Insect and Disease Management Series
6.1

2011

Lee Pederson
Nancy Sturdevant
Darren Blackford

Entomologists
USDA-Forest Service

Western Spruce Budworm Management

Choristoneura freemani **Razowski**

The most chronic, destructive defoliating insect of conifers in the Northern Rockies.

Hosts

- **Douglas-fir**
- **All true firs**
- Spruce
- Western larch
- During epidemics, pines and western hemlock may also be fed on.

Topics

Introduction

The western spruce budworm (WSB), *Choristoneura freemani* Razowski, is a native insect that has co-evolved with Douglas-fir, spruce and true fir forests. WSB populations are somewhat cyclic across many of our forests, especially west of the Continental Divide. These forests, with the exception of the Bitterroot and Lolo National Forests, usually have long periods between outbreaks where WSB defoliation is not found.

On many of our forests east of the Continental Divide, such as the Helena National Forest, populations are chronic, occurring over large areas with relatively short periods between outbreaks. As forests have become denser with proportionally more Douglas-fir and grand fir, WSB outbreaks have become more frequent and severe.

Key Points

- Multi-storied stands of Douglas-fir or true firs are most damaged.
- Shade tolerant trees are defoliated heaviest in mixed stands.
- Heaviest defoliation and tree killing are seen in Douglas fir stands on south facing slopes.
- Manage for resistant species.
- Select for phenotypically resistant trees during harvest.

Management

Encourage pines and larch because outbreaks usually occur in Douglas-fir, grand fir, and subalpine fir forests.

Avoid multi-layered stand conditions in which Douglas-fir or true firs are in overstory as well as understory.

Accept some defoliation as a normal stand-development process.

Periodic outbreaks of western spruce budworm have always been part of western forest dynamics.

Visual quality and recreation are the two resources budworm has the greatest potential to affect.

Damage

WSB feeding can cause growth loss in the form of topkill, deformities, mortality, and reduction in seed production. Tree mortality is usually concentrated in the smaller, suppressed pole and sapling size trees. However, mature trees can be killed with repeated severe defoliation. In addition, trees weakened by repeated defoliation may be predisposed to bark beetle attacks and subsequent mortality.

WSB reduces seed and cone production directly by feeding on seeds and cones, topkilling, and indirectly through the effects of defoliation. Even during light defoliation, significant losses in cone production can occur. A study in Montana demonstrated that up to 71 % of cones were infested during a period of light WSB defoliation. Although defoliation can significantly affect tree growth and survival, foliage recovery can be dramatic and within a few years tree crowns can appear healthy. However, volume of live crown and wood volume may be substantially reduced.

In addition to affecting the timber resource, WSB may adversely impact other valued forest resources, such as wildlife and recreation. Big game habitat, visual corridors, and campgrounds are examples of potentially affected systems. In areas of chronic WSB infestation, big game hiding and thermal cover may be compromised, which could result in wildlife community instability. However, WSB impacts in aquatic ecosystems may actually improve fish habitat. Defoliation in larger diameter trees is concentrated in the upper crowns and should not significantly affect canopy closure. In turn, this should have little to no effect on stream temperature or flow. Low levels of tree mortality in these riparian areas due to WSB may actually improve fish habitat by adding organic debris to streams. WSB larvae and adults may also fall into streams during dispersal, enhancing the food supply of some fish species.

Recreation and its associated economics may be affected if the public perceives its forest experience to be diminished by defoliated, and possibly dying and dead trees. In campgrounds, recreation benefits may be considerably reduced if shading, esthetic quality, and privacy screening is affected by heavy WSB defoliation (Rosenberger and Smith 1997).

Life Cycle and Behavior

Eggs hatch in late summer and first instars migrate to over-wintering sites. The larvae molt to the second instar and overwinter in silken shelters under bark scales. Larvae emerge in spring, April to June, and mine buds and old needles until bud flush. As the buds flush, larvae web new needles together to feed in a protective shelter through the sixth instar. They pupate in these silken shelters and emerge as adults by August. Eggs are laid in a mass containing up to 130 eggs, on the underside of a needle.

Insect dispersal occurs during the adult and larval stages of

Life Cycle and Behavior *(continued)*

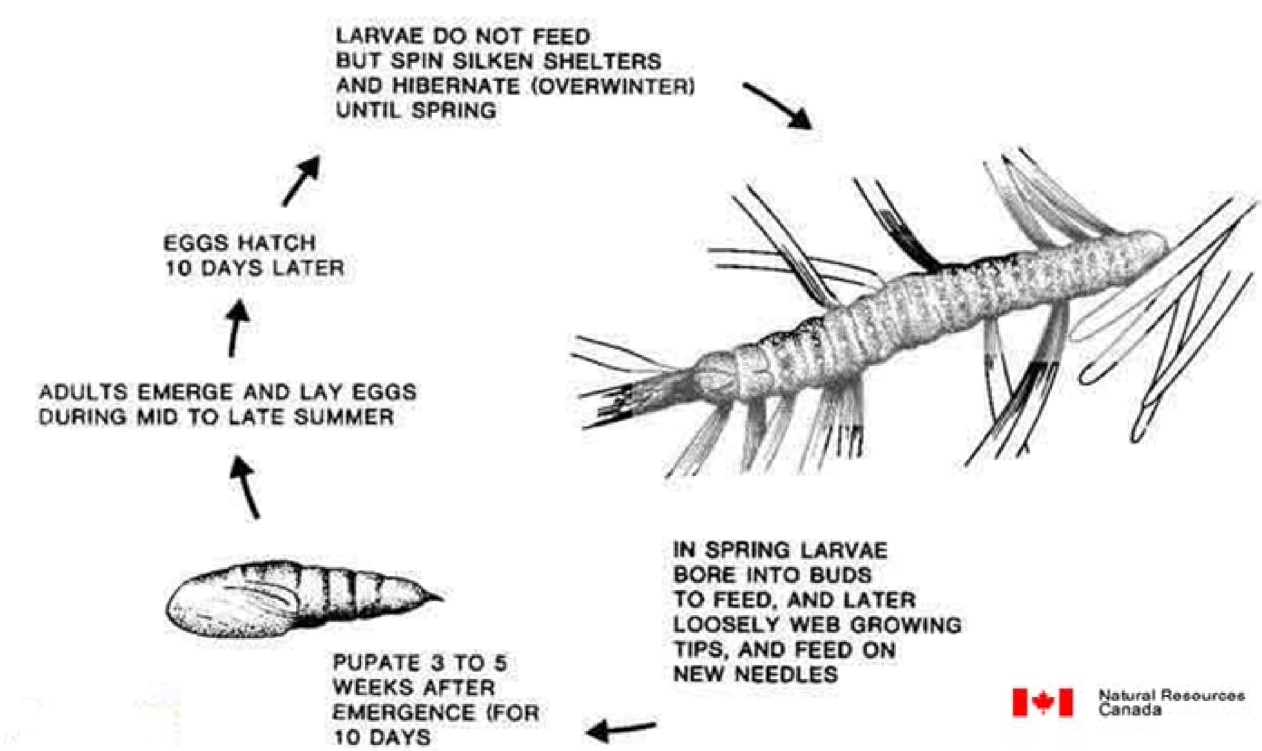
development. Horizontal dispersal, from tree to tree and from one stand to another, occurs mainly during the second larval instar and adult life stages (Carlson et aI. 1988). Frontal systems and associated winds can carry populations from one drainage to another. This may account for sudden population increases in areas previously uninfested. Vertical distribution is more prevalent in the older, larval stages which are not as buoyant on wind currents, but also occurs throughout all larval stages. Through management, we can negatively influence this stage of WSB development, mainly through interrupting dispersal by reducing the number of canopy layers through harvesting.

WSB habitat quality is determined by stand structure, composition, and density. Good WSB habitat consists of dense, multiple layers of climax host species. The climate of these stands may influence the probability of an outbreak, but stand conditions will determine the duration and intensity. The upper story provides a good food source and refuge from predation and parasitism. The lower canopy layers intercept WSB spinning from the upper layers and provide sanctuary from the predators on the forest floor. Dense, even-structured stands will limit the diversity of bird predators (Langelier et al. 1986) and may reduce the efficacy of insect parasites. Temperature fluctuations and precipitation patterns can greatly affect WSB behavior and population development (Kemp et al. 1983). Climatic influences are an integral part of the hazard rating system developed for budworm.

Good WSB habitat consists of dense, multiple layers of climax host species.

Understory layers provide food, shelter, and a moderated climate which promote WSB population growth.

Western Spruce Budworm Life Cycle



Risk rating can be used in combination with hazard rating to project the probability of a WSB outbreak and the level of damage that will result.

Hazard Rating

Stand-level hazard

Hazard rating for insects and diseases can help set priorities for treatment based on stand susceptibility to insects and diseases. Forest insects require three things to cause significant impact to resource values: susceptible hosts, insect populations, and favorable weather conditions. Hazard rating systems measure susceptibility of forested areas to a particular insect by evaluating the amount of susceptible host. High and moderate hazard forested areas are more likely to experience significant damage and/or tree mortality if insect populations are present and the weather is favorable.

The model we recommend for stand level data in the Northern Region is the Generalized Indexing Model developed by Carlson and Wulf (1985). Please refer to this publication for information on using the model.

Hazard Rating for Western Spruce Budworm

Carlson and Wulf (1985)

Character	Descriptive Variable	Index Value Range
Species Composition	% host crown cover and % climax host crown cover	0-2.4 0.6-2.4
Stand Density	Total % crown cover	0.8-1.6
Crown Class Structure	Coefficient of variation of host tree heights	0.9-1.7
Stand Vigor	Basal area stocking/average maximum basal area and incidence of stress-inducing pests	0.9-1.6
Stand Maturity	Basal area weighted mean host tree age	0.3-1.3
Site Climate	Habitat type group	0-1.5
Regional Climate	Geographic location	0-1.2
Surrounding Hosts Type Continuity	% host type in surrounding 1,000 acres and adjacent to the stand	0.6-1.7

Hazard Rating (continued)

Landscape hazard rating

For conducting hazard rating on a larger scale, a system has been developed (Randall and Bush 2010). As of 2011, this model has not yet been validated. Data sources for use in this model may include inventory data where basal area, host composition and trees per acre data are available.

Hazard Criteria for Western Spruce Budworm/Douglas-fir Tussock Moth

Criteria	Attribute	Low (.5)	Moderate (2)	High(3)
A	BA all species (ft^2/acre)	<80 ft^2/acre	80 ≤ BA < 100 ft^2/acre	≥100 ft^2/acre
B	% of total BA that is: Engelmann spruce, subalpine fir, grand fir, and Douglas-fir ≥5" DBH	<50%	50% ≤ % BA < 80%	≥80%
C	Trees per acre ≥5" DBH	<50 /acre	50 ≤ TPA < 100 /acre	≥100 /acre

Directly Calculated Hazard Values and Hazard Rating Multiplicative Index

Hazard	Calculated Values	Hazard Rating
Extremely Low	0	0
Low	<2	1, L
Moderate	2-17	2, M
High	≥18	3, H

High-hazard stands are those in which a large amount of Douglas-fir and true fir defoliation is expected once an outbreak of WSB occurs. Mortality of small- and mid-size trees often occurs under these conditions but seldom occurs in larger trees in Montana and Idaho. High hazard stands contain larger trees, the preferred hosts of Douglas-fir beetle. Douglas-fir beetle may attack and kill trees that experienced repeated, heavy defoliation from WSB. Moderate- and low-hazard stands may experience less defoliation and defoliator-caused growth loss, top kill, or mortality.

Habitat Types

Western spruce budworm defoliation occurs in 46 habitat types described for Montana (Fellin et al. 1983); across much of Montana and part of Idaho.

They fall in these habitat type series—

- Douglas-fir
- spruce
- grand fir
- western red cedar
- western hemlock
- lower elevations of the subalpine fir series.

Hazard Rating *(continued)*

Interpreting Hazard Rating

High-hazard stands are those in which a large amount of Douglas-fir and true fir defoliation is expected once an outbreak of WSB occurs. Mortality of small- and mid-size trees often occurs under these conditions but seldom occurs in larger trees in Montana and Idaho. High hazard stands contain larger trees, the preferred hosts of Douglas-fir beetle. Douglas-fir beetle may attack and kill trees that experienced repeated, heavy defoliation from WSB. Moderate- and low-hazard stands may experience less defoliation and defoliator-caused growth loss, top kill, or mortality.

When high-hazard stands are intermixed with low-hazard stands, defoliator populations may not be as active. Low-hazard stands may have host species, but may be comprised of smaller trees or single-storied stands and/or are not contiguous across the landscape to allow defoliator populations to remain at high levels. Defoliators may still cause significant mortality in the host components of low-hazard stands in a landscape, but losses will be lower than in a landscape where high-hazard stands dominate

Data Considerations

When using hazard ratings in a landscape level analysis, it is assumed that available data are a representative sample of landscape conditions. A spatially balanced inventory across the geographic area of interest can be used to derive estimates of hazard. However, small forested areas, or areas with unique characteristics, may not be represented or have insufficient data for analysis. Users should carefully evaluate available data for a particular analysis area to insure that a representative sample of current forest conditions exists. Hazard ratings calculated for a sampled area assumes that forest conditions in the sample area are homogeneous; if excessive variability in any of the parameters used to calculate hazard ratings occurs within the sampled area, the hazard rating may not accurately reflect the hazard. If that is the case, further stratification of the geographic area of interest into various dominance types, size classes, and densities may be

Permanent Plots

In total, we have established 360 permanent plots located throughout the region in areas at risk to WSB. Plots were established in low, moderate and high defoliation areas. Stands were selected on the premise of representing diverse conditions across stand and site conditions. Since recording the initial measurements, stand information has been collected 2-3 years following an outbreak or at least once every 5-10 years. Defoliation is recorded via Aerial Detection Survey annually when present. Impact data on individual trees and stands are measured from plots, including effects on succession.

FVS-linked Budworm Damage Model

Model description

The WSB damage model, an extension to the Forest Vegetation Simulator (FVS), predicts topkill, height growth, diameter growth, and tree mortality impacts of WSB defoliation on its spruce and fir host tree species (Crookston 1991). This model is formed from two components of the Western Spruce Budworm Modeling System (Sheehan et al. 1989, Crookston et al. 1990): foliage dynamics and damage.

The damage model allows users to specify defoliation patterns by tree species, size class, crown third, and needle age class (Crookston et al. 1990). For the user's evaluation of the specified defoliation patterns, there are two output tables available: a cumulative damage summary and periodic damage tables at each FVS cycle boundary, displaying the results of budworm defoliation on FVS model trees.

Cultural manipulation of stands offers the greatest hope for preventing outbreaks or reducing impacts.

Western Spruce Budworm Control Strategies

Silvicultural Alternatives

Even-aged management systems mimic stand replacement fires and are an applicable system in areas of historically long fire intervals. Multiple use applications of even-age systems are suited to provide increased water yields, diversity of habitat (particularly browse habitat) required by game and non-game wildlife (Gibbs 1978). Clearcutting and seed tree systems promote development of seral plant communities. Climax species invariably become part of the overstory and as the stand develops, increased amounts of suppressed, climax species develop in the understory. Intermediate treatments may be necessary to modify stand density, tree spacing, and favor seral species.

Shelterwood cuts should be used with care but can be used in areas where the probability of WSB infestation is slight. Dependent on the site, residual overstory, and number of entries made to remove the overstory, the climax species are more or less favored. Removal of the overstory should be made within 10 years following initial entry.

Developing two or three-stored stands with one or two levels of regeneration beneath a nearly closed canopy will promote and support WSB infestations. Understory regeneration will be climax species. Should a WSB infestation develop in the overstory, vertically dispersing larvae will be intercepted by the understory. These understory layers provide food, shelter, and a moderated climate which promote WSB population growth (Schmidt et al. 1983). In addition to the development of budworm populations, the genetic quality of the seral species will be lost by the second or third cut. Thus, the future management could be relegated to climax species and chronic WSB infestations. When other management objectives lead to creating multi-storied stands, consideration should be given to maintaining healthy stands through

Intermediate Treatment Objectives
(Schmidt, 1983)

- ⇒ Maintain tree vigor to enhance survival and recovery
- ⇒ Alter the stand physical and biological parameters to reduce budworm habitat
- ⇒ Capitalize on natural resistance of individual trees and species

Silvicultural Alternatives (continued)

Even-aged management systems mimic stand replacement fires and are an applicable system in areas of historically long fire intervals.

intermediate cuttings and fire, and by creating conditions that are favorable to natural enemies of WSB.

Manipulating stand density and tree spacing, if properly timed and applied, can increase growth on other host and non-host trees. The foliage food value, with regard to WSB, appears to be better in foliage from stressed trees. Therefore, reducing stress within stands should reduce the food quality. Increasing tree spacing will reduce interception of larvae by the understory and increase WSB vulnerability to predators, parasites, and erratic weather conditions. Favoring non-host trees and host trees showing less damage as the residual trees, will have an impact on the outbreak by the simple removal of the food source.

Uneven-age management can occur in stands of irregular or uneven-age structure, on fragile sites, steep slopes, high water tables, very dry sites, or sites that would be adversely affected by complete removal of forest canopy. The multiple use applications of uneven-age silviculture are best suited to travel influence zones, water influence zones, watershed protection, scenic areas, wildlife habitat requiring high forest cover and vertical diversity in vegetation (Gibbs 1978).

Chemical and Biological Pesticides

Pesticides provide only temporary protection against budworm. Protection usually only lasts 2 3 years before populations resurge.

Chemical control for WSB can be used to protect high-value trees from defoliation, damage and mortality in the short term. Large forested areas can be aerially sprayed for short-term protection and individual trees can be sprayed using ground equipment.

Over the long term, chemical control is not effective in reducing the impacts of WSB because of re-invasion by the adult moths from surrounding infested stands. Repeated applications during the course of an outbreak may be needed for adequate protection.

Timing of insecticide application is critical for successful reduction of damage and mortality from WSB. Insecticides should be applied in early summer when most WSB larvae are in the 4th instar (3/4 inch long) and before they reach 5th and 6th instar larvae when significant damage results from continued feeding. Insecticides should also be applied when most of buds on trees have flushed and are about an inch in length. Chemicals currently registered for use against WSB include carbaryl and a microbial insecticide, *Bacillus thuringiensis* (B.t.) var. *kurstaki*. B.t. is a naturally occurring host-specific pathogen that affects only the larvae of lepidopterous insects feeding on foliage at the time of application and a short time thereafter. B.t. is used to spray in environmentally sensitive areas where chemical applications may be prohibited. Carbaryl is a broad spectrum carbamate that affects all insects on the foliage at the time of application (Blackford et al. 2007).

WSB Effects on Stand Development and Succession

Insects and diseases, as well as fire, have a natural role and function in forest dynamics. Under endemic conditions, insects and diseases are nature's tools to keep a forest healthy. They work quietly to keep stands thinned. Even periodic outbreaks of insects serve a useful purpose. They weed out genetically inferior stock in a stand providing more growing room for resistant trees.

In unmanaged, mixed-species stands, if fire and insects such as WSB are allowed to play out their natural roles, there would be a shift away from true firs to include more resistant species such as Douglas-fir, larch and pines essentially resetting succession. Over the short term, there would be losses in terms of recovery of volume per unit area, but probably minimal impacts on other resources directly resulting from WSB.

In pure Douglas-fir stands, which comprise much of our east-side WSB habitat, natural cycles of WSB would weed out individual large trees and suppressed smaller, slower growing trees, resulting in a push toward climax.

In Douglas-fir stands...

Natural cycles of budworm weed out individual large trees and suppressed smaller, slower growing trees, resulting in a push toward climax.

References and Other Reading

Blackford, D., L. Lazarus, L. Pederson, and N. Sturdevant. 2007. Western Spruce Budworm in the Intermountain West. USDA For. Serv. Northern and Intermountain Regions. http://www.fs.fed.us/r6/nr/fid/pubsweb/westdef/wsb-brochure-r14.pdf

Carlson, C.E., W.W. McCaughey, and L. Theroux. 1988. Relations among stand structure. Dispersal of second instars of western spruce budworm, defoliation and stand height growth of young conifers. Can. J. For. Res. 18:794-800.

Crookston, N.L., J.J. Colbert, P.W. Thomas, K.A. Sheehan, and W.P. Kemp. 1990. User's guide to the western spruce budworm modeling system. Gen. Tech. Rep. INT-274. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 40 pp.

Crookston, N.L. 1991. Foliage dynamics and tree damage components of the western spruce budworm modeling system. Gen. Tech. Rep. INT-282. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 40 pp.

Fellin, D.G., R.C. Shearer, and C.E. Canson. 1983. Western spruce budworm in the Northern Rocky Mountains. Western Wildlands, A Natural Resource Journal 9(1):2-7.

Gibbs, C.B. 1978. Uneven-aged silviculture and management? Even-aged silviculture and management? Definitions and Differences. In: Uneven-aged Silviculture and Management in the United States. USDA Forest Service. Timber Management Research, Wash., DC.

Kemp, W.P. 1983. The influence of climate, phenology and soils on western spruce budworm defoliation. Ph.D. dissertation, Univ. of Idaho, Moscow, ID. 143 pp.

Langelier, L.A., and E.O. Garton. 1986. Management guidelines for increasing populations of birds that feed on western spruce budworms. USDA Forest Service, Ag. Handbook No. 653.

References and Other Reading *(continued)*

Rosenberger, R.S., and E.L. Smith. 1997. Nonmarket economic impacts of forest insect pests: a literature review. Gen. Tech. Rep. PSW-GTR-164-www. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Dept. of Ag.; 38 pp. http://www.fs.fed.us/psw/publications/documents/psw_gtr164/

Publication Citation

Pederson, L., N. Sturdevant, D. Blackford. 2011. Western spruce budworm management. Chapter 6.1 Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern Region, State and Private Forestry. 10 pp.

Available from USDA Forest Service, Idaho Department of Lands, and Montana Department of Natural Resources.

Online at: **https://fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5186684.pdf**