

**ASSESSMENT OF PEST DAMAGE  
TO SUBALPINE FIR STANDS  
IN THE BULKLEY TSA**

by

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## FOREWORD

This report is one of a series of internal reports distributed by Forest Protection Branch, B.C. Ministry of Forests, to record accomplishments and interim or provisional results for the information of staff, colleagues, and others.

In the Canada-British Columbia Forest Resources Development Agreement (FRDA) 1985 to 1990, over 100 pest control projects were directly funded by the province and administered by protection staff. To facilitate application of the results, and development of improved forest health management strategies, the contractors reports have been edited and distributed as internal reports. Accordingly, any opinions and recommendations expressed are those of the contractor, and not necessarily those of the ministry or the FRDA management committee.

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The guidelines for internal reports outlined in the Protection Manual were adhered to as closely as possible. All manuscripts were altered to comply with a common format, but entire reports were not rewritten to conform to a standardized outline.

Most Executive Summaries were the work of Graham Hawkins of MoF Inventory Branch (formerly with Pacific Coast Forest Biology). All word processing was accomplished by Catriona Kaufman of Top Kat Services. Will Gordon of R. White Woods inc. prepared all maps and figures.

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## EXECUTIVE SUMMARY

The project was implemented in the Bulkley Timber Supply Area (TSA), where sub-alpine fir accounts for a significant portion (41%) of the local timber supply. The subalpine fir stands were suspected of having serious damage levels due to insects and diseases, but much additional data were still required since previous pest surveys had not been intensive enough. Work was to consist of sketch mapping from aerial photos and intensive aerial surveying followed by establishment of ground plots and transects, but all flight reconnaissance had to be cancelled because of continuous poor weather.

Stands were assessed for intensity and extent of damage using large scale maps and recent air photos. Affected area was determined using a dot grid and four classifications of damage were employed, based on percent of red foliage observed in the crowns. For unphotographed areas, the location and limits of infestations were established from aerial sketch maps produced from previous surveys. Affected areas on these maps were labelled as susceptible. Prism plots and transects were established in six representative stands in order to verify damage estimates obtained from the photos. The transect method was more accurate for a clumped distribution of "red attack," while prism plots more accurately assessed "green or grey attack."

Results of the ground survey indicated that an average of 38% of the total volume was damaged for all tree classes in all stands, 60% of the damage being attributable to standing dead within the older age classes 8 and 9. The most common damaging agent was western balsam bark beetle. Diseases were present, but an accurate assessment of their incidence could not be determined during winter. A tentative trend toward verification of damage levels obtained by aerial photos was derived from the ground surveys; however aerial estimates were probably too low.

Permanent Sample Plots (PSP's) were not established during this project, but methods for establishing these were proposed after close liaison with BCFS staff. The proposed plan for determining the causes, rates and associated characteristics of subalpine fir mortality included the following:

- Conduct a variable plot cruise to provide data on age of attacked trees; stand height, density, composition, basal area and volume and mean annual increment; and ecosystem association.
- Label and classify all trees by damage and record damaging agent.
- Establish 5-15ha blocks in representative areas with sampling at one plot per hectare.
- Monitor plots annually for five years or at two-year intervals for ten years.

The following recommendations, pertaining to larger units, resulted from this project:

- Conduct a more intensive aerial survey.
- Re-evaluate volume expectations in overmature subalpine fir stands since losses to bark beetle and decay may be higher than current projections.
- Determine how long standing dead trees remain merchantable.
- Consider any age class of 8 or 9 as being at risk; pest damage and risk in younger stands requires further study.
- Find an estimator of "green attack" success in order to better predict losses.

Recommendations for specific stands could not be made since results from this project were considered to be preliminary. It was considered that such recommendations would best be made after further survey work and/or measurements of PSP's have been completed.

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## 1 INTRODUCTION

Interior subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), also referred to as "balsam" in this report, is an important component of the British Columbia wood industry. Interior balsam accounted for 12% of total B.C. volumes in 1981-82 (B.C. MoF 1983). Extensive mortality of subalpine fir, caused primarily by the western balsam bark beetle (*Dryocoetes confusus* Sw.), has been documented since at least 1952 (Cottrell & Fiddick 1962).

The Bulkley Timber Supply Area (TSA), in the Prince Rupert Forest Region, was selected as a study area to assess pest damage to subalpine fir because the TSA annual allowable cut (AAC) contains significant volumes of that species, and it was suspected that pest damage to subalpine fir was a major problem. As a consequence of suspected/ observed pest mortality, approximately one-half of subalpine fir volume was removed from the TSA volume in analyses.

A description of the location and features of the Bulkley TSA can be found in the Bulkley Timber Supply Area Report (B.C. MoF 1981). The summary that follows here is taken from Dow (1983):

The Bulkley TSA is located in the Bulkley and Babine Valleys in the interior of the Prince Rupert Forest Region....Productive forests are primarily mixtures of subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), and hybrid white spruce (*Picea glauca* x *engelmannii*). The abundance of subalpine fir is an important floristic feature throughout the TSA, most of which is in the sub-boreal spruce biogeoclimatic zone.

The manageable land base contains 66.4% overmature timber (age classes 8, 141-250 years, and 9, 250+ years). Balsam stands account for about 41% of the total net operable volume in the TSA. Balsam stands, as defined by the B.C. MoF (1981) are those stands with 81+% balsam ("balsam types"), or stands with at least 20% of another species, e.g., "balsam-spruce types." Pest damage to subalpine fir has been noted in the TSA since at least 1963 (Fiddick *et al.* 1964), when aerial and ground surveys were conducted. Pest activity has been reported continuously since then (Unger & Humphreys 1982a). Ground surveys to obtain volume estimates of damage have been documented by Fiddick *et al.* (1964), and Cottrell *et al.* (1979).

The western balsam bark beetle has been the most serious pest of subalpine fir in the TSA, but other pests, particularly spruce budworms (*Choristoneura fumiferana* Clemens and *C. biennis* Freeman) and fir-fireweed rust (*Pucciniastrum epilobii* Oth), have also caused problems (Unger & Humphreys 1982a, 1983). Pests associated with subalpine fir in the TSA are listed in Appendix A.

1. To conduct an aerial survey of the Bulkley TSA, in order to accurately establish the extent and locations of pest damage to subalpine fir.
2. To conduct ground surveys in damaged stands to verify aerial survey damage estimates, estimate volume losses, and identify causes of subalpine fir mortality.
3. To propose a permanent sample plot system to measure rates and causes of subalpine fir mortality over time.

## 2 MATERIALS AND METHODS

### 2.1 Extent of Pest Damage

Field work was carried out between January and March, 1986. Weather conditions prevented an aerial survey of the TSA, so locations for a survey of pest damage to sub-alpine fir in the Bulkley TSA were based on available British Columbia MoF 1985 aerial sketch mapping surveys. Existing 1:10,000 scale color aerial photography, taken for mountain pine beetle control programs (1984-85), was used to determine extent and intensity of known damage. A dot grid (6.25 dots/ha at a scale of 1:10,000) was used to estimate red crown coverage on photos. The number of dots touching red crowns was counted and converted to a percentage of total dots within a sampled infested area. Stands were then categorized according to the percentage of crown cover showing red, as follows:

| Class | % of Red Crown Coverage |
|-------|-------------------------|
| 1     | 1 - 5                   |
| 2     | 6 - 15                  |
| 3     | 16 - 25                 |
| 4     | 26+                     |

This was adapted from a similar system used by Fiddick *et al.* (1964), which had only three damage classes (1-5%, 6-30%, and 30+%). The "medium" damage class (6-30%) has proved too broad to provide useful information relating pest population activity to observed damage (personal observations). For this reason the middle class was split, (6-15%, 16-25%) in this study. The 1964 survey was done from an aircraft, and included grey trees in the damage classes. The 1964 survey was therefore not exactly similar to the 1986 photographic analysis, but is useful for comparisons.

Infestations were mapped on 1:50,000 scale B.C. MoF forest cover maps, and a dot grid (4.0 dots/ha at 1:50,000) was used to determine the ha of infestations. Size (ha), infestation class, and forest cover type were thus available for each infested area.

Location and limits of infestations were estimated from aerial sketch maps on 1:50,000 forest cover maps for areas where no photography existed. These estimates were based on the 1985 B.C. MoF aerial survey, and simply tallied "susceptible" types within areas of known damage.

### 2.2 Ground Survey of Damage Intensity

Ground plots were used to verify damage estimates taken from color photos. Ground plot locations were chosen to reflect the most commonly occurring combinations of

damage (percentage red crown coverage) and timber types. Fifteen prism (BAF 4) plots were located at 100m intervals along lines through each sampled type.

All trees over 18cm dbh in each plot were tallied by species, dbh, mortality cause, and tree class in each plot. Tree classes were:

|                  |                                                                                                            |
|------------------|------------------------------------------------------------------------------------------------------------|
| Healthy          | - no obvious damage                                                                                        |
| Red              | - foliage red                                                                                              |
| Grey             | - foliage mostly absent, but fine twigs still present, and bark generally intact                           |
| Resin            | - bark beetle induced resinosis on the stem<br>- "green attack"                                            |
| Resin with frass | - frass on the stem was considered to indicate more intense bark beetle attack (Borden <i>et al.</i> 1986) |
| Snag             | - dead tree (3+m height) with fine twigs gone, and bark loose or absent.                                   |

Results of the prism plot survey were used to estimate volumes of damaged trees (see Appendix C for volume calculation methods).

Line transect surveys were conducted in conjunction with prism plots in six areas. The transect surveys, although not called for in the survey contract, were implemented after some prism plot data had been collected. A concern developed that the prism plots might not be giving adequate estimates of the number of red trees/ha, so the transect system was tested as a possible alternative. Transects were 100m long (between prism plots), and 10m wide (= 0.1ha). The number and type of damaged trees were tallied within each transect. Results and discussion relating to the transect survey can be found in Appendix D.

### **2.3 Permanent Sample Plot Proposal**

A system of permanent sample plots to measure rates and agents of pest-caused mortality in subalpine fir was developed through discussion with MoF staff. The proposal was submitted to the B.C. MoF Protection Branch in February, 1986.

### 3 RESULTS AND DISCUSSION

#### 3.1 Extent of Damage

The 1:50,000 forest cover maps forming part of this report have been submitted to the B.C. MoF Prince Rupert regional office. Summary maps (1:250,000 scale) of the extent of pest damage to subalpine fir in the Bulkley TSA are presented in Appendix E (not included in distributed report). Damage was widely distributed over the entire TSA.

Past estimates of balsam bark beetle infestations have varied widely. In 1963, it was reported by the Canadian Forestry Service, Forest Insect and Disease Survey, in reference to the Prince Rupert Forest Region as a unit, that "almost every stand in the district has been affected to some extent" (Unger & Humphreys 1982a). Estimates since 1980, within the Prince Rupert Forest Region, have been 2 450ha (Unger & Humphreys 1982b), and 8 600ha (Unger & Humphreys 1983). An estimate for the Bulkley TSA was 18 000ha (Unger & Humphreys 1985). The estimates for the Bulkley TSA in 1985 were 34 300 ha, based on aerial sketch mapping by the B.C. MoF (Unger & Stewart 1986). Much of the reason for variation in reported estimates is that surveys are seldom comprehensive or complete (Unger & Stewart 1986). This was the case for the 1985 aerial sketch mapping, which means that the estimates that follow in this report are probably too low (personal communication with K. Bush, Pest Management Technician, Bulkley Forest District, B.C. MoF).

The total extent of balsam stands showing pest damage was about 41 900ha for the 1986 survey (Appendix B, Tables 3 and 4). About 5 800ha of this total were in height class 1 (0-10.4m) and 2 (10.5-19.4m) stands, which are considered to be non-merchantable (B.C. MoF 1981). Approximately 7 300ha of infestations in height class 3+ (19.5+m) stands were in areas classified as "Environmental Protection Areas," which are considered inoperable for various reasons, including steep terrain and wildlife habitat (B.C. MoF 1981). There was therefore a total of 28 800ha of operable infested area, which is approximately 10.1% of the mature operable areas in the TSA (all species, including pulp stands, and areas above 1 100m)(B.C. MoF 1981).

Infestation information from the color photographs is presented in Appendix B, Table 3. About 24 400ha showed some level of subalpine fir mortality. There were about 10 000ha of class 1 damage (1-5% red crown coverage), 10 000ha of class 2 (6-15% red crown coverage), 1 700ha of class 3 (16-25% red crown coverage), and 200ha of class 4 (26+% red crown coverage) damage to height class 3+ stands. About 5 000ha of infestation in height class 3 stands were in inoperable areas. There were also about 2 500ha of damage to height class 1 and 2 stands. The total operable infested area was about 17 000ha (Appendix B, Table 3).

Estimated ha of infestations, based on aerial sketch mapping, for areas not covered by aerial color photography, are presented in Appendix B, Table 4. The total estimated area of infestation was about 17 600ha, of which 2 300ha were inoperable height class 3+, and 3 300ha were in height classes 1 and 2. The total operable infested area was about 12 000ha.

Most damage (88.5% of area) was in balsam types, on poor or medium sites, in stands of age class 8 (141-250 years) or 3 (250+ years). This reflects the situation in the Bulkley TSA, where most sites (87% by area) are poor or medium, and most of the balsam types are in age classes 8 and 9 (B.C. MoF 1981). It would be desirable to sample a wider variety of types before commenting on pest damage in age classes 5, 6, and 7.

Damage within stands was generally distributed in a "clumped" pattern, that is, red trees usually appeared in groups of two or more. These groups could occur throughout an entire stand, sometimes covering 500+ha. This pattern appears to be typical of the western balsam bark beetle. Detailed mapping of this damage from an aircraft is difficult (personal observations).

### 3.2 Damage Intensity

Sampling effort was concentrated in operable areas in the southern part (Supply Blocks A and B) of the TSA. Types were selected on the basis of the number of ha infested. It was apparent from the aerial photography that damage classes 16-25% and 26+% were of limited size and distribution, so sampling effort in these classes was reduced. Sampling effort was allocated as shown in Table 1.

Results of the ground survey are presented in Table 2. Data for the resin (R) and resin with frass (Rf) damage classes were grouped because of the small sample size. All of the stands examined on the ground were overmature types, with all-aged structures.

The average total volume in surveyed stands was 312m<sup>3</sup>/ha. Subalpine fir accounted for an average of 87% (271m<sup>3</sup>/ha) of total volume. An average of 38% (118m<sup>3</sup>/ha) of total volume was damaged for all tree classes in all stands (Table 2).

"Snag" damage accounted for most (average 60%) of the total damage volume (Table 2). These stems were often badly deteriorated so that it was not always possible to identify pest symptoms.

The primary damage agent noted was the western balsam bark beetle. The western balsam bark beetle seems to act in much the same manner as the spruce beetle (*Dendroctonus rufipennis* Kirby), utilizing windfall and cutblock edge blowdown. It is probable that the windstorms of 1978 and 1984 have contributed significantly to balsam bark beetle activity. No major defoliation was noted. Winter conditions made it impossible

to sample for root diseases such as *Inonotus tomentosus* or *Armillaria*, although mortality does occur (Unger & Humphreys 1981). A survey conducted by the Canadian Forestry Service Forest Insect and Disease Survey Section indicated that an average of 20% of trees in surveyed stands had the heart rots *Fomes pini* or *Echinodontium tinctorium* (Unger & Humphreys 1982b). The B.C. MoF has recently conducted volume decay studies in balsam stands in the TSA, and this information has been incorporated into the inventory data base (personal communication, Boyd Brown, R.P.F., Regional Inventory Officer, B.C. MoF, Prince Rupert Forest Region).

There was a (statistically insignificant) trend towards a positive correlation between damage classifications from aerial photos, and the amount of pest damage on the ground. Stands with 1-5% red crown coverage on photos had an average of 8m<sup>3</sup>/ha of red attack, and 16m<sup>3</sup>/ha R, Rf damage. Stands with 6-15% red crown coverage had higher levels of damage (14m<sup>3</sup>/ha red, 25m<sup>3</sup>/ha R, Rf)(Table 2). The average diameter (dbh) of older beetle attacked trees (red=44cm, and grey=45cm) was larger than average stand diameters (39cm,  $p=0.10$ ). Diameters of newly attacked (R, Rf average dbh=35cm) trees were generally the same as or smaller than stand average diameters (Table 2). These two facts indicate that larger stems in surveyed stands were already dead. Molnar (1965) suggested that smaller (younger?) trees seemed to be more resistant to balsam bark beetle attack. This type of attack pattern is typical of other important bark beetle species (Safranyik *et al.* 1974; Schmidt & Frye 1977).

The mortality volume figures are greater than estimates from a ground survey made by Fiddick *et al.* (1964). Fiddick's survey estimated mortality in more lightly damaged stands (1-5% damage) at 9m<sup>3</sup>/ha. This figure excluded R, Rf damage because there was (and is) no readily available method of determining which trees will survive a new beetle attack. The 1986 survey estimated mortality at 97m<sup>3</sup>/ha excluding R, Rf volumes (113m<sup>3</sup>/ha including R, Rf volumes)(Table 2). The difference between the 1964 and 1986 estimates may represent accumulated damage (about 4.0m<sup>3</sup>/ha/year) since 1964 (Unger & Stewart 1986).

Mortality volumes in the more heavily damaged stands (excluding R, Rf) were 85m<sup>3</sup>/ha and 96m<sup>3</sup>/ha for the 1964 and 1986 surveys respectively. The 1986 R, Rf estimate in the more heavily damaged stands averaged 22m<sup>3</sup>/ha (Table 2).

The Bulkley TSA AAC calculation allows for an annual mortality due to insects and diseases of 41 500m<sup>3</sup> in balsam types in a sawlog economy (B.C. MoF 1981). This allowance is 1.5m<sup>3</sup>/ha of annual mortality over a 28 000ha pest infestation.

Assuming that red trees hold their needles for five years (Doidge 1981), and that grey trees represent the transition stage between red and snag trees, total mortality for the last six years can be estimated from Table 2 as being 25m<sup>3</sup>/ha. This represents about 4.2m<sup>3</sup>/ha of annual mortality. This is close to an estimate of 4.4m<sup>3</sup>/ha made by Unger & Stewart (1986), who surveyed recently killed trees (dying trees with foliage turning

from green to red). Both of these estimates would appear to exceed the annual allowance. The B.C. MoF (1981) assumes 50% salvage of these stands, leaving an annual mortality of about 2m<sup>3</sup>/ha, which still exceeds the annual allowance.

The B.C. MoF assumes that balsam types within the Bulkley TSA have a merchantable volume that is only 50% of gross volume (B.C. MoF 1981). Such a large allowance for decay and/or loss would seem to negate the effects of pest damage on volumes in individual stands. It is important to note, however, that recent mortality (red and grey trees) observed in this study is concentrated on the most merchantable (largest) trees. This can be expected to have an adverse effect on stand merchantability.

**TABLE 1      ALLOCATION OF GROUND SURVEY SAMPLE EFFORT  
BY TYPE AND DAMAGE CLASS**

| Type           | Class and % red crown coverage | # of plots |
|----------------|--------------------------------|------------|
| B, B(-), or BS |                                |            |
| 831 p          | 1 0-5%                         | 45         |
| 831 p          | 2 6-15%                        | 30         |
| 831 p          | 2 6-15%                        | 30         |
| 831 m          | 2 6-15%                        | 45         |
| 831 p          | 3 16-25%                       | 10         |
| 841 g          | 3 16-25%                       | 10         |
| 831 p          | 4 26+%                         | 10         |
| Total          |                                | 180        |

**TABLE 2 VOLUME AND DIAMETER DATA FROM PRISM (BAF 4) SURVEYS OF PEST MANAGEMENT IN SUBALPINE FIR IN THE BULKLEY TSA<sup>1</sup>**

| Type/Location            | % Red Crown Coverage | Av. dbh (cm) | Total vol. (m <sup>3</sup> /ha) | Balsam % vol. | H <sup>2</sup> dbh (cm) | H vol. (m <sup>3</sup> /ha) | Red dbh (cm) | Red vol. (m <sup>3</sup> /ha) | Gy dbh (cm) | Gy vol. (m <sup>3</sup> /ha) | Sn dbh (cm) | Sn vol. (m <sup>3</sup> /ha) | Ri,Rf dbh (cm) | Ri,Rf vol. (m <sup>3</sup> /ha) | Total damage vol. (m <sup>3</sup> /ha) |
|--------------------------|----------------------|--------------|---------------------------------|---------------|-------------------------|-----------------------------|--------------|-------------------------------|-------------|------------------------------|-------------|------------------------------|----------------|---------------------------------|----------------------------------------|
| B(S)831-P Gramophone Ck. | 1-5                  | 32           | 231                             | 87            | 32 <sup>c</sup>         | 165                         | -            | -                             | -           | -                            | 32          | 60                           | 28             | 5                               | 65 (=28%)                              |
| B831P Harold Price Ck.   | 1-5                  | 36           | 260                             | 79            | 33 <sup>c</sup>         | 173                         | -            | -                             | 42          | 7                            | 32          | 55                           | 35             | 24                              | 86 (=33%)                              |
| B(S)831P Tenas Ck.       | 1-5                  | 40           | 460                             | 95            | 41 <sup>b</sup>         | 262                         | 42           | 24                            | 42          | 14                           | 39          | 130                          | 36             | 19                              | 187 (=41%)                             |
| B931P Microwave          | 6-15                 | 38           | 229                             | 92            | 34 <sup>c</sup>         | 142                         | 43           | 14                            | 45          | 5                            | 35          | 53                           | 34             | 14                              | 86 (=38%)                              |
| B831P Cronin Lookout     | 6-15                 | 34           | 274                             | 88            | 32 <sup>c</sup>         | 168                         | 34           | 7                             | 38          | 14                           | 31          | 58                           | 36             | 26                              | 105 (=38%)                             |
| B(S)931P Cummings Ck.    | 6-15                 | 38           | 286                             | 100           | 34 <sup>c</sup>         | 140                         | 49           | 24                            | 40          | 10                           | 36          | 72                           | 33             | 41                              | 147 (=51%)                             |
| B(S)831P Gramophone Ck.  | 6-15                 | 38           | 231                             | 89            | 36 <sup>c</sup>         | 195                         | 36           | 10                            | 46          | 6                            | 40          | 82                           | 33             | 16                              | 114 (=37%)                             |
| B(S)813M Willow Lake     | 6-15                 | 44           | 351                             | 81            | 36 <sup>c</sup>         | 226                         | 60           | 2                             | 56          | 7                            | 36          | 94                           | 34             | 22                              | 125 (=36%)                             |
| B(S)831M Microwave       | 6-15                 | 36           | 371                             | 51            | 35 <sup>c</sup>         | 264                         | 40           | 12                            | 37          | 19                           | 35          | 61                           | 35             | 24                              | 106 (=29%)                             |
| B(S)831M Tenas Ck.       | 6-15                 | 47           | 435                             | 91            | 48 <sup>c</sup>         | 260                         | 44           | 29                            | 54          | 10                           | 46          | 108                          | 45             | 29                              | 176 (=40%)                             |
| B(S)831P Rocky Ridge     | 16-25                | 46           | 284                             | 95            | 43 <sup>b</sup>         | 188                         | 59           | 14                            | 51          | 17                           | 45          | 48                           | 34             | 17                              | 96 (=33%)                              |
| S8841G Rocky Ridge       | 16-25                | 45           | 289                             | 91            | 44 <sup>b</sup>         | 202                         | 41           | 2                             | 58          | 7                            | 46          | 60                           | 37             | 12                              | 61 (=28%)                              |
| B831P Cronin Mine        | 26+                  | 37           | 356                             | 94            | 36 <sup>c</sup>         | 185                         | 35           | 26                            | 36          | 41                           | 37          | 51                           | 38             | 43                              | 161 (=45%)                             |
| Average 1-5% Red         |                      | 36           | 317                             | 86            | 35                      | 200                         | 42           | 8                             | 42          | 7                            | 34          | 82                           | 33             | 16                              | 113 (=36%)                             |
| Average 6-15% Red        |                      | 39           | 311                             | 85            | 36                      | 199                         | 44           | 14                            | 45          | 10                           | 37          | 74                           | 36             | 25                              | 123 (=40%)                             |
| Average Total            |                      | 39           | 312                             | 87            | 37                      | 198                         | 44           | 13                            | 45          | 12                           | 38          | 71                           | 35             | 22                              | 118 (=38%)                             |

<sup>1</sup> Column headings are as follows: Red = red crown; Gy = grey; Sn = snag; Ri,Rf = green attack; H = healthy

<sup>2</sup> Numbers in column followed by the same letter are not significantly different (p = 0.05)

<sup>3</sup> Data from the resin (R) and resin + frass (Rf) tree classes were combined because of small sample size

#### 4 RECOMMENDATIONS

1. An aerial survey should be conducted to obtain comprehensive and complete information on the location of pest-damaged balsam stands in the Bulkley TSA, and in other areas with significant balsam volumes. Aerial surveys are most effective when carried out from late summer to early autumn.
2. MoF should carefully re-evaluate volume expectations in overmature stands with significant balsam components. Indications are that allowance for insect losses may have to be increased, and that residual stands are reduced in merchantability. The rate at which stands become non-merchantable should be determined.
3. There is a clear need for a study to relate pest damage to volume loss. Tree mortality does not necessarily mean volume loss, but there is a limit on the length of time a dead tree remains useful. Assumptions about 50% salvage may not be realistic.
4. Any age class 8 or 9 stand should be considered at risk. Pest damage in younger (age classes 5-7) should be assessed.
5. Population activity is extremely difficult to assess. Some estimator of green attack success must be found.

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## APPENDIX A LIST OF PESTS ASSOCIATED WITH SUBALPINE FIR IN THE BULKLEY TSA

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This list was compiled from Canadian Forestry Service, Pacific Forestry Centre (Victoria, B.C.), Forest Insect and Disease Survey File Reports for the Prince Rupert Forest Region, 1969-1985.

### Insect Pests<sup>1</sup>

*Acleris gloverana* Walsingham - western blackheaded budworm

*Choristoneura biennis* Freeman - 2-year spruce budworm

*Choristoneura fumiferana* Clemens - spruce budworm

*Dryocoetes confusus* Swaine - western balsam bark beetle

*Eppirrita autumnata omissa* Harrison - green velvet looper

*Pleuroneura* spp. - balsam shoot boring sawfly

*Zeiraphera* spp. - budmoths

<sup>1</sup> Common names and authors from Furniss & Carolin (1977).

Disease<sup>2</sup>

*Cytospora* spp.- Cytospora canker of true firs

*Echinodontium tinctorium* (Ell. and Ev.) Ell. and Ev. - rusty red stringy rot

*Grovesiella abieticola* (Zell. and Good) Morelet and Gremmen - Grovesiella canker

*Inonotus tomentosus* (Fr.) Gilbn. (= *Polyporus tomentosus*) - Tomentosus root rot

*Lirula abietis-concoloris* May ex Dearn - alpine fir needle rust\*

*Melampsora abieti-caprearum* Tub. - fir-willow needle rust\*

*Melampsorella caryophyllacearum* Schroet. - fir broom rust

*Phellinus pini* (Thor:Fr.) Pilat (= *Fomes pini*) - red ring rot

*Potebniamyces balsamicola* Smerlis - red flag disease

*Pucciniastrum epilobii* Oth - fir-fireweed rust

*P. goeppertianum* (Kuehn) Kleb. - fir-blueberry rust

*Uredinopsis* spp. - needle rust

<sup>2</sup> Common names and authors from Hawksworth *et al.* (1985), except "\*" from Hepting (1971).

**APPENDIX B    AREA (HA) OF PEST-DAMAGED SUBALPINE FIR,  
BY TYPE, IN THE BULKLEY TSA**

**TABLE 3    PEST DAMAGE TO SUBALPINE FIR IN THE BULKLEY  
TSA, BY DAMAGE CLASS AND FOREST TYPE, FROM  
AERIAL COLOR PHOTOGRAPHY**

|          |      | Class and ha |       |     |    |
|----------|------|--------------|-------|-----|----|
| Type     |      | 1            | 2     | 3   | 4  |
| B        | 941m |              | 100   |     |    |
|          | 931p | 248          | 1 120 | 356 |    |
|          | 841m | 72           | 292   |     |    |
|          | 831p | 1 636        | 1 330 | 356 | 68 |
|          | 741g |              | 24    |     |    |
| B(S)     | 941m | 24           |       |     |    |
|          | 931m | 156          | 72    |     |    |
|          | 841g | 72           |       |     |    |
|          | 841m | 120          | 16    | 44  |    |
|          | 831m | 256          | 1 322 |     | 72 |
|          | 831p | 1 670        | 596   | 104 |    |
|          | 630m | 56           |       |     |    |
| B(Pl)    | 831m | 160          |       |     |    |
|          | 831p | 500          | 72    |     |    |
| B(Pl, S) | 831p |              |       |     |    |
| B(SPl)   | 831p |              | 184   |     |    |
|          | 731p | 56           |       |     |    |
|          | 530g |              | 16    |     |    |
| B(SCot)  | 831p | 92           |       |     |    |
| B(H)     | 931p |              | 132   |     |    |
|          | 831p |              | 32    |     |    |
| B(HS)    | 931m | 236          |       |     |    |
|          | 831p | 52           |       |     |    |
| B(SH)    | 941m | 180          |       |     |    |
| BS       | 941m |              | 56    |     |    |
|          | 931m | 132          | 16    |     |    |
|          | 931p | 136          |       | 116 |    |
|          | 841m | 120          | 228   |     |    |
|          | 831m | 552          | 1 104 | 68  |    |
|          | 831p | 202          | 718   |     |    |
|          | 731m |              | 60    | 48  |    |
|          | 731p | 20           |       |     |    |
|          | 630m | 80           | 64    | 16  |    |
|          | 630g | 16           |       |     |    |
|          | 530m |              | 8     |     |    |

TABLE 3 (continued)

|           |      | Class and ha |     |     |   |
|-----------|------|--------------|-----|-----|---|
| Type      |      | 1            | 2   | 3   | 4 |
| BS(Pl)    | 841m |              | 116 |     |   |
|           | 831m | 136          | 20  |     |   |
|           | 831p | 176          | 216 | 24  |   |
| BS(Cot)   | 841g | 12           |     |     |   |
| BCPl      | 841g | 48           |     |     |   |
|           | 841m | 92           | 20  |     |   |
|           | 831m | 104          | 260 |     |   |
|           | 831p |              | 28  |     |   |
| BP        | 183m | 56           |     |     |   |
|           | 841m | 20           | 146 | 40  |   |
|           | 831m | 296          |     |     |   |
|           | 731p | 256          |     |     |   |
| BPIS      | 831m | 172          | 80  |     |   |
| BPI(S)    |      |              | 108 |     |   |
| BPI(S)    | 841m |              | 36  |     |   |
|           | 831p |              | 220 |     |   |
|           | 530m | 16           | 188 | 16  |   |
| BH        | 931p |              | 156 |     |   |
|           | 841g |              |     | 36  |   |
|           | 841m | 164          |     |     |   |
|           | 831m | 128          |     |     |   |
| BHS       | 841g | 28           |     |     |   |
| BH(S)     | 831m | 12           |     |     |   |
| BH(SPl)   | 831m | 56           |     |     |   |
| BSH       | 841m | 60           |     |     |   |
|           | 941m |              |     |     |   |
| SB        | 841g | 12           |     | 256 |   |
|           | 841m |              |     |     |   |
|           | 831m | 26           |     |     |   |
|           | 831p | 28           |     |     |   |
|           | 741g |              | 37  |     |   |
|           | 640g |              | 16  |     |   |
| SB(H)     | 841m |              |     | 144 |   |
| SBH       | 841G |              |     | 48  |   |
| SB(Pl)    | 731m |              | 108 |     |   |
| SBPl      | 831m | 92           |     |     |   |
| SBPl(Cot) | 841g | 112          |     |     |   |

TABLE 3 (continued)

|                         |       | Class and ha |        |       |     |
|-------------------------|-------|--------------|--------|-------|-----|
| Type                    |       | 1            | 2      | 3     | 4   |
| HB(S)                   | 841p  | 56           | 12     |       |     |
|                         | 831p  |              |        | 16    |     |
| HBS                     | 931p  | 80           |        |       |     |
| HB(PI)                  | 831p  | 104          |        |       |     |
| HB                      | 831p  | 64           |        |       |     |
| PIB                     | 831m  | 64           |        |       |     |
|                         | 741g  |              | 24     |       |     |
|                         | 733m  | 8            |        |       |     |
|                         | 731m  | 12           | 40     |       |     |
| PIBS                    | 831g  |              | 80     |       |     |
| PIB(S)                  | 831g  |              | 240    |       |     |
|                         | 831m  |              | 28     |       |     |
|                         | 741g  | 76           | 40     |       |     |
|                         | 631m  | 56           |        |       | 3   |
| PIBBi                   | 430m  | 24           |        |       |     |
| PISB                    | 731m  | 24           |        |       |     |
| SPIB                    | 831m  | 28           |        |       | 20  |
| SPIB(H)                 | 841g  | 264          |        |       |     |
| H(S)                    | 831p  | 56           |        |       |     |
|                         | TOTAL | 9 974        | 10 030 | 1 688 | 192 |
| TOTAL OPERABLE INFESTED |       |              |        |       |     |
| height class 3+         |       |              | 16 846 |       |     |
| TOTAL INOPERABLE AREAS  |       |              |        |       |     |
| all damage classes,     |       |              |        |       |     |
| height class 3+         |       |              | 5 038  |       |     |
| INFESTED AREAS,         |       |              |        |       |     |
| all damage classes,     |       |              |        |       |     |
| height classes 1 and 2  |       |              | 2 468  |       |     |
| TOTAL                   |       |              | 24 352 |       |     |

**TABLE 4    INFESTATION (HA), BY FOREST TYPE, FOR AREAS  
OUTSIDE AERIAL PHOTOGRAPHY, ESTIMATED FROM  
B.C. FOREST SERVICE SKETCH MAPPING**

|         | Type | Ha    |
|---------|------|-------|
| B       | 951g | 80    |
|         | 941m | 264   |
|         | 931m | 408   |
|         | 931p | 1 388 |
|         | 841m | 128   |
|         | 831p | 4 324 |
|         | 831m | 48    |
|         | 832p | 12    |
| B(S)    | 931p | 104   |
|         | 841m | 120   |
|         | 831m | 716   |
|         | 831p | 724   |
| B(Pl)   | 831m | 496   |
| B(H)    | 931p | 12    |
|         | 841m | 84    |
| BS      | 931p | 196   |
|         | 841m | 436   |
|         | 831m | 1 372 |
|         | 831p | 1 360 |
|         | 731p | 104   |
|         | 530m | 44    |
| BS(Pl)  | 931m | 172   |
|         | 831m | 32    |
|         | 831p | 36    |
|         | 731g | 52    |
| BS(H)   | 831m | 40    |
| BS(A)   | 530m | 12    |
| BS(PlH) | 741g | 48    |
| BSPi    | 841g | 36    |
| BPl(S)  | 831m | 12    |
|         | 831p | 156   |
| BH      | 951g | 68    |
|         | 941m | 120   |
|         | 841m | 20    |
| BH(S)   | 931m | 180   |
| BSH     | 841m | 168   |

**TABLE 4** (continued)

| Type                                                     |      | Ha     |
|----------------------------------------------------------|------|--------|
| SB                                                       | 941m | 88     |
|                                                          | 931p | 80     |
|                                                          | 932m | 4      |
|                                                          | 841g | 44     |
|                                                          | 841m | 280    |
| SB(H)                                                    | 941m | 64     |
| SB(PI)                                                   | 841g | 48     |
| HB(S)                                                    | 951m | 52     |
|                                                          | 841p | 160    |
| HB                                                       | 941m | 72     |
|                                                          | 931p | 16     |
|                                                          | 851m | 88     |
|                                                          | 841p | 296    |
| H(B)                                                     | 941m | 28     |
|                                                          | 941p | 32     |
|                                                          | 831p | 72     |
| PIB                                                      | 831m | 20     |
| PIB(s)                                                   | 831m | 24     |
|                                                          | 731m | 24     |
| PI(SB)                                                   | 831m | 20     |
| SPI(B)                                                   | 831m | 136    |
| SPIB(H)                                                  | 630m | 12     |
| HPIB                                                     | 530p | 32     |
| SH(B)                                                    | 951g | 20     |
| TOTAL OPERABLE INFESTED,<br>height class 3+              |      | 11 996 |
| TOTAL INOPERABLE AREAS,<br>all types,<br>height class 3+ |      | 2 298  |
| INFESTED AREAS,<br>all types,<br>height classes 1 and 2  |      | 3 296  |
| TOTAL                                                    |      | 17 590 |

## **APPENDIX C VOLUME (m<sup>3</sup>/ha) CALCULATION PROCEDURES**

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Whole tree volumes were estimated from:

Whole stem cubic metre volume equations and tables, centimetre diameter class merchantable volume factors 1976. B.C. Forest Service Inventory Division, Victoria, B.C.

Equation for Interior Balsam, Table 42:

$$\begin{aligned}\log.\text{volume} &= 4.291919 + 1.872930 \\ \log.\text{dbh} &+ 0.998274 \log.\text{ht.}\end{aligned}$$

The midpoint of height class 3 (23.85m) was selected as the height estimator. Stump height was set at 45cm, and top diameter was set at 10cm. It was found, after decay allowances were made, that the volume/ha for each tallied tree in a prism plot was quite similar, regardless of dbh class. A volume of 3.61m<sup>3</sup>/ha (+/- 1.8m<sup>3</sup>/ha, p = .01) was therefore used to estimate the volume represented by each tallied tree.

## **APPENDIX D    COMPARISON OF PRISM AND LINE TRANSECT SURVEYS**

Line transect surveys were implemented after some prism plot data had been collected because it was felt that the prism plots might not be giving accurate estimates of the number of red stems/ha. It was also apparent, from color photography and ground observations, that red trees occurred in a "clumped" distribution. Line transect surveys can be more valid than point samples in this situation (Bloomberg 1980).

Analysis of the transect data treated each 100m strip (between prism plots) as a separate transect. It was assumed that each strip was independent of influence from other strips, which is a requirement for valid data analysis (Burnham *et al.* 1980).

Comparison of the line transect and prism plot surveys revealed some notable differences. The transect surveys indicated a higher number of red attacked stems/ha than did the prism plots, particularly where low levels of red attack were encountered ( $p = 0.05$ , paired t-test, Table 5). This was not the case for grey trees, where estimates varied between the two surveys. Most importantly, the transect method appeared to seriously underestimate green attack ( $p = 0.05$ , paired t-test, Table 5).

These discrepancies were partially related to detection difficulties on the ground. Red trees were easy to tally because of their visibility, and a transect survey is likely to be more accurate when this type of data is clumped. Grey trees were more difficult for an observer walking a line on the ground to detect. Green attack was very difficult to tally. The balsam bark beetle normally attacked trees above the bottom three to five metres of the stem, and the primary symptom of attack was thin streams of resin flowing down the outer bark of the upper stem. The amount of visible resin varied widely. An observer's chance of noting a green attack tree would probably be much better while in a prism plot, because each tree in a plot would be inspected during diameter measurements.

**TABLE 5 PRISM (BAF 4) PLOT AND LINE TRANSECT ESTIMATES OF PEST DAMAGE TO SUBALPINE FIR IN THE BULKLEY TSA**

| Damage<br>Type and Location  | % Red<br>Coverage | Red <sup>1</sup>  |                      | Gy                |                      | R <sub>i</sub> R <sub>f</sub> <sup>2</sup> |                      |
|------------------------------|-------------------|-------------------|----------------------|-------------------|----------------------|--------------------------------------------|----------------------|
|                              |                   | Prism<br>stems/ha | Transect<br>stems/ha | Prism<br>stems/ha | Transect<br>stems/ha | Prism<br>stems/ha                          | Transect<br>stems/ha |
| B(S)831-P<br>Gramophone Ck.  | 1-5               | 0                 | 3.83                 | 0                 | 1.17                 | 9.6                                        | 0                    |
| B931P<br>Telkwa Microwave    | 6-15              | 18.89             | 25.82                | 4.36              | 14.51                | 21.72                                      | 5.74                 |
| B831P<br>Harold Price Ck.    | 1-5               | 0                 | 6.37                 | 3.32              | 3.46                 | 30.98                                      | 0.63                 |
| B831P<br>Cronin Lookout      | 6-15              | 8.68              | 15.49                | 16.08             | 9.95                 | 32.56                                      | 2.37                 |
| B(S)813M<br>Willow Lake      | 6-15              | 0.9               | 5.72                 | 3.51              | 5.67                 | 27.39                                      | 3.5                  |
| B(S)831M<br>Telkwa Microwave | 6-15              | 11.66             | 2.81                 | 10.39             | 5.69                 | 25.34                                      | 4.25                 |

<sup>1</sup> Red stems/ha estimates significantly different between prism plots and line transects, paired T-test,  $p = 0.05$

<sup>2</sup> R<sub>i</sub>R<sub>f</sub> stems/ha estimates significantly different between prism plots and line transects, paired T-test,  $p = 0.05$