present on these sites were taller than, or as tall as, the surrounding vegetation.

3. Effects on Selected Browse Species Four growing seasons after treatment, the glyphosate application resulted in a decrease varying from 18-100% in the quantity of selected browse species. The magnitude of the effect varied from site to site due to a number of factors. The time and method of application, weather conditions at the time of application, the condition (age, height and size) of both the selected browse species and the surrounding vegetation, and the sensitivity of the selected browse species all appear to influence the severity of the impact of the herbicide on browse species.

* Years refers to years or growing seasons after treatment.
Young plants of all species were severely affected. Older plants were almost completely killed on the Nilkitkwa site, where an early frost immediately prior to application may have influenced the outcome.

Dogwood and willow were less sensitive than maple and mountain ash. Dogwood sprayed late in the season, or growing under a heavy canopy of other brush, was only lightly affected and responded to removal of competing vegetation with a big increase in growth by year two. Similarly, lower branches of the selected browse species, except mountain ash, escaped severe impact and were recovering by year two. Although mountain ash is extremely sensitive and suffered a very severe impact, a number of surviving plants were showing recovery and good growth by year two.

Selected browse plants that survived and were producing good growth 2 years after treatment were usually recovering well by the 4th year after treatment. Most plants with severe, or very severe, initial damage were dead by the second year after treatment. Most plants that showed poor recovery by the 2nd year after treatment were dead by year 4. Plants that were lightly or moderately damaged usually recover well and were producing normal growth by year 4 after treatment.

An initial monitoring of sites within 1 or 2 years after glyphosate application can be used to make some general predictions about the potential recovery of browse species in subsequent years.
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Description of the Damage Category Classification System used in Assessing Glyphosate Impact on Selected Browse Species.
1.0 BACKGROUND AND INTRODUCTION

An Sx trial is a silviculture trial, generally of a short-term and operational nature. All trials have Working Plans and are given a trial number, and are catalogued with the B.C. Ministry of Forests, Silviculture Branch.

This trial was established in 1987 to address herbicide effects on moose browse and conifer release and establishment. An establishment report and interim reports, one and two years after treatment, were prepared (Pojar, 1987, 1988, and 1990). This is the final report of the project, which includes previous year's input as well as a 1991 assessment of the sites.

The experimental design was operational, and the results were confounded by many factors (both site and historical). These have been documented in past project reports (Pojar, 1987, 1988, and 1990) and make firm interpretations impossible. Furthermore, the site evaluation process and planning of herbicide usage have become refined since the trial establishment. These changes have made this trial's results somewhat redundant to operational forestry users of herbicides for other than subjective information.

The 5-year remeasurement (i.e. 4 years after treatment) was subjectively performed. This final report summarizes the history of the trial and presents subjective trends in browse species and vegetation invasion following herbicide use. Information on conifers is no longer considered to be an objective of the trial (due to historical confounding of the experiment), however, subjective comments are offered.
2.0 GLYPHOSATE APPLICATION, SITE LOCATION, AND MEASUREMENTS

Eight clearcut blocks (sites) were chosen for study. Three blocks were located in the Sub-Boreal Spruce biogeoclimatic zone (SBS) and five in the Interior Cedar-Hemlock zone (ICH). These were located in 4 different Forest Districts (Kispiox, Bulkley, Morice and Lakes) in the Prince Rupert Forest Region. Their location is indicated on an area map (page 3).

Glyphosate (Vision - Monsanto) was applied to six of the blocks by aerial spraying (helicopter) and by back-pack to the other two. Spraying was all carried out in 1987 and the rate and timing is summarized in Table 1.

<table>
<thead>
<tr>
<th>Site</th>
<th>Rate</th>
<th>Rate</th>
<th>Method of</th>
<th>Weather Conditions</th>
<th>Time of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babine</td>
<td>1.78</td>
<td>5.00</td>
<td>aerial</td>
<td>mild winds; R.H. = less than 48% on July 16</td>
<td>July 15 - 16</td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>1.80</td>
<td>5.00</td>
<td>aerial</td>
<td>early frost on Aug. 25 smoke from slash-burns</td>
<td>August 25 - 26</td>
</tr>
<tr>
<td>Morice River</td>
<td>2.00</td>
<td>6.00</td>
<td>backpack</td>
<td>generally good; heavy rain on September 12 rain after midnight</td>
<td>September 9 - 11 (incomplete)</td>
</tr>
<tr>
<td>Kwon Creek</td>
<td>2.00</td>
<td>6.00</td>
<td>aerial</td>
<td>good</td>
<td>August 26</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>1.91</td>
<td>5.50</td>
<td>aerial</td>
<td>generally good; gusty to 12k - on Aug. 4 wind gusty to 15k - forced to stop. light rain (R.H. 45, 47, 50 recorded) heavy dew to 10 a.m.; winds up at 11 a.m.; light rain; dew next a.m</td>
<td>August 25</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>1.96</td>
<td>3.50</td>
<td>backpack</td>
<td>generally good; gusty to 12k - on Aug. 4 wind gusty to 15k - forced to stop. light rain (R.H. 45, 47, 50 recorded) heavy dew to 10 a.m.; winds up at 11 a.m.; light rain; dew next a.m</td>
<td>August 26</td>
</tr>
<tr>
<td>Hoppes Ranch</td>
<td>1.78</td>
<td>5.00</td>
<td>aerial</td>
<td>generally good; gusty to 12k - on Aug. 4 wind gusty to 15k - forced to stop. light rain (R.H. 45, 47, 50 recorded) heavy dew to 10 a.m.; winds up at 11 a.m.; light rain; dew next a.m</td>
<td>August 25</td>
</tr>
<tr>
<td>Kispiox - Elizabeth Lake</td>
<td>1.76</td>
<td>5.00</td>
<td>aerial</td>
<td>generally good; gusty to 12k - on Aug. 4 wind gusty to 15k - forced to stop. light rain (R.H. 45, 47, 50 recorded) heavy dew to 10 a.m.; winds up at 11 a.m.; light rain; dew next a.m</td>
<td>September 2</td>
</tr>
</tbody>
</table>

Table 1 - Application of Glyphosate
The Sx Trial (#87711) was initiated in 1987. Plots and transects were established and their positions on the blocks is shown on maps and aerial photographs in Appendix B. There were no controls established - i.e. blocks, or parts thereof, that were not sprayed.

Baseline measurements of the vegetation, browse and conifers (described in the 1987 Working Plan - Appendix D) were taken in the summer of 1987 just prior to, or within two weeks after, the application of glyphosate. Photopoints were established along the transects and photos were taken at these points in years 1, 2, 3, and 5 of the trial. A selection of photographs taken at exactly the same photopoints on each cutblock in years 2, 3 and 5 are included in Appendix B. These provide a visual comparison of the vegetation changes that took place.

The results of the baseline studies are given in detail in Pojar, 1987.

Re-measurement of the plots etc. was carried out in the summers of 1988 and 1989 and details are given in annual reports (Pojar, 1988 and Pojar, 1990 respectively).

In the fifth year of the trial - i.e. 4 years after treatment (1991), the trial was evaluated subjectively by a walk through of all the blocks and the revised Working Plan, results, and photographs are in Appendix A.

The history of each site is summarized in Appendix B. More detailed information on site history is given in Pojar (1987).
3.0 FIVE YEAR SUMMARY OF TRIAL RESULTS AND DISCUSSION

3.1. Target Brush

Brush is defined as those plant species which compete with or impact on the establishment and growth of crop trees.

3.1.1. All Tallest Brush

"All tallest brush" means all those brush species which are, or are potentially capable of, overtopping crop trees. It does not include lichens, mosses, or plant species that never attain a total height sufficient to overtop crop tree seedlings. Most of the tallest brush consists of woody shrubs, but tall grasses and forbs, especially fireweed, are also included.

One year after treatment, the application of glyphosate had reduced the volume/hectare of all the tallest brush by between 60 and 90% on 6 out of the 8 sites (Figure 1). On the remaining two sites, the volume of all tallest brush was reduced by 40-50% of the original. Two years after treatment, the volume of brush was increasing again, but only exceeded that originally present on one site (North Babine). Much of the increase seen in year two was the result of a shift of species to invasive grasses and forbs (see below).

By the fourth year after treatment, the woody brush species were showing recovery but, for the most part the volume was estimated to still be lower than that originally present on all sites, except North Babine.

3.1.2. The Three Major Competing Brush Species on Each Plot and Species Shift

The three most abundant brush species of all the tallest brush on each plot before spraying were selected as the major competing species. Cover and height measurements for each of these three species were made according to the Working Plan (Appendix D).

The results (Pojar, 1987, Table 12) revealed that there was, in total, over 80% reduction of these major competing brush species on 6 out of the 8 sites and a 40% reduction on the remaining two sites. The three major competing brush species measured were sorted according to the main plant groups (i.e. shrubs, forbs, and grasses) and the results are presented graphically in Figures 2, 3, and 4.

Because most of the three major competing species measured prior to treatment were killed or severely reduced by glyphosate, to follow just these three species through successive years would have yielded very little information about vegetation changes. The original species were replaced by others that may, or may not, have been originally present on the site, but in smaller
amounts. In the second year after treatment, these new or 'additional' dominant species were measured and their volume is represented on Figures 2, 3, and 4 by broken lines.

Since these additional species were not recorded or measured in the baseline study, direct comparisons between the baseline results and those of subsequent years are not possible. However, the results did show a trend towards a **species shift** where the original major brush species, which were mainly woody shrubs or fireweed, were largely replaced by forbs and grasses together with the woody, invasive, red raspberry (**Rubus idaeus**).

Of the grasses, the native wildrye (**Elymus glaucus**) was particularly abundant on most of the sites by the 2nd year after treatment. Weedy annuals were abundant, especially on disturbed and compacted soils or in wet depressions. A more detailed discussion of this species shift can be found in Pojar 1990.

A composite of photos taken at the same point in the 1st, 2nd, and 4th years after treatment shows the vegetation changes on each site (Appendix B).
LEGEND - FIGURES 1 - 4

B = North Babine
N = Nilkitkwa
M = Morice River
Kw = Kwun Creek
A = Andi Creek
S = Sharpe Creek
H = Hopps Ranch
Kx = Kispiox - Elizabeth Lake
Fig. 1 MEAN VOLUME/HECTARE OF ALL TALLEST BRUSH BEFORE AND AFTER TREATMENT WITH GLYPHOSATE

- **= BEFORE TREATMENT
- □ = 1 YEAR AFTER TREATMENT
- ☐ = 2 YEARS AFTER TREATMENT

SCALE: 1 cm = 100 m$^3$

Mean volume/hectare (m$^3$/10)

<table>
<thead>
<tr>
<th>Site</th>
<th>B</th>
<th>N</th>
<th>M</th>
<th>Kw</th>
<th>A</th>
<th>S</th>
<th>H</th>
<th>Kx</th>
</tr>
</thead>
</table>

8
Fig. 2 MEAN VOLUME/HECTARE OF ALL MAJOR SHRUBS BEFORE AND AFTER TREATMENT WITH GLYPHOSATE

= BEFORE TREATMENT
= 1 YEAR AFTER TREATMENT
= 2 YEARS AFTER TREATMENT
= + ADDITIONAL SPECIES

SCALE: 1 cm = 50 m³

Mean volume/hectare (m³)

Site

B  N  M  Kw  A  S  H  Kx
Fig. 3  MEAN VOLUME/HECTARE OF ALL MAJOR FORBS BEFORE AND AFTER TREATMENT WITH GLYPHOSATE

- □ = BEFORE TREATMENT
- □ = 1 YEAR AFTER TREATMENT
- ◼ = 2 YEARS AFTER TREATMENT
- [ ] = ADDITIONAL DOMINANTS

SCALE: 1 cm = 20 m³
Fig. 4 MEAN VOLUME/HECTARE OF ALL MAJOR GRASSES BEFORE AND AFTER TREATMENT WITH GLYPHOSATE

- ■ = BEFORE TREATMENT
- □ = 1 YEAR AFTER TREATMENT
- ▲ = 2 YEARS AFTER TREATMENT
- ◐ = ADDITIONAL DOMINANTS

SCALE: 1 CM = 10 m³

Mean volume/hectare (m³)

Site

B  N  M  Kw  A  S  H  Kx
By the fourth year after treatment, on most sites, the flush of grasses and forbs (additional dominants) was beginning to decline. Wildrye grass was still present but, together with weedy species (thistles and annuals), appeared to be much less abundant and was apparently being replaced by recovering woody shrubs. Original major brush species such as fireweed, thimbleberry, bluejoint grass (Calamagrostis canadensis) and red-osier dogwood were recovering from the impact of the glyphosate. The recovery of taller woody shrubs (alder and willows) as well as aspen was more sporadic. Details on the year 5 assessment (4 years after treatment), on a site by site basis, are given in Appendix A.

The North Babine site was the one exception. The vegetation cover was extremely high on most of this block 4 years after treatment and most of the cover was still due to showy forbs and grasses. Bluejoint grass was becoming more abundant as wildrye and other grasses declined.

Re-vegetation of the sites was influenced by the conditions on the site prior to treatment. Factors such as species composition, structure (age, height and size) of competing vegetation, as well as the site preparation methods employed prior to treatment, all affected the post treatment re-vegetation.

It is possible that the observed impact of glyphosate and subsequent heavy vegetation cover (even 4 years after treatment) on the North Babine site is, in part, related to the site preparation prior to treatment. This block was mechanically site prepared and the brush piles were burned. It was then left for one year before herbicide treatment. In addition, this site was obviously quite wet. Black cottonwood was very abundant in the original stand and the was extensive ponding on the northern part of the block.
3.2. Selected Browse Species

Plant species considered important as winter browse for moose were selected and their response to glyphosate followed over the 5 year study. On Sub-Boreal Spruce sites, the selected browse species were willows and red-osier dogwood. On Interior Cedar-Hemlock sites, selected browse species were willows, red-osier dogwood, mountain ash and Douglas maple.

3.2.1. Tagged Browse Stems

Stems of selected species of browse were located and tagged as per the 1987 Working Plan (Appendix D). The growth condition and measurements of shoot length were made according to the method described by Lloyd (1987, revised 1989). This method was developed to describe the impact of herbicides on willows. Since the growth patterns of red-osier dogwood, maple and mountain ash differ from willow, some modifications were made and are described in Pojar, 1987, 1988 and 1990. Problems encountered in the use of this method for monitoring and changes to overcome these problems are discussed in Appendix E.

Essentially the method assumes that, in winter, moose prefer to browse new growth that was produced during the previous one (or two) growing seasons. Hence, the presence of new shoots and their length, gives the observer a subjective measure of the quality and, to some extent, the quantity of potentially 'available' browse on a site. Glyphosate typically kills actively growing shoots. It is also translocated down the plants to the roots and, in sufficient quantities, will kill the whole plant. If the stem is not completely killed, the plant will produce deformed growth the following year.

The extent of the deformities observed after treatment with glyphosate were determined by measuring the length of the longest new shoot arising from each 20 cm segment of the main stem. These were then depicted in graphical form (Figures 5 and 6) and used to form the basis of a system of classifying the impact of glyphosate (damage category) described in Appendix E.
Figure 5. Interpretation of Graphic Representation of Tagged Browse Before and After Treatment with Glyphosate

**severely affected**
- note rosettes of growth
- some short new laterals

**moderately affected**
- laterals do not exceed 20 cm in general
- longest ones are lower down stem
Figure 6. Graphic Representation of Tagged Browse Before and After Treatment with Glyphosate

WILLOWS

Before Treatment

One Year
After Treatment

Spots (S)

Very Severe

Severe

Moderate

Light

Number of the 20 cm Segment Down the Stem (L = Leader)

Length of Laterals (cm)

Length of Laterals (cm)
The results of the year two (i.e. one year after treatment) assessment of the impact of glyphosate (Table 2) show that there was considerable variation in the impact of glyphosate both between sites and between species. The majority of the willow stems were killed on the North Babine and Sharpe Creek sites. On the remaining sites there were quite high percentages (ranging from 26-44%) of 'very severely' affected willow stems. Similarly, high percentages (32-90%) of the stems of the other 3 species were severely damaged.

<table>
<thead>
<tr>
<th>Site</th>
<th>Total No. stems</th>
<th>Unaffected</th>
<th>Light</th>
<th>Moderate</th>
<th>Severe</th>
<th>V. Severe</th>
<th>Dead</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WILLOWS</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Babine</td>
<td>21</td>
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<td>&lt;5</td>
<td>&lt;5</td>
<td>0</td>
<td>&lt;5</td>
<td>90</td>
</tr>
<tr>
<td>Nilkitkwa</td>
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<td>0</td>
<td>4</td>
<td>0</td>
<td>44</td>
<td>52</td>
</tr>
<tr>
<td>Morice</td>
<td>25</td>
<td>56</td>
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<td>4</td>
<td>0</td>
<td>28</td>
<td>4</td>
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<td>Kwun Creek</td>
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<td>16</td>
<td>5</td>
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<td>16</td>
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<td>Andi Creek</td>
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<td>13</td>
<td>7</td>
<td>13</td>
<td>64</td>
<td>0</td>
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<td>Sharpe Creek</td>
<td>24</td>
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<td>13</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>75</td>
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<td>8</td>
<td>17</td>
<td>4</td>
<td>13</td>
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<tr>
<td>Kispix - Elizabeth Lake</td>
<td>29</td>
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<td>17</td>
<td>7</td>
<td>14</td>
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<td><strong>RED - OSIER DOGWOOD</strong></td>
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<td>&lt;5</td>
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<td>32</td>
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<tr>
<td><strong>DOUGLAS MAPLE</strong></td>
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<td>7</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>82</td>
</tr>
<tr>
<td>Hoppas Ranch</td>
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<td>0</td>
<td>0</td>
<td>43</td>
<td>36</td>
<td>7</td>
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<tr>
<td><strong>MOUNTAIN ASH</strong></td>
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<td></td>
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<td>8</td>
<td>25</td>
<td>59</td>
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<td>0</td>
<td>15</td>
<td>77</td>
<td>8</td>
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<td>8</td>
<td>25</td>
<td>59</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

* - see Appendix E for explanation
Possible explanations for the observed variation in the impact of glyphosate were discussed at length by Pojar (1988) and include differences in the method and timing of herbicide application, the weather conditions at the time of application, the condition (age, size, and vigour) of the browse plants themselves, and the composition and structure of the surrounding vegetation.

Sensitivity to glyphosate also varies from species to species. Douglas maple is extremely sensitive. Mountain ash is sensitive but appears to be able to recover better than maple. Willows are moderately resistant (or sensitive), whereas red-osier dogwood seems to be the least sensitive, especially when sprayed late in the season.

The ability of the browse stems to recover depended largely on the severity of the impact. Hence, most of the 'very severe', many of the 'severe', and a few of the 'moderate', did not survive through to the 2nd year after treatment (Table 3). The recovery growth condition categories of the surviving stems were defined based on the length of new shoots.

Four years after treatment (year 5 of the trial) the recovery of those tagged stems which had been previously classed as having 'poor' or 'fair' growth was evaluated. The results are presented in Appendix A. A summary of the results in Table A5 (Appendix A) and Table 3, show that the stems continue to die even up to 4 years after treatment and most of those that died were stems classed as having 'very poor' or 'poor' growth in the 2nd year after treatment. Most stems with 'fair' growth continued to recover and produce healthy growth by the 4th year after treatment. However, these are generalizations. The recovery of browse plants, like the response to glyphosate, varies considerably from species to species and each species should be assessed independently from the others.

Table A5 also includes values in parentheses that indicate how many of the dead stems are sprouting from bushes that are still alive. The sampling method chosen (i.e. selecting a single stem rather than a whole plant) should give a valid assessment of the overall browse condition on the site, providing enough stems are sampled. However, sampling a single stem from a multi-stemmed bush does not give information about the health of the rest of the bush.

Table 3 shows that, on 6 out of the 8 sites, over 50% of the willow stems were dead by the 4th year after treatment. The North Babine and Nikitkwa sites had 90% and 100% reduction of willows respectively by the 4th year. On the remaining two sites 36-44% of the willows were dead.

The decrease in the amount of red-osier dogwood was not as dramatic, reflecting the fact that this species is not as sensitive to glyphosate as willows. The North Babine site suffered 100% loss of the red-osier dogwood on site prior to treatment. This can be partly explained by the fact that all
stems tagged on this site were young and hence very sensitive to glyphosate and partly because the block was sprayed early in the season when dogwood is more sensitive. There was a 62% loss of tagged stems of this species on the Sharpe Creek site which was treated by backpack spraying. The reduction on the other sites, sprayed later in the season, was less than 30%.

Douglas maple, although highly sensitive, was only reduced by 46% on the Kwun Creek site, where heavy foliage cover afforded protection of lower branches. Where the maples were more exposed, (Hopps Ranch and Andi Creek sites) the reduction was higher (71% and 100% respectively).

Mountain ash was never abundant on any site, but of those stems tagged the reduction varied from 36% on the Andi Creek site to 91% on the Nilkitkwa site.

It was noted (Pojar, 1990) that many of the species originally present on the sites, other than those selected browse species examined, have been identified as having some value as winter browse for moose and deer (Pojar, 1990 - Table 3). Many of these were completely killed or severely reduced by glyphosate application.
<table>
<thead>
<tr>
<th>Site</th>
<th>Year 5</th>
<th>Condition of plants - year 3 (% stems recorded in year 1)</th>
<th>No. stems in Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>WILLOWS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babine</td>
<td>20</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>25</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Morice River</td>
<td>25</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>Kwon Creek</td>
<td>19</td>
<td>58</td>
<td>0</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>30</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>24</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Hopp's Ranch</td>
<td>24</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Kispiox - Elizabeth Lake</td>
<td>29</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>RED - OSIRED DOGWOOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babine</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morice River</td>
<td>18</td>
<td>78</td>
<td>0</td>
</tr>
<tr>
<td>Kwon Creek</td>
<td>22</td>
<td>81</td>
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</tr>
<tr>
<td>Andi Creek</td>
<td>10</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>26</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Kispiox - Elizabeth Lake</td>
<td>27</td>
<td>48</td>
<td>19</td>
</tr>
<tr>
<td>DOUGLAS MAPLE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kwon Creek</td>
<td>30</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>Andi Creek</td>
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<td></td>
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<td>Hopp's Ranch</td>
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<td>7</td>
<td>0</td>
</tr>
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<td>MOUNTAIN ASH</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>11</td>
<td>0</td>
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<td>Andi Creek</td>
<td>14</td>
<td>43</td>
<td>0</td>
</tr>
<tr>
<td>Hopp's Ranch</td>
<td>12</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>

* Good = shoots normal, over 30 cm; Fair = shoots normal, under 30 cm; Poor = shoots < 10 cm, in clusters or spindly to 30 cm; Dead = no growth
3.2.2. Browse Counted Along Transect - non-tagged

The number of stems of these same species present in an area 1 metre either side of the transect were also counted and classified according to their damage and recovery condition. These counts gave an overall impression of the quantity and quality of the remaining browse on the different study sites. The results from 2 years after treatment (Pojar, 1988 and 1990) showed the same trends as the tagged stems. A general evaluation of the browse remaining on the sites by the 4th year after treatment is summarized in Appendix A.
3.3. Conifer Crop Trees

The third objective of this trial was to study the impact of glyphosate on the conifer crop trees. Evaluation of this was, however, confounded by the fact that planting of conifers on the study sites was carried out at different times during the course of the trial. Some sites were treated with glyphosate to release conifers already on the site and to create additional planting spots. Other sites were treated with glyphosate prior to planting and did not have any conifers on them as the start of the trial. In addition, some sites were fill-planted at various times throughout the course of the trial. Hence, it was impossible to follow the impact of glyphosate on the crop trees except on those trees that were present before treatment (5 sites). The data collected is summarized in Pojar 1990, Table 6).

The impact of glyphosate per se on trees planted after treatment is indirect and in reality is an evaluation of how the re-invading vegetation was affecting their growth. The results are inconclusive (see Pojar 1987, 1988, and 1990).

The final assessment (four years after treatment - Appendix A) concluded that conifers present on study sites prior to treatment with glyphosate were all growing well and either have, or will soon, achieve 'free-to grow' status. The condition of conifers planted after treatment varied from site to site and is discussed briefly on a site basis in Appendix A.
3.4 Grasses on Hopps Ranch

The progress of the grasses on the Hopps Ranch site was followed at the request of the Bulkley District Office.

The block was seeded with a commercial grass mix (non-native species) in 1986 and cattle have been allowed to graze on the block since then. The cover of grasses on each plot was recorded over the 5 year trial.

Table 4. Percentage Cover of Grasses (native and introduced) on Hopps Ranch. (expressed as the total percentage of grasses within all plots)

<table>
<thead>
<tr>
<th>Before Treatment</th>
<th>After Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yr 1</td>
</tr>
<tr>
<td>8.6</td>
<td>16.0</td>
</tr>
</tbody>
</table>

* = estimated.

One year after treatment with glyphosate there was a marked increase in the quantity of grass on the block. This was due largely to an increase in the native grass - *Elymus glaucus* (wildrye grass) with some increase in the amount of the introduced species, especially *Dactylis glomerata* (orchard grass).

Two years after treatment wildrye and orchard grass were the dominant grass species on the block and cover values were very high for both species. Both were overtopping the conifers.

Four years after treatment the wildrye grass had decreased in quantity and was being replaced by fireweed and other original brush species. Orchard grass was the most common grass over most of the block. Except on the steepest slopes, this species was being heavily grazed by the cattle and hence was not overtopping the conifers. The conifers were growing extremely well on the lower, flatter part of the block where most of the cattle grazing is occurring. There was no obvious cattle damage to the trees.

On the steeper slopes, the orchard grass was overtopping the conifers, but they were growing well, although slower than on the flatter areas. There was no sign of snow press.

There was cause for concern at the top of the block (around plots 1-4 - see map Appendix B) and locally in wet spots elsewhere on the block, where bluejoint grass (*Calamagrostis canadensis*) had recovered and was responsible for cover values up to 100%.
4.0 SUMMARY CONCLUSIONS

4.1 General

1. The application of glyphosate was generally effective in reducing target brush species. Variations in efficacy can be attributed to a variety of factors, including the method and timing of application, condition of the target vegetation (age, height and size) and the site preparation methods employed prior to treatment.

2. The application of glyphosate was effective in achieving temporary vegetation control for conifer release.

3. The application of glyphosate as a method of site preparation was effective on some sites, but not on others. Conifers planted after treatment were often being shaded out by the heavy re-vegetation by grasses and forbs that occurred after treatment (see 5).

4. There were no obvious differences in the efficacy of glyphosate between sites in the Sub-Boreal Spruce (SBS) and Interior Cedar-Hemlock (ICH) zones.

5. A species shift was observed on all the study sites. After a glyphosate application, the original competing brush (woody shrubs and fireweed) was largely replaced by showy forbs, grasses and red raspberry (Rubus idaeus). This shift appeared to be temporary and, on all but one site, was reversing by year 5 of the study (i.e. 4 years after treatment) with the concomitant recovery of some of the original species.

6. The application of glyphosate resulted in a decrease in the quantity of species utilized as winter browse. The extent of the response varied according to the browse species, the condition of the browse plants (age, size and vigour), the time and method of application, and weather conditions at the time of application, among other factors (see attached site by site summary).

7. Douglas maple and mountain ash are extremely sensitive to glyphosate but mountain ash recovers better than maple. Willows are moderately sensitive to glyphosate. Red-osier dogwood is the most resistant of the four species examined, especially if sprayed late in the season.

8. On the North Babine and Sharpe Creek sites over 90% of the willow stems had died by year 4 after treatment. On the remaining 6 sites, the quantity of willow stems still alive varied from site to site, although many stems were severely or very severely damaged by glyphosate.

9. Red-osier dogwood stems were less severely affected than willows on most sites and, on some sites, were growing abundantly 4 years after treatment.
10. Most of the stems (all species) that were recorded as 'severely' or 'very severely' impacted in year 1 after treatment, were dead by the following year. Of those that were still alive 2 years after treatment, but showing 'poor' or 'very poor' recovery, most were dead by year 4 after treatment. Depending on the species, most stems with only 'light' or 'moderate' glyphosate damage were recovering well by 4 years after treatment.

11. An initial monitoring of glyphosate damage to browse species in year 1 or year 2 after treatment can be used to make some very general predictions about the recovery of browse on a site. However, the ability of browse plants to recover varies from species to species and each should be assessed independently.
4.2 SUMMARY OF THE CONDITION OF SELECTED BROWSE ON EACH SITE
Four Years After Treatment with Glyphosate

North Babine
-Willows were reduced by 90% and red-osier dogwood by 100%.
-Most of the willow stems and all of the red-osier dogwood stems were very young and hence very sensitive to glyphosate at the time of spraying.
-There was very little browse left on this site.
-There was some regeneration of both species from seedlings by the fourth year after treatment.

Nilkitkwa
-Tagged willow stems were reduced by 100% by glyphosate application.
-Red-osier dogwood was not present.
-Tagged mountain ash stems were reduced by 91%, although some stems showed a remarkable ability to recover after very severe damage.
-There is virtually no willow browse left on this block.

Morice River
-Tagged willows were reduced by 52%, whereas there was only a 22% reduction in the tagged red-osier dogwood stems. This reflects the fact that the spray was ineffective on red-osier dogwood due to the late application of glyphosate.
-Some large willow bushes were slashed prior to treatment and there was abundant new growth from the stumps.
-Red-osier dogwood and willow are present, but are patchy across the block.

Kwun Creek
-Willows and red-osier dogwood were reduced by 42% and 18% respectively. Douglas maple was reduced by 46%.
-A very heavy canopy cover on this block meant that the lower branches of the willows and maples and most of the red-osier dogwood shrubs were afforded some protection from the spray.
-Red-osier dogwood growth was apparently stimulated by the removal of the heavy canopy.
-Browse was abundant on this site four years after treatment.
Andl Creek
-Tagged willow stems were only reduced by 36%. The site appears to be quite dry and the willows were not producing much new growth at the time of glyphosate application. They may not have been as seriously affected as a result.
-Red-osier dogwood stems were reduced by 30%.
-All of the 7 Douglas Maple stems tagged were killed.
-Mountain ash stems were only 36% reduced and the remaining ones were showing very healthy growth four years after treatment.
-There is quite a lot of browse left on this site.

Sharpe Creek
-Willow stems were reduced by 79% and red-osier dogwood by 62%. The site was sprayed by backpack in mid-season. Results suggest that backpack spraying may be more effective against red-osier dogwood.
-By the 4th year after spraying the red-osier dogwood was showing healthy recovery. Willow were very scattered.

Hopps Ranch
-Tagged willow stems were reduced by 62%.
-Red-osier dogwood was not present in sufficient amounts to measure.
-Douglas maple and mountain ash were reduced by 71% and 66% respectively.
-Plants that survived the impact of glyphosate application and subsequently recovered tended to be located within the windrows where they were more protected from the spray.
-Browse was not abundant on the site four years after treatment although there were patches of new seedling willows.

Kispiox-Elizabeth Lake
-Tagged willows were never abundant on this block. Of those tagged 62% died.
-Only 26% of the red-osier dogwood stems died. The low impact reflects the late application of glyphosate.
-Red-osier dogwood was very abundant on the block four years after treatment. There were a few scattered large willows.
LITERATURE CITED


APPENDIX A

SUMMARY - YEAR 5 ASSESSMENT - Four Years After Treatment

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    stems - Four years after treatment - willows.............. v
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Photographs
The effects of operational application of the herbicide
glyphosate on target brush species, selected browse species, and
conifer crop trees.

1.0 BACKGROUND & INTRODUCTION:

This trial was established in 1987 to address herbicide
effects on moose browse and conifer release and
establishment. An establishment report and an interim
report two years after treatment were prepared (R. Pojar).
The experimental design was operational, and the results
were confounded by many factors (both site and
historical). These have been documented by past reports
and make firm interpretations impossible. Furthermore, the
site evaluation processes and planning of herbicide usage
have become refined since the trial establishment. These
changes have made this trial's results somewhat redundant
to operational forestry users of herbicides for other than
subjective information. For these reasons, the trial
5-year remeasurement will be subjectively performed, and
the final report will summarize the history of the trial
and present subjective trends in browse species and
vegetation invasion following herbicide use. Information
on conifers is no longer considered to be an objective of
the trial (due to the historical confounding of the
experiment). There are now numerous FRDA I trials
established and the Northern Interior Vegetation Management
Association has established plots on many operationally
treated sites.

2.0 OBJECTIVES

2.1 To evaluate the response of browse species to the
glyphosate application five years after treatment.
Identify those species affected and the degree of their
elimination. Identify the recovery of species that
were reduced to a "poor" and "fair" condition code by
previous reports. Identify those species unaffected.

2.2 To evaluate the effects of the herbicide use on moose
browse (quantity and quality) five years after
treatment.

2.3 To evaluate the invasion of the site by browse species
and herbaceous species.

3.0 METHODS:

3.1 For each site treated, photograph the established photo
points from previous measurements.
3.2 Utilize previously established transects and plot layout, in order to formulate an assessment of the browse species that were noted previously as "poor or fair". Assess the regrowth of these classes of browse species. The regrowth may be classified as:
- dead.
- severely stressed. Typically, the top portion is dead, but some limbs still exhibit signs of life.
- minor symptoms of herbicide induced stress.
- healthy, and fully recovered.

3.3 Subjectively evaluate the browse species, and the effect of the herbicide on the quality and availability of the browse. This shall attempt to incorporate all the browse species "in concert"; as well as comments that may be possible on individual species.

3.4 Prepare a written report which summarizes the trial, beginning with the Working Plan (1987) and subsequent monitoring reports. This final report shall be a concise summary of the trial and shall include an abstract. The use of simple graphs, figures and tables is encouraged. Comments and statements should be qualified by the Contractor.
4.0 RESULTS AND DISCUSSION

4.1 Tagged Browse

The condition of those plants which were identified as showing 'poor' or 'fair' recovery 2 years after treatment was re-evaluated and each stems was re-classified according to the four different categories outlined in the Revised Working Plan. These four categories were assigned a number:

Class 1 = dead
Class 2 = severely stressed, Typically the top portion is dead, but some limbs exhibit signs of life.
Class 3 = minor symptoms of herbicide induced stress.
Class 4 = healthy, and fully recovered.

The results for each species on each site are presented in Tables A1 to A3. The data for each species was then summarized in Table A4.

The total number of dead stems of each species is given in Table A5. Since most sites had several tagged stems that had died but the bush (and presumably rootstock) from which they sprouted was still alive, the condition of the re-growth of the bush was also recorded where relevant. The percentage of the dead tagged stems that are coming from bushes that are still alive are recorded in parentheses in Table A5. This information is included to illustrate one of the inherent problems with using the method of sampling individual stems as opposed to bushes.
Table A1. Assessment of 'Poor' and 'Fair' Tagged Browse Stems  
Four Years After Treatment - Willows

<table>
<thead>
<tr>
<th>Site</th>
<th>Total Stems Tagged</th>
<th>Years After Treatment</th>
<th>Damage Category</th>
<th>Condition Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>4</td>
<td># stems</td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>25</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Morice</td>
<td>25</td>
<td>1</td>
<td>Very Poor</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>30</td>
<td>7</td>
<td>Poor</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>24</td>
<td>2</td>
<td>Fair</td>
<td>1</td>
</tr>
<tr>
<td>Hopps Ranch</td>
<td>24</td>
<td>1</td>
<td>Very Poor</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Poor</td>
<td>1</td>
</tr>
<tr>
<td>Kispiox</td>
<td>29</td>
<td>1</td>
<td>Very Poor</td>
<td>1</td>
</tr>
<tr>
<td></td>
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<td>Poor</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

* Class Condition 1 = dead; 2 = severely stressed; 3 = some symptoms of glyphosate damage; 4 = healthy, normal growth
Table A2. Assessment of 'Poor' and 'Fair' Tagged Browse Stems
Four Years After Treatment - Red-osier Dogwood

<table>
<thead>
<tr>
<th>Site</th>
<th>Total Stems Tagged</th>
<th>Damage Category # Stems</th>
<th>Years After Treatment</th>
<th>Condition Class Stem</th>
<th>Condition Class Bush</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kwun Creek</td>
<td>22</td>
<td>1</td>
<td>Very Poor</td>
<td>1</td>
<td>class 1</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>10</td>
<td>5</td>
<td>Poor</td>
<td>1</td>
<td>class 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>class 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>class 3</td>
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<td></td>
<td></td>
<td></td>
<td>class 4</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>26</td>
<td>1</td>
<td>Very Poor</td>
<td>1</td>
<td>class 2</td>
</tr>
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<td></td>
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<td>Poor</td>
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<td>Poor</td>
<td>1</td>
<td>class 4</td>
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<td>Kispiox</td>
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* Class Condition 1 = dead; 2 = severely stressed; 3 = some symptoms of glyphosate damage; 4 = healthy, normal growth
<table>
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<th>Site and Species</th>
<th>Total Stems Tagged</th>
<th>Years After Treatment</th>
<th>Damage Category # Stems</th>
<th>Condition Class Stem</th>
<th>Condition Class Bush</th>
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</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maple</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kwun Creek</td>
<td>30</td>
<td></td>
<td>2 Very Poor</td>
<td>2 class 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 Poor</td>
<td>1 class 1</td>
<td>1 class 2</td>
</tr>
<tr>
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* Class Condition 1 = dead; 2 = severely stressed; 3 = some symptoms of glyphosate damage; 4 = healthy, normal growth
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<td>Fair</td>
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<td></td>
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<td></td>
</tr>
<tr>
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<td>3 class 4</td>
<td></td>
</tr>
</tbody>
</table>

* Class Condition 1 = dead; 2 = severely stressed; 3 = some symptoms of glyphosate damage; 4 = healthy, normal growth
Table A5. TAGGED BROWSE - Percentage of Dead Stems
Two and Four Years After Treatment

<table>
<thead>
<tr>
<th>Site and Species</th>
<th># Stems tagged</th>
<th>Percentage Stems Dead** (% of these from live bushes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 Years</td>
</tr>
<tr>
<td><strong>Willows</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babine</td>
<td>20</td>
<td>85 (10)</td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>25</td>
<td>96 (8)</td>
</tr>
<tr>
<td>Morice River</td>
<td>25</td>
<td>44 (36)</td>
</tr>
<tr>
<td>Kwun Creek</td>
<td>19</td>
<td>42 (10)</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>30</td>
<td>23 (3)</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>24</td>
<td>79 (16)</td>
</tr>
<tr>
<td>Hopps Ranch</td>
<td>24</td>
<td>58 (16)</td>
</tr>
<tr>
<td>Kispiox</td>
<td>29</td>
<td>59 (6)</td>
</tr>
<tr>
<td><strong>Red-osier Dogwood</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Babine</td>
<td>20</td>
<td>100 (0)</td>
</tr>
<tr>
<td>Morice River</td>
<td>18</td>
<td>22 (-)</td>
</tr>
<tr>
<td>Kwun Creek</td>
<td>22</td>
<td>14 (0)</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>10</td>
<td>30 (10)</td>
</tr>
<tr>
<td>Sharpe Creek</td>
<td>26</td>
<td>64 (7)</td>
</tr>
<tr>
<td>Kispiox</td>
<td>27</td>
<td>26 (3)</td>
</tr>
<tr>
<td><strong>Maple</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kwun Creek</td>
<td>30</td>
<td>37 (0)</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>7</td>
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<td>14</td>
<td>36 (14)</td>
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<td><strong>Mountain Ash</strong></td>
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<td></td>
</tr>
<tr>
<td>Nilkitkwa</td>
<td>11</td>
<td>73 (0)</td>
</tr>
<tr>
<td>Andi Creek</td>
<td>14</td>
<td>21 (0)</td>
</tr>
<tr>
<td>Hopps Ranch</td>
<td>12</td>
<td>41 (16)</td>
</tr>
</tbody>
</table>

** Figures in () are the % of the dead tagged stems that are coming from bushes that are still alive.

* - Data not collected.
4.2 Summary of 'Poor' and 'Fair' Tagged Browse Stems

Four Years After Treatment

The results show that the condition of the regrowth of 'poor' or 'fair' plants by the 4th year after treatment varies from species to species as would be expected.

Willows show a broad spectrum of results. 'Very Poor' stems usually die, although the bush they come from may not. The 'poor' plants did not necessarily recover, but a certain number recovered well. The majority of the 'fair' plants did recover well.

Red-osier dogwood appears to be able to recover better than willows. Most of the 'poor' and all of the 'fair' stems have recovered and most are producing good to normal growth. Half the 'very poor' plants are dead and the other half are sickly but the sample size (2 stems) is rather small to be sure this is typical.

Douglas Maple is very sensitive to glyphosate. Recovery of 'poor' and 'very poor' stems is very slow with very little really healthy regrowth. On the whole, if the stem was still alive, shoot elongation was poor. The foliage was, however, looking more normal which should mean a return to more typical photosynthetic activity and may mean that even rather sickly looking plants have a chance of recovery. The sample size was rather small, but there seems to be a correlation between the size of the bush and the recovery of 'poor' or 'very poor' maple stems.

Mountain Ash appears to be better able to recover than maple and even willows. Plants that were very severely affected by glyphosate have managed to survive through 4 years post treatment and some were producing extremely healthy regrowth. This type of recovery suggests that the underground rootstocks of this species were not as severely affected as the above ground parts either because the glyphosate was not translocated efficiently or perhaps the plants had almost shut down when spraying occurred.

Conclusions The method devised by Lloyd (1986, revised 1988) of monitoring the impact of herbicides on species important for moose winter browse can be used to predict long term effects of glyphosate, but with caution. "One-shot" monitoring 1 or 2 years after treatment will give a general idea of the impact of the treatment and some generalized predictions of the browse species recovery could be made. However, these will not be accurate as the other factors controlling browse survival are unknown and/or uncontrolled in operational situations. For example, the effect of the amount of annual precipitation on recovery, or death, of plants that have survived for 2 years after treatment, but only have 'poor' or 'fair' growth, is unknown.
4.3 Summary of Browse, Vegetation, and Conifers - Four
Years After Treatment - Site by Site

North Babine (Opening Number 93K - 061 - 504)

Browse - General

Prior to treatment, young willow and red-osier dogwood plants (less than 1 m tall) were scattered across the block. Red-osier dogwood was particularly abundant.

By the fourth year after treatment there is very little browse on this site. Scattered patches of young willow are present, usually in association with the remnants of the windrows or where mineral soil was disturbed and/or compacted. Most plants are about 1-2 years old and no taller than 1 metre. Most of the plants on mineral soil compacted by machinery during site preparation are new seedlings. Some of the plants appear to be sprouts arising from rootstocks of the original willows that were buried during site preparation. A few scattered seedlings (all under 1m) of red-osier dogwood are also present. Overall the quantity of available browse is very low.

Browse - Tagged Stems

Willow Of the original 20 willow stems tagged and measured, 90% are now dead (5% more than 2 years after treatment). The majority of the original willow were very young and would have been more sensitive to glyphosate. Ten percent (10%) of the stems are from bushes that are still alive (see page 17 for explanation).

There were no stems classed as 'poor' or 'fair' on this site 2 years after treatment as most were dead with only 2 plants alive and both showing 'good' growth (Table A1).

Red-osier Dogwood None of the tagged stems of red-osier dogwood survived the the original application of glyphosate. All of the tagged stems were very young (1-2 years old). Young growth had not developed a protective waxy cuticle prior to spray application early in the season (July 15-16); hence, the plants were very sensitive to glyphosate.

Vegetation

Over most of this block the vegetation cover is extremely thick (75-100%) and is comprised primarily of lush herbs and grasses up to 1 metre tall (see photographs - Appendix B). Between plots 11-16 (see map, Appendix B), the vegetation cover was not as thick or as tall (varying from 50-65% cover and 25-75 cm height).

The grasses (Elymus glaucus, Cinna latifolia, and Bromus species) that were so abundant 2 years after treatment, are declining in abundance. On the drier parts of the block, where
the soils are deeper, they are gradually being replaced by original species such as aspen, fireweed, thimbleberry, and snowberry and large amounts of showy herbs such as larkspur, yarrow, northern bedstraw, meadow rue, and fireweed among others. On the wetter parts of the block, cow parsnip, kneeling angelica and bluejoint grass (Calamagrostis canadensis) are very thick. Where mineral soil was exposed and compacted, weedy species, especially large-leaved avens (Geum macrophyllum), are still the most common species. Raspberry (Rubus idaeus) is still very abundant throughout the block.

The heavy growth of vegetation (forbs and grasses) on this site after glyphosate treatment may possibly be related to the fact that it was mechanically site prepared and burned and then left for a year before treatment. This would allow for the build up of the seed load. The site is also wet as evidenced by extensive ponding, especially at the north end and conditions favour lush growth of fast growing species.

Conifers

Most of the conifers planted on this block are totally shaded by the thick cover of grasses and forbs, especially those planted in 1990. Between plots 11-16, where the vegetation is not as thick, the conifers originally planted (1987) are doing well. The newly planted conifers (planted 1990) might be able to outgrow the surrounding vegetation in the less sparsely vegetated parts if it does not get any thicker in the next two years.
Nilkitkwa (Opening Number - 93M - 047 - 002 Blk H)

Browse - General

Willows were abundant on this block prior to treatment. Red-osier Dogwood was very scarce and was not measured. Mountain ash was quite abundant.

There are virtually no browse plants left alive on this block. Only two of the original 655 willow stems were observed to be showing any growth on the total length of the 2 m wide transect. Some widely scattered mountain ash bushes that survived the herbicide application are producing some good growth.

Browse - Tagged Stems

Willow All of the original 25 tagged willow stems are now dead. One stem, that was previously classed as having 'fair' growth, has since died but is coming from a bush that is still alive and producing healthy (class 4) growth - see Table A1. Another willow, classed as dead 2 years after treatment, is now resprouting from the base.

Mountain Ash Three mountain ash stems were classed as 'poor' or 'very poor' in year 3. All are now dead, but the bushes from which they originate are still alive and showing fair growth - see Table A3.

Vegetation

The two most common brush species are fireweed and bluejoint grass (Calamagrostis canadensis). Cover was rarely above 75% and averaged around 45-50% for most plots. Several had cover values less than 10%, whereas between plots 27-30 (see map, Appendix B, where it is wetter, the cover was 95-100%. The fireweed was tall in places (up to 1.5 m), but the average height was estimated to be 65-70 cm (see photographs - Appendix B)

Nodding wood-reed grass (Cinna latifolia) was the most common grass species in year 3, but it seems to have been largely replaced by fireweed and bluejoint grass. Alder is resprouting in the thickets, but over most of the study area was showing minimal growth and foliage. There is also some recovery of aspen, thimbleberry, and hardhack. Wild raspberry is locally fairly abundant. In the wet areas around plots 27-30, alder is producing more growth and bluejoint is very thick and represents almost 100% of the cover.

Trees

The original trees are all growing well on this block and are well above the level of the surrounding live brush (estimated average height = 352 cm). Smaller spruce (thought to have been planted since the trial started) are either showing poor growth or are dead (estimated average height = 35 cm).
Moric River (Opening Number 93L - 026 - 001)

Browse - General

Willows and red-osier dogwood were the selected browse species present on this site. Many of the large willow bushes were slashed prior to treatment and, hence, could not be tagged.

Willows that were slashed before herbicide application are producing large amounts of new growth (i.e. browse). They are, however, widely scattered and not abundant. Red-osier dogwood was restricted mainly to the area around plots 25-30 (see map, Appendix B) and most of it was unaffected by glyphosate because it was applied so late in the season. Hence, it is all growing very well and producing lots of new growth that is being browsed heavily by moose.

Browse - Tagged Stems

Willows Of the original 25 tagged stems, 52% are now dead as opposed to 44% in 2 years after treatment (Table A5). One of these was previously classed as having 'very poor' growth. The fate of the stems classed as 'poor' or 'fair' is given in Table A1. Note that one of the stems with 'fair' growth 2 years after treatment has since died, but that the bush is alive and producing healthy growth. Of those stems that were classed as dead in the 2nd year after treatment, 36% came from live bushes. By the 4th year after treatment, most of these bushes had died leaving only 4% (1) dead stems from live bushes.

Red-osier Dogwood All are healthy.

Vegetation

The vegetation cover over plots 1-22 is generally low and varies from 10-50%. On a few of these plots it was as high as 75-85% and most of the cover was due to wildrye grass (Elymus glaucus). The estimated average height was 72 cm although on some plots it was considerably less. Cover values were very high (90-100%) on plots 25-29 where the original application of glyphosate (1987) was ineffective against the target brush (see photographs - Appendix B).

The most common species of brush on site 4 years after treatment were prickly rose, fireweed, red raspberry and wildrye grass (Elymus glaucus). Thimbleberry was coming back slowly but is very short. The wildrye grass is less abundant than in previous years and is slowly being replaced by the other species. Calamagrostis canadensis (bluejoint) is very thick in wetter spots. Willows and alders are recovering well.

Trees

The naturally regenerated conifers were all growing
well but there was very poor survival of the pine planted in spring 1989. It was concluded that the poor condition of the planted pine was not due to excessive competition from brush, but from some other cause.
Kwun Creek (Opening Number 93M - 014 - 072)

Browse - General

Willow, red-osier dogwood and Douglas maple are the selected browse species studied on this site.

There are a lot of live browse plants left on this site, partly due to the patchiness of the original application of glyphosate and partly due to recovery of species in the subsequent years. Use of the area by wildlife (moose, bear, grouse and songbirds) is very heavy.

Willows are abundant in the "skips", but where sprayed, recovery is slow. Between plots 11 and 15 (see map, Appendix B), where willow was hit the hardest, most are dead.

Red-osier dogwood is the most abundant browse species and for the most part is producing luxuriant new growth (i.e. available browse) that is being heavily utilized by moose.

Many of the maples were so big prior to spraying (up to 10 metres tall) that the bushes were not completely killed. On most of the maples that were not killed by the glyphosate, the plants are recovering slowly with limited new shoot extension.

It was noted that the birches are all dead unless they were in "skips".

Browse - Tagged Stems

Willow Of the original 19 stems tagged, 42% are now dead. Of these, 10% are from bushes that are still alive. None of the remaining willows showed 'poor' or 'fair' growth in the 2nd year after treatment.

Red-osier Dogwood Of the original 22 stems tagged, 18% are now dead and one (4%) is from a bush that is still alive. The one bush previously classed as having 'very poor' growth subsequently died (Table A2). As stated above, most of the red-osier dogwood is very healthy and producing large amounts of available browse.

Maple Of the original 30 stems tagged, 46% are now dead, 4 (i.e. 13%) are from live bushes. Table A3 shows there were 5 maple classed as having 'poor' growth and 2 with 'very poor' growth. Remarkably, none of these died as might be expected of a such a glyphosate sensitive species. However, one of the stems classed as having 'fair' growth did die since the last assessment.

Vegetation

Red-osier dogwood, fireweed, red raspberry and wildrye
grass (Elymus glaucus) were the species contributing the most to the total brush cover. Also present, but recovering slowly, are maple, thimbleberry, prickly rose, and high-bush cranberry. An estimate of overall average cover is hard to give because of the numerous "skips". In the plots most affected by glyphosate, cover 4 years after treatment varies from 10 to 70% with E. glaucus responsible for most of it. Although this grass was abundant in affected areas 2 years after treatment, it's overall abundance has decreased as the original brush recovers. Cover values for the remaining plots are generally high (80-90%) with red-osier dogwood being the most common species (See photographs - Appendix B). Peavine has shown a dramatic decrease in abundance as other species recover and outcompete it. False box forms abundant ground cover in drier plots.

**Trees**

There appears to be plenty of natural regeneration in the block and the planted spruce, although generally overtopped by the surrounding brush, are growing fairly well. In areas where the spray was effective, they will probably escape the surrounding brush.
Andi Creek (Opening Number 93M - 011 - 044)

Browse - General

Willows, red-osier dogwood, Douglas maple and mountain ash were all present on this site. Browse plants, especially willows, were not as severely affected by glyphosate on this site. The willows were not producing much annual shoot extension and it appeared the site was quite dry. It was suggested that the plant growth may not have been very active at the time of spraying and, hence, they may not have taken up much of the glyphosate.

Red-osier dogwood is locally abundant on the block and most of it is producing healthy long new shoots. Willows are also plentiful and are more evenly distributed than dogwood across the block. Many of the willows have recovered and a few were producing healthy long shoots (available browse). However, new growth on many of the bushes is not very long, but this is typical of this site and is probably related to the dryness of the block. Mountain ash is also abundant and there is fairly good recovery of those plants that survived the herbicide spray.

Browse - Tagged Stems

Willow Thirty stems were tagged and, of these, 36% are now dead (an increase over the number dead in year 3). None of the dead stems come from live bushes. Of those willow stems which survived (Table A1), the 2 stems classed as 'fair' are still alive and 1 out of the 7 classed as 'poor' has died. Most of the surviving stems are producing healthy foliage but often short shoots (see above)

Red-osier Dogwood Thirty percent (3/10) of the original tagged dogwood stems are dead. Two of the dead stems are from live bushes. Most of the stems classed as 'fair' or 'poor' are recovering well and producing healthy growth (Table A2).

Mountain ash As was noted on other sites, some of the mountain ash stems which survived the application of glyphosate but exhibited poor or very poor growth, are showing remarkable recovery (Table A3). Two of the four stems died, but for one of these the bush is still alive. The other two however are producing very healthy growth (class 4).

Maple In the 2nd year after treatment, 100% of the maples were reported dead. However, one of the bushes resprouted from the base.

Vegetation

Over much of the block the cover of brush vegetation is very low (estimated average = 40%) because the site is quite dry. Most of the brush by the 4th year after treatment consists of the original species with false box, fireweed, and red-osier dogwood
being the most abundant. Wildrye grass (Elymus glaucus) is the most abundant grass, although it has declined in quantity since the 2nd year after treatment when there were large patches of this grass and thistles between plots 14 and 20. Much of this had died out by the 4th year, presumably because of the recovery of the original brush. Prickly rose and thimbleberry are making a slow, but steady recovery. There are patches of higher brush cover (70-80%), but this is not affecting the growth of the conifers which are all taller than the surrounding vegetation. The main large shrubs are willow and some localized patches of alder (See photographs - Appendix B).

There was originally a fair amount of birch on this site, but most of it was completely killed by the glyphosate.

**Trees**

The pine is growing very well and most are between 3.5 and 5 m tall. The spruce is generally smaller, but healthy. There is some natural regeneration of subalpine fir (average height 1-2m).
Sharpe Creek (Opening Number 93M - 014 - 066)

Browse - General

Willow and red-osier dogwood were the selected browse species examined on this block.

There is a fair amount of both dogwood and willow on the block. Both tend to be patchy with the dogwood more abundant. The dogwood was less severely affected and hence is recovering very well. It is generally producing healthy long shoots (available browse). Most of the original willows were killed, but those that remain are recovering well overall and producing healthy growth.

Browse - Tagged Stems

Willow Of the original 24 tagged stems, 21% are still alive. Of those that are dead, 12.5% are originating from bushes that are still alive. Two willow stems were classed as 'fair in the 2nd year after treatment and are both still alive (Table A1).

Red-osier Dogwood Twenty-six stems were tagged and 62% were dead by year 5. Of these 11% were from bushes that were still alive. Of the 6 stems that were classed 'very poor', 'poor' or 'fair' 2 years after treatment, all but one are still alive and this one is from a live bush. Growth on most of these is classed as healthy (Table A2). One dogwood bush, declared dead in the 2nd year after treatment, resprouted from the roots.

Vegetation

Many of the original brush species - fireweed, thimbleberry, red-osier dogwood, willows, prickly rose and Calamagrostis canadensis (bluejoint) are all slowly coming back across the block. Bluejoint is abundant enough in isolated patches to form a cover of 80-100%. Red raspberry and wildrye grass (Elymus glaucus) are still common, but are being replaced by other species. The thistles that were very abundant in the 2nd year after treatment have almost completely died out. There are a few isolated patches of aspen and alder. Grass cover by native and weedy species is high, but the average height is low due to grazing by cattle, especially on skid trails and landings. Species that are not recovering well are birch, hazel and twinberry (See photographs - Appendix B).

Trees

In general the height of the brush vegetation across the block is low enough that most of the planted conifers are not being overtopped. Most of the spruces were healthy and did not appear to be trampled by cattle. The pine was growing very well.
Willow, Douglas maple and mountain ash were the selected species present on the site. Red-osier dogwood was present, but not in sufficient amounts to sample.

There was not a lot of willow on this block prior to treatment. Slightly more than half the willows along the transect survived the application of glyphosate and were still alive by the 2nd year after treatment. Most of these are growing in or near the windrows, where they received some protection from the spray, and are recovering well and producing healthy growth. On the more level areas of the block, especially where mineral soil was exposed and compacted during site preparation, there are patches of new willow seedlings. New seedlings are less frequent on the steeper parts of the block.

Maple was the second most common browse species examined. Much of it was killed outright by glyphosate, and most of the plants that were still alive 2 years after treatment were dead by the 4th year. A few large bushes are starting to recover. For the most part the annual growth of the shoots was poor, but the foliage looked healthy.

The recovery of mountain ash is variable with some plants recovering very well (producing a lot of annual growth) and others not.

**Browse - Tagged Stems**

Willows One of the stems (previously classed as 'poor') died since the last assessment making a total of 62% dead of the original 24 stems tagged. Of the remainder, one had 'very poor' growth and although stressed is still alive (Table A1). of the 62% dead, 12.5% are coming from bushes that are still alive.

Maple By the 4th year after treatment, 71% of the 14 tagged stems are dead. This is because 5 out of the 8 classed as 'poor' or 'very poor' died (Table A2). Of the remaining 3, two were stressed. Three of the dead stems are coming from live bushes, but note that, on most of these, the growth is very poor and has been assigned to Class 2. These plants may yet die.

Mountain ash More of the stems have died since the 2nd year after treatment and the total is now 66% of the original 12 tagged. Four of the six stems showing poor or very poor growth in the 2nd year after treatment are dead, one is severely stressed, and the other one is healthy (Class 4).
Vegetation

A commercial grass seed mix was applied to this block and the site is being grazed by cattle. Originally, fireweed was the most common native brush species of concern. After glyphosate treatment, fireweed was severely reduced and largely replaced by the introduced grasses from the seed mix, especially by orchard grass (Dactylis glomerata). By the 4th year, the fireweed has recovered and in parts of the block is back up to it's original cover (See photographs - Appendix B). The orchard grass is the most dominant grass on the planting trails over much of the block, in particular on the steep slopes and the lower part of the block. Cover values for this species are high. However, on the more level parts of the block the cattle are grazing it heavily so that it is not overtopping the conifers.

Alders are coming back very heavily on the planting trails, especially at the top and down the steep planting trails. In the wetter parts of the block, in particular at the top, bluejoint (Calamagrostis canadensis) is very thick and forming 100% cover in places. Other species recovering are devil's-club and Ribes spp. (restricted to windrows) and thimbleberry from seed. Although the estimated average cover of competing brush over most of the block was around 72%, most of the conifers appear to be growing through it and are doing well. This is particularly noticeable where the cattle are grazing.

Grasses The grass cover was estimated to be approximately 25% over 28 of the 30 plots by the 4th year after treatment. This represents a slight decrease from that recorded in the 2nd year. Most of the grass is the introduced species - Dactylis glomerata (orchard grass), although Calamagrostis canadensis (bluejoint) was locally very abundant. Most of the other introduced species, together with the native wildrye grass (Elymus glaucus) have declined in abundance since year 2 after treatment.

Trees

The conifers are generally doing well. On the flatter, grazed, areas at the bottom of the steep slope, the spruce are growing extremely well with an average height estimated to be between 100-150 cm. There is no sign of damage by cattle on any of the trees examined. On the steeper slopes (planting trails) spruce are generally smaller (60-120 cm tall) but are healthy. The condition of the conifers is more variable with some being overtopped by bluejoint grass.
Kispox - Elizabeth Lake (Opening Number 103P - 060 - 012)

Browse - General

On this site, willow and red-osier dogwood were the only selected browse species abundant enough to be measured. There was very little willow on this site prior to treatment and 46% of the stems along the transect were killed by glyphosate. There are scattered bushes across the block and most are producing good growth. Red-osier dogwood, however, was abundant over the whole block and most of it has survived the application of glyphosate, probably because the block was sprayed late in the season. Growth on the dogwood is very healthy with many long new shoots.

Browse - Tagged Stems

Willows 62% of the tagged stems were dead 4 years after treatment. Of these dead stems, 10% (i.e 3) were sprouting from live bushes. Table A1 shows that the 4 stems classed as 'fair' are still alive and the 1 stem classed as 'poor' is also alive, but very stressed. The one stem previously classed as having 'very poor' growth has died, but the bush still has some stressed growth.

Red-osier dogwood Only 26% of the 27 tagged stems were killed by glyphosate. Of these 2 (7%) are coming from live bushes. Five stems had 'fair' growth and 2 had 'poor' growth in year 3. All of these are still alive and most are producing good growth with two still showing some glyphosate induced symptoms (Table A2).

Vegetation

The most common brush species 4 years after treatment are red-osier dogwood, fireweed and thimbleberry. False box is common but grows too low to overtop conifers. Wildrye grass (Elymus glaucus) had been abundant together with Cinna latifolia 2 years after treatment, but it appears that it is being replaced as many of the original brush species recover. Species such as prickly rose, hazelnut, Douglas maple and mountain ash are recovering slowly and often occur in localized patches. Over most of the block the cover values average around 50-60%. In general the brush is not very tall - (under 75 cm). It is either not overtopping the conifers or, if it is, they are coming through well (See photographs - Appendix B).

Trees

The pine is growing very well with an estimated average height around 166 cm. Most of the spruce is also growing well and the estimated height averages around 130 cm.
<table>
<thead>
<tr>
<th>SPECIES NAME</th>
<th>COMMON NAME</th>
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<tr>
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<td>Alnus viridis ssp.sinuata</td>
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<td>Amelanchier alnifolia</td>
<td>Saskatoon berry</td>
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<tr>
<td>Angelica genuflexa</td>
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<td>Athyrium filix-femina</td>
<td>lady fern</td>
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<td>Cinna latifolia</td>
<td>nodding wood-reed</td>
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<tr>
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<tr>
<td>Viburnum edule</td>
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APPENDIX D

1987 Working Plan
1.0 INTRODUCTION

Herbicide Efficacy Results in the Prince Rupert Forest Region have been collected a variety of areas. In addition, there have been operational research trials established on a species specific basis as well as studies of species shifts on alluvial sites.

This trial was designed to obtain efficacy data on selected browse species utilized by moose and target brush species. Additionally, data on conifer growth will also be collected.

2.0 OBJECTIVES

The measurement of the effects of operational herbicide (glyphosate) application on:

1) Target brush species
2) Selected moose browse species.
3) Coniferous crop trees.

3.0 DESIGN AND LAYOUT

Establish 30 plots per cutblock located along transects through a proposed treatment area. Plot centres will be marked with a cedar stake (1.3m x 2cm x 4cm) and attached metal tag. The top 20 cm shall be orange.

Plot centres and position of lines shall be identified on 1:10,000 maps. Metal tags shall identify location, plot number, direction and distance to next stake, name of surveyor and opening number.

Point of Commencement (P.O.C.) of plot lines shall be located in landings or off skid trails and marked by cedar stakes and ribboned.

Measurement of browse species shall be along the transects located between HER plots. The main 2 to 3 browse species shall be identified on each block and 20 to 30 individuals will be tagged.

4.0 MEASUREMENT AND RECORDS

Plots will be measured immediately before herbicide treatment and 1, 2 and 3* growing seasons after treatment.

* The third growing season was not measured.
4.1 Herbicide Efficacy Plots. The following data will be collected: average brush height and coverage; the height and coverage of the three major competitor species in each plot and damage and growth information of conifer crop tree. Plot size shall be 10m (1.78m radius).

A. **Plot Data** (baseline - immediately before treatment/ 1, 2, 3 years in late August before senescence).
   - the average height (nearest 10cm) of all the tallest major brush species within each 10m subplot
   - the percent coverage (nearest 5%) of the plot by combined brush species using the quadrant method of estimating plant canopy coverage.

B. **Brush Species Data** (baseline - immediately before treatment/ 1, 2, 3 years in late August before senescence).
   - for each of the three major competitor species within each 10m subplot:
     a) species (Appendix 2)
     b) the average height (nearest 10cm)
     c) the percentage canopy coverage (nearest 5%)
     d) condition code (Appendix 3)
   - not more than three brush species will be examined per plot and these may change from plot to plot.

C. **Crop Tree Data**: One undamaged seedling (nearest to the plot centre - must be staked and tagged on lateral species
   - total height (cm)
   - current annual height increment (nearest cm)
   - percentage overtopping (nearest 5%) as measured by a cylinder at 1 metre radius from the bottom of the last complete year's leader growth. Measurement shall take place at full leaf.
   - condition code (Appendix 3)
   - identify location of crop tree by distance from the central stake and clock direction using 12 o'clock as bearing to the next plot.

4.2 Selected Browse Species Data

For each selected browse species, individuals will be counted along the transect lines as well as tagging and numbering of 20 to 30 individuals of each species. For plots in the SBS collect red-osier dogwood and willow; for ICH collect red-osier dogwood, willow, mountain ash and maple.
A. Individual Tagged Browse Species

A numbered tag will be placed on each of the 20 to 30 individuals of each browse species to be collected. At each plot site along the transect one plant (or more if necessary) of each of the required browse species will be located within reasonable distance (within sight) of the plot. The location of the plant will be identified by clock direction (using 12 o'clock as a bearing to the next plot) and its distance to the plot center. If no plant is in the vicinity of a particular plot, the numbers will be made up by tagging more than one plant of that species at another plot.

Growth pattern and shoot length will be measured for each of the tagged stems. The stems will be divided into 20cm segments starting at the highest point of the living stem below the leader (if any present). The length of the leader (new apical growth) will be measured. Within each 20cm segment the length of the longest lateral, new, growth arising directly from the main stem will also be measured.

5.0. PROPOSED ANALYSIS

The plots established will be followed through time to examine changes in cover and height for the plots and 3 major brush species in each plot, as well as changes in crop tree height, vigour and supression.

The data will be analysed to show the effect of the herbicide spray in an operational setting, to predict response of major competitor species.
APPENDIX E


Description of the Damage Category Classification System used in Assessing Glyphosate Impact on Selected Browse Species.
APPENDIX C

CRITIQUE OF the 'Standard Guidelines for Monitoring Herbicide Effects on Wildlife Browse' produced by Ruth Lloyd for Fish and Wildlife Branch, Ministry of Environment, Smithers

The following criticism draws on three years of experience working with the basic methods outlined in these guidelines which were originally described in Lloyd (1986) and subsequently modified and updated in Lloyd (1988) and the current guidelines.

Section 4. Damage Assessment - page 3

The method outlined in this section works reasonably well for obtaining an overall (qualitative) evaluation of the effect of the operational application of herbicides on plant browse species.

However - there are some basic underlying assumptions which may or may not be acceptable to the user:

a) It assumes that the observed post-treatment condition of the browse is entirely due to the effect of the application of the herbicide and does not take into account that so-called "damage" may be caused by browsing, microclimate conditions, innate growth properties of the individual species or yearly changes in weather conditions (i.e. changes which may occur regardless of herbicide application).

b) The shoot lengths given in Table 1a apply only to plants growing on sites with a good supply of moisture and nutrients - i.e. optimal growth conditions. "Normal" (i.e. of untreated plants) maximum shoot lengths vary from site to site depending on site conditions.

If a representative control sample is included some of the variation due to factors other than herbicide damage may be accounted for. However, the control must be truly representative. I suggest that in many cutblocks, this may be difficult to achieve.

If the underlying assumptions are understood and the error factors and possible variables are acknowledged, I suggest that this method is easy and can be used to obtain a qualitative assessment of browse condition after herbicide application.

I question the use of the word "damage" since it assumes the condition of the browse is a result of the impact (in this case) of herbicide application and does not allow for growth changes resulting from natural phenomena outlined above. In the context of these guidelines there is no recognition of the impact of browsing by wildlife on the plants - a considerable complicating factor. I suggest that "browse condition" would be more appropriate.
I also question the maximum shoot lengths given in table 1a. I think they are too high. For example, shoot lengths on healthy untreated dogwood may exceed 40 cm but are more often in the region of 20 - 25 cm. Based on three years of data collection on willow, dogwood, maple and mountain ash, I would adjust the maximum shoot lengths given downwards. Ruth addresses this problem on page 7 but states that shoot lengths should not be recalibrated for each cutblock. Based on my field experience I would suggest that they should be done for each cutblock unless the blocks being assessed are side by side and are very similar.

There is no mention of how new seedlings should be recorded.

N.B. A minor point - If Level I is "aimless" then why do it? A better way of expressing this is that it is a 'subjective reconnaissance'.

Section 4.3.2. Level I - page 8

I suggest that, by walking through an area along a defined transect and examining every plant within one metre either side of the transect, the problem of favouring larger, more conspicuous bushes will be avoided and a more random sample will be obtained. If no control is required for Level I, then the observer must acknowledge site variations and any browse conditions which may be ambivalent or could be attributed to other causes.

Section 4.3.3 Level II and Section 4.3.4 Level III - pages 9 - 11

The sampling procedures are fine but I am curious as to why several short transects are recommended, rather than a continuous transect on a grid?

Section 4.4 Interpretation of Results - pages 11 - 13

O.K.

Section 4.4.2 Effects on Browse - pages 13 - 14

I have a lot of trouble with this section. Ruth bases her statements on a very brief study (over two days in one single season) (Lloyd 1988). Details on sampling procedure and sample sizes are poor. While her findings may indeed show trends, they cannot be considered as absolute. I would also question how she was able to assign "damage" categories to plants in mid winter (see page 8 - Lloyd 1988).

I would also question the claim that most category 3 plants do not "recover" from herbicide impact (page 13 - guidelines). Based on my own Year Two field work, I found remarkable recovery of both dogwood and mountain ash which had been impacted severely, or even worse. (N.B. This data has yet to be analysed thoroughly).
I do not think enough is known about normal browsing patterns of moose let alone what, or how much, herbicide treated browse is utilised. A study by Miquelle (1983) on the utilization of re-foliated browse by moose suggested the possibility that re-foliated browse plants may produce higher quantities of defensive allelochemicals (which do not taste good and hence are avoided by moose) as a survival strategy. Do we know for sure that browse species do not have a similar response to herbicide treatment. Can we say for sure that moose are not interested in the long, spindly shoots of class C in Table 2 (page 15) ? . Ruth refers to this as poor growth (bottom of page 15) - and indeed it is not normal in appearance - but do we know for sure that moose will not touch it? There are too many unknowns.

Section 5 Recovery Assessment - pages 14 - 20

This is the section I personally have had the most trouble with in implementing in the field.

I question the use of the word "recovery". As used in this guide it refers to how well the browse plants "recover" from herbicide impact - but the categories for defining this "recovery" are based on the length on the new shoots produced. Hence good recovery - i.e. Category A in Table 2 - means it is producing healthy new, long shoots - which are potentially available as browse. However, my field observations indicate that plants may produce large numbers of leaves, but no concomitant shoot growth after herbicide treatment. To state that these plants are showing poor recovery is erroneous. They are showing poor shoot elongation but they still presumably have good photosynthetic capability and while it may take them longer to recover to a point where they can start producing shoot elongation - they will probably recover and recovery cannot be called poor. In other words this section should be referring either specifically to shoot elongation (and by implication potentially available browse) or generally be regarded as Year Two "follow-up".

Tables 2 and 2a

Category C should be further subdivided. It is very broad and is ambivalent. I found at least three plant conditions which I had to place in this category:

1) plants with clusters of very short (less than 1 cm) growth arising from the main stem or with clusters of numerous deformed leaves of very reduced size (similar to Category 4 on Table 1).
2) plants with clusters of numerous leaves, but with no shoot elongation. The leaves were often normal size or only slightly reduced.
3) plants showing shoot elongation but where the shoots were very spindly, the leaves reduced in size and frequently chlorotic.
Based on my own field studies, I suggest that the maximum shoot lengths defining the categories A - D are too long, especially for dogwood and maple.

No mention is made of the fact that red-osier dogwood in particular and, to a lesser extent, willow produce basal sprouts after glyphosate treatment.

Section 5.3.1. Describing growth patterns - page 16

Ruth states that "recovery assessment" is "quick and easy to do" and requires that the surveyor understand the growth patterns of the individual species. I suggest that the method outlined for understanding the growth patterns (pages 16 - 18) is not as straightforward as it may appear from the way it is presented in these guidelines.

The method was originally devised to obtain an understanding of the impact of herbicides on willow. For the most part it works well for this species although there are a few problems (see under Willow below). The method does not work as well for other species - primarily because of the basic differences in the innate growth characteristics of each species. The problems are described below.

Before elaborating on the problems, I would like to suggest that an examination of the growth characteristics of a representative sample of each of the selected browse species under study, should be carried out at the very beginning of any project - i.e. before treatment and subsequently at the beginning of every field season after treatment. Once the observer is familiar with the growth patterns and their response to herbicide application, assessment of "damage" (impact) and subsequent "recovery" (follow-up) will be easier to understand. However, it is a waste of valuable time to tag large numbers of plants and follow their progress over several years. Subsequent evaluation of the condition of the plant - especially in Year Two - can be done at a glance or preferably by measuring the longest new shoot produced anywhere on the tagged stem or bush. (see my comments below).

The problem of what to tag

Using the point quarter method (outlined on pages 9 - 10) to locate the plants to be tagged is recommended because it eliminates the problem of biasing the sampling towards the larger, more visible bushes, especially on a less brushy site. Once the plant is located - the question arises as to what to tag and measure. If it is a large bush, does the surveyor measure the closest stem or the easiest one to measure (which may not be the tallest)? Should the selection of the stem be randomised in some way? Should the surveyor allow the direction of the proposed flight path to influence the selection of the stem?. Or should all the stems in the bush be measured?
This is of some concern to me, as on at least one block, I found that approximately half of the stems selected from large bushes and subsequently tagged and measured before treatment were dead one year after treatment. However, the many of the other stems in these same bushes were not as severely impacted and by Year Two are showing good growth. (I am even tempted to wonder if I inadvertently predisposed these stems to a more severe impact !!). Obviously the sample size must be large enough to ensure that the whole range of impacts can be followed through successive years — but not so large that valuable time is spent on this aspect of the study.

Perhaps it should be reinforced at this time that measurement of tagged plants is merely to give the observer an understanding of how the plants respond to herbicide treatment. The evaluation of the condition of browse over the whole block is obtained from the transect.

Problems with Describing Growth Patterns

What one learns from the study of growth patterns before and after glyphosate application is that prior to treatment most species produce the most of the current year's growth from the tips, or near the top, of the main stems or woody lateral branches. These actively growing soft tissues are the most sensitive and are often killed (unless only lightly impacted). The plant then responds in Year One by producing new shoots lower down the stem and these arise directly from the main stem. If the plant is severely or very severely impacted (see categories 3 and 4 — Table 1) the new growth consists of tight clusters of numerous shoots which do not elongate, but do produce leaves. The more severe the impact, the more reduced and deformed the leaves appear. This response to glyphosate forms the basis of all the methods outlined in these guidelines. The methods were designed to attempt to record these responses. In Year Two, the way the plant recovers does not necessarily fit such a neat and tidy scenario. Herein lies many of the problems associated with trying to devise one standard method of recording the changes which can then be used in successive years.

Ruth does not state anywhere how the uninitiated observer decides what is the current year's growth. While this may appear to be obvious to any one with some botanical knowledge, it is apparently not so easy to figure out, especially with dogwood (as 4 field assistants will confirm). In general, when buds burst in the Spring, the bud scales drop off and leave scars on the stem. For most species these scars are obvious. They are not in red-osier dogwood. Current year's growth is all that growth which has leaves arising from the stem.

The following outlines some of the problems encountered in understanding the growth patterns and hence problems in assessing the condition of the plants after herbicide application. I feel it is essential that anyone intending to adopt the proposed guidelines be made aware that there are problems.
WILLOW -

(1) It may be difficult to establish which are the first year laterals, especially if they are browsed.

(11) In Year Two - if only the new laterals (current year's growth) arising from the the first year's (previous year's) laterals are measured, but new laterals arising from older (3 or more years old) woody growth are not recorded, it is possible to get the erroneous impression that no new shoot elongation is being produced (see also dogwood).

RED - OSIER DOGWOOD

(1) red-osier dogwood does not produce distinct bud scale scars. Hence, it is extremely difficult to establish where one year's growth ends and another's begins.

(11) this species is frequently heavily browsed. We observed current year's growth being browsed in August of the same year. Browsing of the new growth stimulates new shoots to be produced as the plant attempts to survive. New shoots will be produced almost anywhere on the plant, but most frequently are produced from the top of the plant. Repeated browsing results in the plant having a candelabra like appearance with many shoots arising from the top - often from old woody material several years in age. The current year's growth is often browsed before the observer can remeasure the plant in the next season.

(111) lightly impacted plants respond in the same way as heavily browsed plants, making the exact cause of the plant's condition difficult to assess.

In other words, it is virtually impossible to tell what was a first year lateral and in some cases the current year's growth is half eaten.

(iv) Measuring just the longest new lateral in the top 20 cm of the main stem gives no idea of how much potentially available browse these plants are capable of producing in one year. Up to 20 new laterals each over 20 cm in length have been recorded on one single plant in the top 20 cm stem segment.

(v) periodically the plant will decide to produce flowers at the end of all the stems. The flowering shoots do not contribute to the overall increase in the size of the plant. Ruth does not explain how these should be recorded.

MAPLE

(1) An examination of maples growing in an untreated area showed that, under "normal" conditions, some stems of a bush may produce shoot elongation at the tips of the stems whereas others will have no shoot elongation. The buds of the latter will burst and produce leaves, but no increase in length of the stem will occur. Pairs of buds producing leaves but no shoot elongation also normally occur down the length of the upper stem.
If a maple plant is encountered in a part of the block where it is not clear whether the plant was hit by herbicide (e.g. on the edge of a skip) it is extremely difficult to state whether or not the plant is unaffected ("damage" category 0) or is severely impacted (category 3). Sometimes the leaves are obviously deformed or reduced in size and the plant can be placed in category 3. However, I found many maples with clusters of normal-sized leaves all down the stem. Unless these clusters contain more than the normal number of leaves, it is often difficult to ascertain what level of impact is being observed.

**MOUNTAIN ASH**

It should be noted that, under "normal" circumstances, the bulk of the annual growth increments are from the apex of the leading shoot or main woody lateral branches. Shoot elongation from shorter lateral branches can occur, but not until these shoots are 2-3 years old. For the first 2-3 years these side shoots only produce leaves and less than 1 cm of shoot elongation. After this initial lag phase these shoots will start to elongate. If one only measures new laterals arising directly from the main stem in this species, these side shoots will be ignored. Potentially these side shoots are available as browse and should not be ignored.

The amount of annual growth of this species is very site dependant. On dry sites it appears to produce less annual growth than on very wet sites. What constitutes normal vigorous growth in this species must be assessed taking into account the individual site conditions.

**PLEASE NOTE**

In the past field season (Year Two) we were forced to abandon the idea of measuring dogwood plants as outlined in Ruth Lloyd's Year Two guidelines. Instead, we examined the whole stem and measured the length of the longest new shoot on the plant regardless of where it arose on the plant. We also adopted this system to measure most of the maples, mountain ash and some heavily browsed willows.

**CONCLUSIONS regarding growth pattern measurements**

It is important that surveyors take the time to study the changes in growth patterns of the selected browse species before and after herbicide application. They should bear in mind that each species presents it's own peculiar responses. It is recommended that the Year Two measurements as outlined in the guidelines be dropped and that surveyors simply measure the longest new growth any where on the tagged stem or plant.
GENERAL COMMENTS AND CONCLUSIONS

The methods outlined in these guidelines do not provide a quantitative estimate of the available browse on a cutblock before or after treatment. I suspect some people (myself included) were initially under the impression that they would. Ruth Lloyd never intended that they would.

What one can obtain from these methods is a qualitative assessment of the condition of the browse on the blocks. This information can be quantified as explained on pages 11 - 13. Hence, if 60% of the browse plants encountered along a transect are only lightly damaged they fit into category 1 and have new shoots of a length over a certain pre-calibrated length. Assuming that this new growth constitutes potentially available moose browse, one can hypothesize that 60% of the browse plants in the area occupied by the transect are still producing potential forage for wildlife. If the transect is truly representative of the whole block and browse distribution is reasonably homogeneous, one could project from this that 60% of the browse on the whole block is still producing forage.

A truly quantitative assessment of the amount of available browse being produced and the changes in the amount after operational application of herbicides requires some other sampling method to be employed. Some of the methods suggested in the literature include:

a) the traditional estimates of biomass based on destructive sampling and dry weight determinations. Obviously this method is not suitable for long-term study of the same plant over successive years.

b) measurement of the length and diameter of all new shoots on all stems of any one plant or bush for all plants along a representative transect. This is very time consuming and probably not suitable for operational monitoring purposes.

c) photography - standardized photographs of plants taken every year at the same time would give a permanent record of changes which occur. This has been done in a study on the effects of browsing by hares on small shrubs. It may be rather hard to do at an operational level and I suggest almost impossible where the browse species are over 2 - 3 metres tall.

d) estimates of cover and volume - probably the simplest method to implement. While subjective, evidence suggests that can be reliable as other methods.

e) correlations of twig basal diameter and weight.

References Cited


DAMAGE CATEGORY CLASSIFICATION
Used in Assessing Glyphosate Impact on Selected Browse Species

Light
- Some top-kill may be present. Lateral shoots generally 20-50 cm long.

Moderate
- Some top-kill present. Lateral shoots generally less than 20 cm long, usually considerably shorter at top of plant. Some dwarfism often seen in leaves.

Severe
- Some top-kill present. Laterals generally less than 3 cm long, leaves shortened and narrowed, especially on willows. Top of plant usually shows characteristic 'rosettes' consisting of numerous tiny laterals (<1 cm) with miniature leaves.

Very Severe
- Some top-kill present. No normal lateral shoots or leaves, only 'rosettes'.

Dead
- No visible signs of life.