Western Hemlock Looper and Disturbance

in ICH Forests

of the Robson Valley

Research Note

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Introduction

Western hemlock looper (*Lambdina fiscellaria* ssp. *lugubrosa* Hulst) (WHL) outbreaks have resulted in two significant defoliation events in forests located in the Interior Cedar Hemlock zone (Meidinger *et al.* 1991) of the Robson Valley since 1950 (Parfett, Otvos and Van Sickle 1995). The 1954-55 event defoliated over 45 000 ha of forest (Parfett et al. 1995). The 1990s outbreak defoliated 39 000 ha, mostly between 1991-92 (Taylor unpublished). Existing studies have mainly focussed on biology and control of WHL (see Raske, Otvos and Jobin 1996), rather than on its effect on the structure and function of forests. Very little information exists regarding the effect of WHL on forest ecosystems.

A study was initiated in 1998 to investigate the impacts of WHL on forests in wetter sub-zones of the ICH zone in the Robson Valley Forest District. Major objectives of the study were to:

1. Determine the relative importance of WHL over time as a natural disturbance agent.
2. Document the effects of the 1990s WHL outbreak on the structure and composition of stands within ICH forests.
3. Compare the structural and compositional impacts of WHL with other major disturbance agents.
4. Relate these findings to the provision of commodity and amenity values through the implementation of ecosystem management.

Some of the results of the study have been fully documented in previous reports (Hoggett 1999, Hoggett 2000). This note reviews the major findings of the investigation to date.

Methods

Details of field methodology for the project are described by Hoggett (1998b, 1999, 2000). The study area included all the ICHwk3 (Goat Variant) (Anon. 1996) situated within the Northern Trench and Crescent Spur Landscape Units of the Robson Valley Forest District.

Disturbance history information was collated from existing forest cover maps, 1958 and 1995 aerial photography, recent ortho-photos of current logging, local histories, newspapers and knowledge, and BC and Canadian Forest Service records. The collated disturbance history information was used to stratify the landscape units into disturbance history classes. Sample plots were randomly selected within disturbance history strata. Plots were restricted to within one to three km of a road and located at least 50 m from a watercourse.

Over three years, forty-one large (0.14 to 0.2 ha) plots from four different known disturbance history classes were measured. They included WHL defoliation (17 plots), fire (13 plots), selective logging (5 plots) and old growth (6 plots). A further twenty-two moderate (0.08 ha) size plots of unknown disturbance history were assessed. Variability due to site factory was reduced by generally sampling on sites with average soil moisture and nutrient regimes.

A variety of stand and site variables were assessed in each plot. They included measures of site, stand structure, stand age and composition, understory vegetation abundance, height, and composition, non-living organic matter, and indicators of disturbance, such as soil charcoal. Increment cores were extracted from a randomly selected sub-sample of trees from all canopy classes.

Data from stands of known disturbance history were used to develop and test classification keys. The classification keys were developed using ecosystem characteristics that were persistent and reliable indicators of disturbance history. Their purpose was to separate stands into one of four history classes: intense fire, intense WHL, moderate canopy disturbance and old growth.

Increment cores from 784 trees in 63 plots provided supplementary evidence on the intensity and timing of historic disturbance events. Of primary importance was the identification of regeneration and release events. Single tree release was defined as a growth increase of at least 250 % for the current five years of growth compared to the previous five years (Velben 1991). Radio carbon dating of charcoal found at the boundary of the organic and mineral soil was conducted to indicate the timing of previous fires.

In order to extend disturbance history record for the study area, each of the 22 stands of unknown disturbance origin was classified using the two best classification keys. The classification, coupled with supplementary data from tree ring analysis and radiocarbon dating, was used to build a picture of disturbance in the sections of the study area where disturbance history was previously unknown.

Results

Identification of New Disturbance History Information

Table 1 summarizes the results of the collation of disturbance history records. It provides areas for disturbance events identified in the study area by the project but not previously recorded on the Ministry of Forests (MoF) disturbance history maps. Significant additional disturbance information, mostly relating to post 1950s logging history, was already recorded on MoF maps.

Table 1. New Disturbance History Information Identified in the Study Area

Disturbance Agent	Estimated Date	Area Disturbed (ha)
Clearcut	1970	22
Selective Logging	1940 – 1950	937
	1950 – 1960	680
	Post 1958	84
Total Selective Logging		1701
Fire	1912	6681
Western Hemlock Looper	1955	2548
	1991 - 1992	3781
Total Western Hemlock Looper		6329
Total Disturbed Area		**14734**
Total Area of ICH in Landscape Units		**52388**

Effects of WHL on Stand Structure and Composition

Areas affected by severe WHL defoliation experienced high mortality, from 40 to 100%, of trees from all canopy positions. A relationship[1] existed between tree mortality, tree species and trees size but not forest composition. Sub-alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) suffered greater mortality than either western redcedar (*Thuja plicata* Donn ex D. Don in Lamb) or hybrid spruce (complex of white spruce (*Picea glauca* [Moench] Voss) and Engelmann spruce (*P. engelmannii* Parry ex Engelm.). Western hemlock (*Tsuga heterophylla* [Raf.] Sarg) suffered

[1] Reported statistical relationships were significant at a=0.05 and data met the assumptions of the analyses. Relationships indicate correlation, not necessarily causation.

greater mortality than hybrid spruce. Generally, sub-alpine fir and western hemlock suffered the greatest mortality with western redcedar and hybrid spruce the least.

No significant correlation was found between relative proportions of overstory species and total basal area mortality. Species-related mortality differences within stands were masked by high variability in mortality between stands. Within a given stand, relative mortality of each species showed a similar pattern. However, stands with a high basal area composition of hemlock and sub-alpine fir did not always experience commensurately high mortality.

There were significant differences in mortality between diameter classes. The largest diameter class (>50 cm dbh) suffered the lowest mortality and the smallest class (10 – 29.9 cm) the highest. The middle class (30 – 49.9 cm) had intermediate mortality.

On the sites sampled, which had average soil moisture and nutrient conditions tree death was not significantly related to any recorded features except forest floor (duff) depth, which decreased as red cedar mortality increased.

Tree death significantly promoted the growth and development of understory vegetation. The strongest correlation was between tall shrub abundance and: total basal area mortality; the basal area mortality of both hemlock and redcedar and the amount of canopy gap attributable to WHL. The relationship between cover of vegetation species normally found on disturbed sites and holes in the canopy attributable to WHL was particularly strong.

Hemlock seedlings that had regenerated after the disturbance dominated tree species regeneration. Redcedar was an important component of sapling regeneration. Sub-alpine fir regeneration occurred at relatively low densities. Virtually no spruce regeneration was recorded.

Total regeneration (seedling and saplings of all tree species), seedlings and hemlock regeneration (both seedlings and saplings) densities decreased as density of understory vegetation increased. Sapling densities decreased as death of red cedar increased.

Data for observed mortality and regeneration were used to develop a regeneration ratio. This ratio provided an indication of the amount of regeneration available five years post-WHL outbreak to replace mortality. Figure 1 indicates how stands with high basal area mortality were associated with high total understory covers and low regeneration ratios.

The relationship between overstory mortality, understory development and tree species regeneration following WHL determines medium term ecosystem dynamics. Higher overstory mortality was associated with more abundant development of non-tree understory species, which in turn was related to inhibited regeneration of tree species. Low regeneration ratios in stands with high levels of mortality meant that some stands would not regenerate to full-canopied forest in the foreseeable future. A period of site dominance by non-tree understory species following severe defoliation appeared to be part of the natural medium-term dynamic in the ICHwk3.

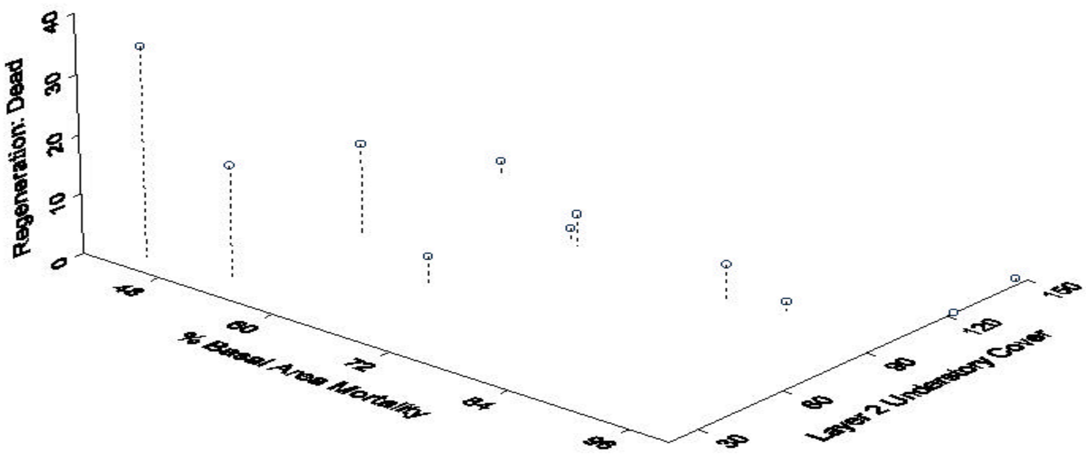

Figure 1: Regeneration Ratios (# regenerating stems/ # of dead stems) vs. basal area mortality and total understory cover

Comparing WHL Stands with Fire Origin and Old Growth

Four natural disturbance types were identified as a result of examining stands of known disturbance history. These included old growth, fire-origin, heavy WHL impact, at least 40% canopy basal area (BA) mortality, and moderate WHL impact, less that 40% canopy BA mortality. They were in addition to large areas of non-natural disturbance located within the study area associated with selective logging and clear-cutting. The characteristics of the different natural disturbances represent potential stand conditions that can serve as useful targets for management that seeks to emulate natural disturbances. They can assist in implementing ecosystem management using approaches such as the landscape level scenario planning conducted for the McGregor Model Forest (Scott 2001). Average characteristics for the natural disturbance types are summarised below.

Old-Growth

These stands were old. Tree ring records that extend beyond 220 years were found in all stands, despite the fact that most cored trees had a large part of their early ring record missing due to internal decay. Old growth stands still occurred in patch sizes of over 100 ha within the study area.

Key stand characteristics of old growth included a stocking of 545 stems per hectare (stems >10cm diameter at breast height, outside bark or dbhob). This was dominated by redcedar followed by hemlock (less than 10 % of redcedar basal area) and minor components of sub-alpine fir, spruce and other species. Old growth stands had a well-developed sub-canopy tree layer. As stem diameter increased, the number of stems of that size decreased. The greatest numbers of stems were of trees with smaller diameters. Holes in the tree canopy (canopy gaps) accounted for about 3 % of ground area. Regeneration (stems <10 cm dbhob) was abundant, with approximately 9 000 stems/ha of mainly redcedar, hemlock and sub-alpine fir. Spruce regeneration was rare and other species absent. A well-developed understory of non-tree species was present, dominated by relatively low growing plants (generally <0.3m height). There were 63 small (<30 cm dbhob) and 20 large snags per hectare and 501 m^3/ha of coarse woody debris.

Fire-Origin

Sampled fire origin stands were all initiated in the first decades of the 1900’s. Though ignition was probably due to railway development activity, their subsequent action was virtually uninfluenced by humans. Their effect was therefor considered relatively natural.

Fire disturbance was found in patches with a maximum size of larger than 1000 ha. The initiating fires caused 80% or more canopy tree mortality.

Fire origin stands had a stocking of 1115 stems per hectare. The overstory was usually dominated by spruce. Hemlock, redcedar and sub-alpine fir were well represented in the canopy and sub-canopy tree layers. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), paper birch (*Betula papyrifera* Marsh.), black cottonwood *(Populus balsamifera ssp trichocarpa* Torr. & Gray) and trembling aspen (*Populus tremuloides* Michx.) were also present in some stands. Stems were found almost equally in canopy, intermediate and sub-canopy layers. Canopy gap areas covered 5 % of the ground area. Regeneration averaged just under 10 000 stems per hectare with redcedar most abundant followed by hemlock, sub-alpine fir and a lesser amount of spruce. The non-tree understory was weakly developed. There were 160 small and 26 large snags per hectare and 372 m^3/ha of coarse woody debris.

Severe WHL Impact

Stands sampled for WHL damage were all affected by the 1990s WHL event. Severely affected areas were small to moderate in size, with a maximum patch area exceeding 100 ha, and canopy tree mortality exceeding 40%.

WHL stands had a residual stocking of 225 stems per hectare. Hemlock and redcedar dominated residual live trees in the overstory. Spruce and sub-alpine fir formed a minor element. The canopy formed the most abundant overstory layer with the intermediate and sub-canopy layers much less well developed. Canopy gaps covered 64 % of the disturbed area. Regeneration, including all living individuals of trees species from seedlings to stems less than 10 cm dbh, numbered approximately 5200 stems per hectare and was very strongly dominated by hemlock with a minor cedar component. Sub-alpine fir and spruce were also present. High average numbers of regeneration were the result of inflation by several plots with extremely high regeneration density. The non-tree understory was well developed and had the tallest maximum height of all four disturbance types. Sites with low regeneration ratios characteristically showed high mortality in the overstory, vigorous understory development, and low numbers of surviving regeneration. These coinciding conditions will lead to an extended period of regeneration delay on some sites and dominance by understory species. Some sites will regenerate to tree cover with little delay but some, about half of those examined in the study, have already had a significant regeneration delay and may have entered an extended period of understory dominance and will achieve only patchy tree regeneration, at best.

There were 475 small and 100 large snags per hectare and 344 m^3/ha of coarse woody debris in areas of severe WHL impact.

Moderate WHL Impact

Moderate defoliation by WHL occurred in medium to large patches, with maximum patch sizes of up to 1000 ha. Canopy disturbance caused 10 to 40 % mortality.

Residual stands in this disturbance type had a stocking of 416 stems per hectare. Redcedar with lesser amounts of sub-alpine fir and hemlock dominated the overstory basal area. Spruce was a minor component. Canopy layer abundance was similar to that in the *Severe WHL Impact* disturbance class. Canopy gaps covered 21 % of the area. Regeneration averaged approximately 4500 stems per hectare and was dominated by hemlock with lesser amounts of redcedar and sub-alpine fir. The non-tree understory was moderately well developed. Its maximum height was the lowest of all four disturbance types. There were 175 small and 45 large snags per hectare and 308 m^3/ha of coarse woody debris.

Evidence for Known and Unknown Disturbance Events

Classification of the 22 plots from the unknown disturbance history strata provided an estimate of the current natural disturbance history condition of the study area. The proportion of the landscape in each disturbance class estimated by each of the two best classification trees has been indicated in Table 2. It may be argued that the unknown disturbance history stratum was unrepresentative of disturbance history in ICHwk3 as human influence was non-random in the study area. However, the unknown stratum, coupled with information from stands that have survived human influence, offers the only method of determining pre-settlement disturbance patterns. It provided the best available estimate of landscape level disturbance history.

Table 2. Classification of Stands of Unknown Disturbance History

Disturbance Type	Estimated Occurrence (% stands of unknown disturbance history)
Old Growth	14 - 27%
Fire	9-14%
Severe WHL	4%
Moderate Canopy	59-68%

Dendrochronological evidence revealed three significant periods of at least low-intensity stand release (at least 20% of sampled trees in sampled stands releasing) which coincided with known disturbance events identified in Table 1. These included growth accelerations in: young 1912 fire-origin stands during the period 1932-1944; selectively logged stands during the period 1947-1962; and the 1990 WHL looper outbreak in the last years of the 1990s.

Two low-intensity release events of unknown origin were also evident. These were significant and widespread release events that reinforced the conclusions on disturbance history presented in Table 2. The first of these events occurred in the period 1876 – 1905 and affected plots in a range of disturbance classes (both known and unknown). During this period, 73% of plots with a tree ring record demonstrated low-intensity release. The average period of release was 5.1 years. The second event occurred between 1978-84 and affected a smaller proportion of plots for a shorter period of time (23% with an average release period of 2.2 years).

Medium and high-intensity release criteria (33% and 40% of sampled canopy trees within a stand releasing) highlighted the more intense examples of these events.

Regeneration data indicated only one stand- replacing event in the period 1820 to 2000 in the 50 plots that were not replaced by the 1912 fires. Partial regeneration events were more frequent, occurring in a further nine of the non-fire disturbed plots, or 18% of the sampled area.

The major period of release of unknown cause, from 1876 to 1905, occurred prior to settlement of the Robson Valley (Wheeler 1979) and covered a broad area. Its effects were long lasting, causing growth declines in the last half of the 1800s and subsequent growth releases that began about 1875 and had largely subsided by 1905. The release resulted from a natural, broad-scale and long lasting event. Wind damage and soil slumping were eliminated as probable causes as there was no evidence of these events in sample plots and these disturbance types have not been observed to occur at the stand or landscape levels in the ICHwk3. Fire was also eliminated as most (>85%) of stands showed no evidence of fire (extensive regeneration, charcoal or other stand features that indicate fire). The extent of the event, its intensity and the subsequent ecosystems were consistent with characteristics of a moderate intensity WHL defoliation. WHL was considered the most likely causal agent of this widespread and moderate disturbance event.

The second period of release of unknown cause occurred between 1978-84 in a smaller proportion of plots. No disturbance history record that explains this release was found. Alfaro et al (1999) noted two minor outbreaks of WHL in Prince George Region in 1963-1965 and 1983, but neither of these appears to match neatly with the observed release period.

Radio carbon dating confirmed that fire was an endemic feature of ICH stands within the study area. Charcoal was found in 18 stands, and at in at least two of these stands fires had occurred in every century from 1300 A.D. onwards.

Conclusion

Sufficient information on the natural disturbance regimes in the Robson Valley Forest District is available to guide the implementation of ecosystem management in the ICHwk3. Information on the effects of WHL, fire and old growth stands all provide models for managers to follow and are available from this study. Each of these disturbance histories has unique implications for ecosystem composition, structure and dynamics.

WHL infestation results in a wide range of tree mortality at all canopy positions. Within an infested stand, hemlock and sub-alpine fir experience greater mortality than redcedar or hybrid spruce. Smaller trees tend to succumb more than larger trees. Redcedar may play a role in maintaining tree cover in heavily defoliated stands until a canopy is established by regeneration. Increased mortality was associated with increased understory development and inhibited tree regeneration. A period of site dominance by non-tree understory species is a medium term prognosis for some stands following severe natural defoliation events. Survival and regeneration data indicate that WHL reinforces the importance of redcedar and hemlock in ICHwk3 stands.

Classification of stands sampled in areas of previously unknown disturbance history revealed the importance of medium intensity disturbance events in shaping ICHwk3 forests. The extremities of the disturbance intensity spectrum (high intensity fire or WHL and old growth) were found to be less common in the landscape. A long period of medium intensity disturbance occurred within the study area prior to its settlement by non-indigenous humans. A range of evidence eliminated other potential causes but was consistent with the effects of WHL. The implication is that WHL was present in the Robson Valley in the pre-settlement era.

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