Report on Forest Pest Conditions and Special Projects: Queen Charlotte Islands, British Columbia, 1998

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Severe defoliation in regenerating western hemlock caused by western blackheaded budworm

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Introduction

A Memorandum of Understanding (MOU) between the British Columbia Ministry of Forests (MoF) and Natural Resources Canada-Canadian Forest Service (CFS) to report on forest health and pest conditions on the Queen Charlotte Islands was initiated in 1991. The required field studies have been funded by the South Moresby Forest Replacement Account (SMFRA). Since 1991, the Forest Health Unit of the CFS (formerly the Forest Insect and Disease Survey - FIDS), has carried out annual aerial and ground surveys of selected forest pests. In 1997, a special project was initiated in response to expansion of an outbreak of the western blackheaded budworm, *Acleris gloverana*, and associated hemlock sawfly, *Neodiprion tsugae*. This is the third outbreak of these defoliators recorded in as many decades. In 1998, additional funds were made available to undertake studies of the impact of these defoliating insects and to provide predictions of where future damage may occur.

This report includes the results of ground and aerial surveys carried out in 1998 and predicted defoliation in selected areas in 1999. Also included are the results of remeasurement of growth rates of mature hemlock in permanent sample plots to assess either their continued decline or their recovery following collapse of the previous outbreak. Finally, we describe initiation of a study designed to estimate impact of various levels of defoliation on regenerating stands of different stocking densities of western hemlock.

Surveys

Surveys focussed on known or potential pest problems. Aerial and ground surveys were carried out by CFS personnel between August 5th and 15th, 1998 using both rotary and fixed-wing aircraft. Because of poor weather, western portions of the islands were not surveyed at that time but were surveyed later in the month by MoF personnel.

General surveys

Surveys for the Cooley spruce gall adelgid, *Adelges cooleyi*, centered around known plantings of ornamental Douglas-fir on Graham Island where previous surveys had identified the presence of this insect. Neither Douglas-fir nor the Cooley spruce gall adelgid are native to the Queen Charlotte Islands and there is justifiable concern that these exotic plantings with their attendant pests could spread to infest local Sitka spruce. Spruce is the alternate host for this adelgid, and there is potential for significant impact on spruce if this adelgid becomes established in the Islands. The 1998 survey confirmed the continuing presence of the Cooley spruce gall adelgid on the introduced Douglas-fir but there was no evidence of infestations on nearby spruce.

Extensive road-side surveys on both Graham and Moresby Islands (including Sewell Inlet) failed to find evidence of the spruce (white pine) weevil, *Pissodes strobi*, on Sitka spruce. There is serious concern that this weevil, which is not found on the Islands, could cause significant damage to spruce regeneration, as it has in the Kitimat Valley and Prince George areas, if it were accidentally introduced to these islands.

Severe defoliation by the green spruce aphid, *Elatobium abietinum*, was evident on larger Sitka spruce along the major waterways (Tlell, Mayer, Ball, and Oeanda Rivers) of eastern Graham Island. Defoliation was more sporadic and confined to the largest, isolated spruce near Port Clements, along the Yakoun River and south of Tlell to Skidegate on Graham Island. Only occasional evidence of the aphid was noted on Moresby Island.

Defoliator Surveys

The blackheaded budworm and hemlock sawfly are native insects that periodically cause extensive defoliation of western hemlock (Koot, 1991). The blackheaded budworm feeds preferentially on current-year foliage while the sawfly feeds primarily on older foliage. In combination, these insects can totally defoliate trees. Historically, outbreaks have occurred mostly in mature forests. Recent outbreaks, however, have caused dramatic defoliation in regenerating stands.

The nearly 100% defoliation levels seen in some young stands during this current outbreak, apparently caused almost exclusively by the budworm, are only a recent phenomenon. Given the high silvicultural investment and importance of this regeneration to sustained wood supply, the potential impact of this defoliation causes considerable concern in the commercial forest.

Ground surveys for the larval and pupal stages of blackheaded budworm and hemlock sawfly were carried out in August 1998, at selected locations on the Islands, by beating foliage to collect insects and assess the life stages of the populations prior to aerial surveys. This helped to confirm the identity and relative abundance of the insect species causing the defoliation observed in aerial surveys. The sampling also served to determine the extent of defoliator populations outside the area of defoliation mapped in aerial surveys and to assess predictions made from egg samples taken in 1997 (Koot, 1997).

The ground surveys indicated that, by the time of the aerial surveys, blackheaded budworm populations were approximately half late-stage larvae and half pupae, and sawfly populations were just beginning to pupate. Thus nearly all of the defoliation had occurred prior to aerial surveys. The ratio of budworms to sawflies varied, but in all locations the density of blackheaded budworm greatly exceeded (4x to 10x) that of sawflies. We conclude that, at least in the areas of significant visible defoliation, the blackheaded budworm was largely responsible for the observed damage. Interestingly, sawflies were relatively more common than budworms only in those sites where defoliation had decreased from visible to nil between 1996 and 1998. Blackheaded budworm were common in beating samples from western hemlock east of Masset, between Port Clements and Juskatla, between Queen Charlotte City and Yakoun Lake on Graham Island and near Copper Bay and Heather Lake on Moresby Island, despite the absence of visible defoliation in these areas.

Sites where egg samples were collected in 1997 were examined for defoliation in 1998. The accuracy of the defoliation predictions from 1997 egg samples was acceptable although the data do not represent an adequate test of the method of prediction because of the low range of observed egg densities in the 1997 samples (Table 1, Koot, 1997). None of the areas where trace to light defoliation was predicted in 1997 experienced more than light defoliation in 1998. Moderate defoliation was observed as predicted at Gregory Beach on Graham Island in 1998.

Egg Surveys

Adult female blackheaded budworm lay their eggs singly on hemlock needles in late summer. We collected branch samples to estimate the density of blackheaded budworm eggs from 16 regenerating hemlock stands in the autumn of 1998 (Figure 1). Branch samples were returned to Victoria where eggs were extracted by soaking the branches in boiling water, filtering the resulting extract, and counting the number of eggs with the aid of a microscope. The results are shown in Table 1.

Table 1. Location, stand treatment, 1998 defoliation, mean 1998 egg numbers, and predicted 1999 defoliation by the blackheaded budworm, Queen Charlotte Islands, 1998.

Site/Opening Number/ Location[1]	Stand Treatment	1998 Defoliation	Mean 1998 Egg Numbers/45cm Branch	Predicted 1999 Defoliation[2]
2 - J1105-Haans Creek	Spaced	Moderate	87	Severe
4 - J1108-Haans Creek	Spaced	Light	43	Moderate
10 - J1185-Sachs Creek	Spaced	Severe	15	Light
6 - J1065-Macmillan Creek	Spaced	Severe	243	Severe
9 - Block 57-Alliford	Spaced	Light	44	Moderate
1 - J1041-Haans Creek	-	Moderate	29	Moderate
3 - J1107-Haans Creek	-	Light	17	Light
5 - J1137/1054-Sachs Creek	-	Severe	19	Light
7 - J1109-Macmillan Creek	-	Severe	51	Moderate
8 - Block 57-Alliford	-	Light	12	Light
11 - Skowkona Creek	Spaced	Trace-Light	82	Severe
12 - Phantom Creek	Spaced	Nil-Trace	65	Severe
13 - Upper King Creek	Spaced	Nil	34	Moderate
14 - Survey Creek	-	Trace	62	Severe
15 - Lower King Creek	-	Nil	36	Moderate
16 - Brent Creek	-	Nil	6	Light

[1]Sites 1-10 located on Moresby Island and 11-16 on Graham Island.

[2]1-5 eggs = Nil-Trace Defoliation;
6-26 eggs = Light Defoliation
27-59 eggs = Moderate Defoliation
60+ eggs = Severe Defoliation

The egg sample estimates indicate that the blackheaded budworm population remains high in this the third year of the current infestation. Moderate or severe defoliation is predicted for 11 of the 16 sites surveyed, with light defoliation predicted at the remaining five sites. One of these sites, Brent Creek, falls just within the light category, so the predicted defoliation may not be noticeable. New estimates of defoliation in August, 1999 will permit evaluation of these predictions, particularly in view of the age structure of the stands surveyed (the original thresholds for defoliation predictions were based on samples from mature stands).

Continued monitoring and further research on the biology of budworm populations should be undertaken to evaluate outbreak dynamics and impact of native defoliators in coastal western hemlock, particularly in view of the changes in the age structure of the host type over the past few decades.

Aerial Surveys

Defoliation mapped by aerial surveys in 1998 totaled 37 300 ha, compared to the 37 000 ha recorded in 1997. There were 30 760 ha of light, 4280 ha of moderate and 2260 ha of severe defoliation. Most of the severe defoliation observed in 1998 occurred in regenerating western hemlock stands above Alliford bay. As in previous years, the defoliation in 1998 was mainly on Moresby Island and the islands in the eastern archipelago. However, there was an increase in area of defoliation on the west and north coastal areas of Moresby Island and on western Graham

Island, particularly in the area around Rennell Sound (Figure 2). There was an equivalent decrease in area of defoliation on northern Graham Island and the southeastern portions of the Moresby archipelago. Table 2 shows the area defoliated for the three years the current infestation has been recorded.

Table 2. Year, area by defoliation intensity, and total area defoliated by the blackheaded budworm and sawflies, Queen Charlotte Islands, 1996-1998

	1996[1]	1997[2]	1998
Light	8100	15 000	30 760
Moderate	1180	14 800	4 280
Severe	180	7 200	2 260
Total	9460	37 000	37 300

[1]Vallentgoed, 1996
[2]Koot, 1997

Special Projects

Damage appraisal in mature western hemlock

At the beginning of the last outbreak, in 1985, the CFS established permanent sample plots at 10 locations within the Moresby archipelago south of Sewell Inlet. All locations were in mature western hemlock type and had been moderately to severely defoliated in 1985 and 1986. Following that outbreak, in 1989, increment cores were taken from trees in each of these locations to determine growth losses associated with the previously observed defoliation. The results of this study were reported by Wood and Garbutt (1990). In the autumn of 1998, 10 years following the collapse of the outbreak, we returned to four of these original damage-appraisal plots to re-measure growth rates on the same trees. The plots re-measured in 1998 are located at Jedway, and Point Langford (or Forsyth Point) on Moresby Island and PowRivCo Bay and Atli Inlet on Lyell Island (Figure 1). All remaining live trees marked in 1985 were located at these four sites; 9 trees each at Jedway and Point Langford; and 13 trees each at PowRivCo and Atli. The diameter at breast height (DBH), crown class, current defoliation and overall crown condition was recorded for each tree. Increment cores were also extracted from each tree and the radial increment from these cores was measured using the “MEASU-CHRON” tree-ring reader at the Pacific Forestry Centre in Victoria, B.C.

DBH Measurements

Field-measured DBH can be affected by several variables and so provides only a rough indication of rate of growth. To check the veracity of our measurements, recorded DBH’s in 1998 were compared to those recorded in 1985 and to radial increments measured in 1998 in order to identify obvious mis-measurements. Of the 43 trees measured (one tree at Atli was not measured during field work), only one tree had a recorded DBH increase that could not be reconciled reasonably with the measured radial increment and so was not considered in the following results. The average increase in DBH at each of the four sites between 1985 and 1998 was: 12% at PowRivCo, 6 % at Atli, 7% at Pt. Langford and 5% at Jedway. Table 3 compares the change in DBH at these sites. The greatest increase in growth occurred in the youngest stand (PowRivCo).

Table 3. Location, age, mean DBH and mean-paired differences of DBH of western hemlock at four mature, long term study plots, Moresby Archipelago, 1985 and 1998.

		Mean DBH(cm)		Mean-Paired
Location	Age	1985	1998	Difference
Jedway	145	62.1	66.3	4.2
Pt. Langford	115	52.3	55.7	3.2
Atli	111	42.3	45	2.4
PowRivCo	63	37.1	42.4	5.1

Radial Increment

Measurement of radial increment from cores of trees at the 4 plots confirmed the general decline in growth during the 4 years of the previous outbreak, 1985-1988, relative to the 5 years preceding the infestation as reported in the original measurements in 1989 (Wood and Garbutt 1990). Our measurements of radial growth at the 4 plots for the last outbreak showed large reductions at the Lyell Island locations, Atli and PowRivCo, (49% and 36% respectively) but only slight reductions at Jedway (4%), and even an increase in radial growth during the outbreak period at Point Langford (Figure 3). Overall, average radial increment during the 1980s outbreak from our measurements was 22% less than the average increment during the five years prior to 1985. Given measurement errors associated with cores, this estimate compares well with the overall estimate of 30% loss for the same period given by Wood and Garbutt (1989), though that estimate was based on cores from 9 plots.

The 1998 measurements indicate that affected trees have recovered their radial rates of growth during the five years following the collapse of the infestation (Figure 3). Radial increment for the five years following the collapse of the outbreak (1989-1993) averaged 45% more than the 4 years of the infestation (1985-1988) and, in most sites, increment growth had recovered to at least the pre-outbreak rates. These changes in growth rates were most dramatic in the youngest stand at PowRivCo (Figure 3).

The 1998 measurements also suggest a recent reduction in growth rates associated with the current infestation. All 4 sites are within the area of general infestation that began in 1996 although no direct observations of defoliation were made on these particular trees. The cores show a decline in growth from 1996 to 1997, and from 1997 to 1998 (Figure 3). The average growth at all four sites in 1997 was 27% less than 1996, and in 1998 was 67% less than 1996. This last figure likely overestimates increment loss because cores were taken before seasonal growth was completed .

In conclusion, surviving mature western hemlock show reductions in radial growth rates during and immediately following defoliation by blackheaded budworm. The magnitude of these reductions will vary among sites and according to severity of the defoliation and the age of the trees. The reduction in growth, however, is short-lived and growth rates recover within a few years of the end of the outbreak. Although the quantitative estimates reported here must be qualified by noting the unavailability of comparative growth rates from non-host trees from the same locations, the cumulative evidence indicates that these short-term reductions in growth followed by recovery are typical responses of the mature western hemlock to periodic insect defoliation.

Damage appraisal in regenerating western hemlock

In 1998 a project was initiated to examine the impact of the current infestation of defoliators on naturally regenerating western hemlock . Plot establishment and measurement of stocking densities, tree heights, and levels of 1998 defoliation were completed in late September/early October, 1998. All plots were established in a large area of regeneration in the Haans, Sachs, and Macmillan creeks area, south of Alliford Bay on Moresby Island (Figure 1). The area has a mix of spaced and unspaced stands dominated by naturally regenerating western hemlock with a minor component of Sitka spruce, western red cedar and cypress, in the 15-30 year age class. Ten study sites were selected based on defoliation category, as determined by 1998 aerial surveys, and on stand density, as determined by timber management information provided by MacMillan-Bloedel, Queen Charlotte Division. Five fixed-radius plots were established at each site along a compass bearing following a contour. The radius of the plots was fixed within sites but varied among sites according to stocking density to include an average of 10 trees. Each plot was at least 25m from the stand edge and plots were at least 25m apart. Within each plot, 10 trees were tagged; 1 at the plot center and 9 distributed roughly evenly throughout the area of the circular plot. The height, DBH, an estimate of defoliation in each crown third, and length of top-stripping were recorded for each tree in each plot at each site. Thus 50 trees were measured in each site and a total of 500 trees measured overall. One 45-cm branch-tip was taken from each of two trees at each plot to estimate egg density. The results of this egg sampling were reported in Table 1.

Site descriptions and a summary of initial data suggest an association between severity of defoliation and stand treatments, with the median percent defoliation greater in spaced stands than in unspaced stands. Further, four of five sites where complete stripping of tree tops was observed were in spaced stands (Table 4). The possibility of a relationship between damage by defoliators and silvicultural practices, such as juvenile spacing, will be an important aspect to examine when assessing the impact of defoliation.

Table 4. Location, mensuration data and defoliation statistics from young western hemlock at ten long-term study sites, Moresby Island, Queen Charlotte Islands, 1998.

Location/ Opening No.	Stems/ha (hemlock)	Stand		Mean		Median % Defoliation by Crown Class			Mean Stripped Top Length (m)
		Age	Treatment	DBH (cm)	Height (m)	Upper	Middle	Lower	
J1185	1000	25	Spaced	15.11	11.39	100	80	40	4.54
J1105	950	20	Spaced	9.69	6.81	90	75	30	1.49
J1065	1060	20	Spaced	8.89	7.15	80	75	20	0.94
Block 57	660	29	Spaced	10.85	7.50	35	25	10	0.1
J1108	880	20	Spaced	10.41	7.94	15	10	5	0
J1137/1054	3040	14-18	-	9.99	8.69	80	65	25	1.83
J1041	3000	23	-	7.50	6.03	20	15	10	0
J1107	1840	21	-	8.91	6.79	10	5	0	0
J1109	3800	19	-	8.72	6.71	60	40	10	0
Block 57	6399	15	-	7.04	6.48	40	20	5	0

Plans for 1999

In 1999, we propose to re-visit each of these stands to evaluate the severity of 1999 defoliation relative to predictions made from egg samples, assess the impact of 1998 defoliation in terms of tree mortality and height loss, and to measure recovery of surviving trees in stands defoliated in 1998. To complete this study, we anticipate another set of similar measurements taken when the current infestation has disappeared from all stands, and a last assessment 2 to 3 years later to assess final impact at the stand level. Specific issues we will address include:

- Quantitative estimates of losses due to defoliation in regenerating western hemlock
- Estimating collateral damage to associated conifers
- Relative susceptibility and vulnerability of spaced and unspaced stands (hazard rating)
- Accuracy of egg sampling to predict defoliation in advanced regeneration
- Behavior of defoliator populations in advanced regeneration compared to known behavior in mature stands
- Relative importance of budworm and sawflies in this current outbreak

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