Forest Health Protection and State Forestry Organizations

May 2004

6.1
WEB July 2010

By Darren Blackford
US Forest Service

Management Guide for
Western Spruce Budworm
Choristoneura occidentalis Freeman

Topics

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.

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

Hosts

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

Periodic Outbreaks with Severe Defoliation

Larvae mine buds and old needles prior to bud burst in May and June. They consume new foliage as the buds flush. Radial growth is decreased after several years of heavy defoliation. After 3 to 5 years, branch dieback, top kill, and tree mortality can occur. Cones and seeds of Douglas-fir, larch, true firs, and spruce are also destroyed. Terminal and lateral new larch shoots can be severed.

The western spruce budworm is a native insect that has co-evolved with Douglas-fir, spruce and true fir forests. Budworm populations are somewhat cyclic across many of our forests, especially west of the Divide. These Forests, with the exception of the Bitterroot and Lolo National Forests, usually have long periods between outbreaks where no budworm defoliation is detected. On many of our forests east of the Continental Divide, such as the Helena National Forest, the population is chronic, occurring over large areas with relatively short periods between outbreaks. As forests have become denser with proportionally more Douglas-fir, budworm outbreaks may have become more frequent and severe.

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.

Life History and Behavior

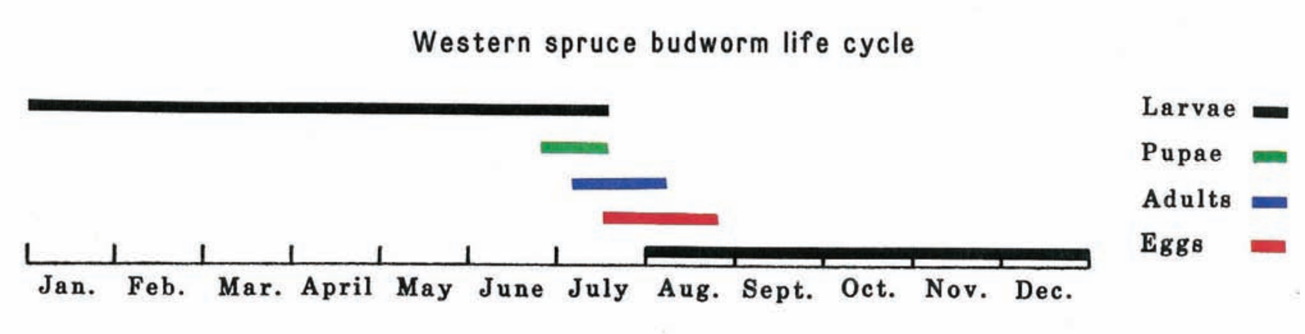
Good budworm habitat consists of dense, multiple layers of climax host species.

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 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 un infested. 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 budworm development, mainly through interrupting dispersal by reducing the number of canopy layers through harvesting.

Budworm habitat quality is determined by stand structure, composition, and density. Good budworm 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 budworm 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 at. 1986) and may reduce the efficacy of i~ parasites.

Temperature fluctuations and precipitation patterns can greatly affect budworm behavior and population development (Kemp et al. 1983). Climatic influences are an integral part of the hazard rating system developed for budworm.



History

Present conditions exhibit more synchrony of infestations that are more widely dispersed across our forests than we have seen In the past. The most popular hypothesis is that the greater extent and immensity of budworm outbreaks in this century is related to human-caused forest changes. Selective harvesting of ponderosa pine and Douglas-fir in the past, and fire suppression after 1900 led to 20th century forests with higher proportions and densities of budworm host trees than existed in pre-settlement forests (Swetnam & Lynch 1993).

Outbreaks were reported as early as 1922 in the Northern Region. Outbreaks have not become more frequent across most forests but have increased in duration and intensity (Anderson et al. 1987). Although temporal patterns of budworm may not have significantly changed, the composition and structure of forests have, and subsequently have effected the spatial dynamics of budworm outbreaks.

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

Current Conditions

The most extensive defoliation reported in the Northern Rockies occurred in 1958 and affected more than 4.9 million acres. The least defoliation recorded since the beginning of aerial surveys in 1948 was in 1993 where only 45,000 acres were reported defoliated. This was a significant decline from 1992 and was probably due to the unusually wet and cool summer of 1993. Weather has a direct effect upon larval development and dispersal and adult dispersal.

During the mid-1990s, we expect the population to recover slowly across the Region. However, in areas where budworm was thriving in 1993, defoliation will probably continue to increase in both intensity and area affected. Most of our Douglas-fir and true fir stands across the region are susceptible to budworm. Although certain forests such as the Kootenai and Clearwater appear to have longer periods of time between outbreaks than many of our east-side forests.

More than 4.9 million acres were defoliated by western spruce budworm in 1958.

Future

If we continue to restrict fire from most of our Douglas-fir, true fir forest types, we will continue to intensify the outbreaks across the region. Silvicultural practices and management objectives are changing which might either contribute to, or reduce the potential of future outbreaks.

The most effective approach from a budworm management perspective is to evaluate larger land areas and prioritize treatment of stands based upon hazard and risk rating when possible.

Budworm can disperse over long distances. Although treating a stand may protect individual trees within the stand, the effects of budworm from surrounding stands will in turn effect the protected stand.

Hazard Rating

When conducting large scale area analyses, hazard rating for insects and diseases should be an integral part of the process. This can help set priorities for treatment based on stand susceptibility to insects and diseases. Hazard rating for budworm integrates site and stand conditions known to influence budworm. The model we recommend for the Northern Region is the Generalized Indexing Model developed by Carlson and Wulf (1985).

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 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

Risk Rating

Risk rating refers to stand vulnerability, or how much damage will result from an insect outbreak. A risk rating system for budworm is based upon cumulative years of budworm defoliation taken from aerial survey information. Risk rating can be used in combination with hazard rating to project the probability of a budworm outbreak and the level of damage that will result. We are in the process of developing an indexing system to rate susceptibility and vulnerability to budworm for a larger land unit such as drainage.

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

Risk Rating

(Continued from page 4)

This should complement our current ecosystem management philosophy. Its also very practical because budworms disperse across many stands during an outbreak therefore the impact on the landscape should be considered and not just on individual stands.

Permanent Plots

By 1995, we will have 360 permanent plots located throughout the region in areas at risk to budworm. Plots were established in low, moderate and high defoliation areas. Stands were also selected to represent diverse conditions across stand and site conditions. After the initial measurements, stand information is collected 2-3 years following an outbreak or at least once every 5 years. Defoliation and population measurements are made annually. Impact data on individual trees and stands are measured from plots, including effects on succession. The data will also serve as a measure of impacts on wildlife habitat, recreation and visual qualities.

FVS-Linked Budworm Damage Model

Permanent plot data is also being used to validate a budworm damage model for application in Northern Region. The budworm damage model is linked to the FVS model and can be used to adjust tree growth and mortality based on budworm defoliation rates.

We are also in the process of improving and streamlining the budworm population dynamics model. The budworm population dynamics-FVS model can simulate budworm-stand interactions over long time periods. The model can be used to make long-term projections of population dynamics and defoliation which can then be used to help determine outcomes of different management alternatives.

For more information or assistance in using any of these models, contact an FPM specialist.

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

Silvicultural Alternatives

The silviculturist has a variety of management options to prevent or reduce budworm impacts. These options include both even- and uneven-aged regeneration systems, and intermediate treatments on stands not ready for harvest. Maintaining a healthy forest offers the greatest potential for preventing or reducing the severity of budworm outbreaks. Providing diverse habitat for insectivorous birds, mammals, and other insects is also important for preventing budworm outbreaks.

Silvicultural Alternatives

(Continued from page 5)

This can be accomplished by proper snag management, leaving adequate woody residues on the site, and enhancing the edge effect. Natural predators and parasites are not as effective during outbreaks as they are when populations are at lower levels. However, their presence at low population levels may prevent an outbreak from occurring.

Even-aged management systems mimic stand replacement fires and are an applicable system in areas of historcal1y long fire intervals.

Even-aged management systems mimic stand replacement fires and are an applicable system in areas of historcal1y 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. Imermediate 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 budworm 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.

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

Developing two or three-stored stands with one or two levels of regeneration beneath a near1y closed canopy will promote and support budworm infestations. Understory regeneration will be climax species. Should a budworm 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 budworm 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 budworm infestations. When other management objectives lead to creating multi-storied stands, consideration should be given to maintaining healthy stands through intermediate cuttings and fire, and by creating conditions that are favorable to natural enemies of budworm.

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 budworm, 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 their 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.

Silvicultural Alternatives

(Continued from page 6)

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).

How can uneven-age management be recommended in budworm situations and not multi-storied management? In properly applied uneven-age management, the fast-growing, quality trees are left to grow to maximum size: they produce seed and their progeny, because of their fast growth, are always an integral part of the stand (Gibbs 1978). In an uneven-age stand, each crop tree has adequate room to grow so the vigor of the regeneration is insured. Harvest entries occur at more frequent intervals in an uneven-age stand and regulation of the understory to promote seral species development and occur at that time. In multi-storied stands, harvest entries occur at 80- to 100-plus-year intervals by which time suppression is already occurring in the understory. Promoting seral tree development is not likely unless intermediate treatments to accomplish this objective are scheduled.

Intermediate treatments are effective in preventing or reducing damage from budworm outbreaks. Generally, they are applied to stands not ready for harvest. (See sidebar.)

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

Chemical and Biological Pesticides

The most recent operational spray program for budworm on national forest land in the northern Rocky Mountains took place in 1979. In the near future, we do not expect to implement any large spray programs aimed at budworm because of both economic and environmental constraints.

Several chemical insecticides are registered for use on budworm: they include acephate, carbaryl, malathion, methomyl, naled. The naturally occurring bacterium, *Bacillus thuringiensis*, is also registered for budworm control. Acephate implants can be used on individual trees to protect cone crops.

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

Natural Control
General recommendations for improving natural enemy habitat

Natural control agents, or natural enemies of budworm, play a significant role in lengthening the period of forest stability between pest outbreaks. Birds and ants play an especially important role in stabilizing budworm populations across the region (Carlson et aI. 1984).

Several wasp and fly parasites also have critical roles in the population dynamics of budworm, and some important budworm pathogens have also been identified.

Maximizing the survival of natural enemies by habitat conservation and enhancement can reduce the impact of budworm on all resources.

⇒ **Diversify the managed forests by utilizing irregularly shaped cutting techniques.**

⇒ **Plant a variety of tree species where possible, conserve streamside or pond habitat which will improve bird nesting success.**

⇒ **Leave dead woody materials to increase carpenter ant habitat (Torgersen et al. 1990). Both carpenter and mound building ants are important predators of spruce budworm.**

Effects of Budworm on Resources

Timber—

The amount of defoliation is often highly variable among stands and even among trees in a stand. 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. Budworm feeding can cause growth loss in the form of topkill, deformities, mortality and reduction in seed production. Most of these effects are concentrated to specific trees based upon individual tree characteristics; and localized areas, usually based on individual stand dynamics such as species composition and structure. Mortality is usually concentrated in the smaller, suppressed pole and sapling size trees. With both Douglas-fir and grand fir, the stimulation of adventitious and epicormic branching during an outbreak or a chromic period of budworm feeding, may significantly contribute to tree recovery.

Mortality is usually concentrated in the smaller, suppressed pole and sapling size trees.

Budworm reduces seed and cone production directly by feeding on seeds and cones. topkilling, and indirectly through the effects of defoliation. During periods of even light defoliation, significant losses in cone production can occur. One study conducted in Montana, demonstrated that 9-71 % of cones were infested during a period of light budworm defoliation.

Effects of Budworm on Resources (Continued from page 8)

Stands 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 budworm were 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 budworm.

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

In managed stands, depending upon objectives, we have the opportunity to create resistant stands composed of primarily resistant trees. In mixed conifer stands, openings could be created to encourage invasion by seral species. In pure Douglas-fir stands, stand maintenance and improvement could be obtained through intermediate thinnings across size classes, management of understory, and by leaving individual trees that show resistance to budworm damage.

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.

Wildlife—

Depending upon the duration and intensity of an infestation, budworm has the potential to adversely impact big game habitat. In areas that have chronic budworm infestations, both hiding and thermal cover could be affected. However, top killing and tree mortality will open up the stand and forage production will increase. This might affect hiding cover but probably not thermal cover over the long term except in isolated instances where an area is defoliated repeatedly. In areas where budworm occurs less frequently and/or the duration of outbreaks is short, neither thermal or hiding cover are probably affected.

Budworm larvae and pupae provide a valuable food resource for many species of birds and small mammals. Carpenter ant populations, which benefit from increases in budworm populations, are a primary source of food for animals such as grizzly bears and the pileated woodpecker during certain times of the year.

Budworm larvae and pupae provide a valuable food resource for many species of birds and small mammals.

Effects of Budworm on Resources

(Continued from page 9)

Aquatic Ecosystems—

Even during budworm outbreaks, little or no mortality usually occurs in larger diameter size trees and less than 100 percent defoliation usually results. The greatest amount of defoliation occurs in the upper portion of tree crowns and should not significantly effect canopy closure and therefore neither stream temperature or flow. Low levels of tree mortality in riparian areas due to budworm may actually improve fish habitat by adding, organic debris to streams. Budworm larvae and adults may also fall into streams during dispersal, enhancing the food supply of some fish species.

Visual Quality and Recreation—

Visual quality and recreation are the two resources budworm has the greatest potential to affect. People have an image of what a forest should look like and to most people that means needles on trees. During a budworm outbreak, between 75-100 percent of foliage can be consumed especially if the outbreak has been occurring over many years. Forests appear reddish-brown in color, and the perceived texture changes drastically as well. An impacted area may take up to a decade to significantly recover in both color and especially texture. Color and texture changes affect the quality in the fore-, middle and background of a person's visual area. Top-kill and mortality affect viewing at all three distances. but have the greatest impact in the foreground. Recreation and recreation economics can be greatly affected in outbreak areas where top-kill and tree mortality occurs.

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

Other Reading

Anderson. L., C. E. Carlson, and R. Wakimoto. 1987. Forest fire frequency and western spruce budworm outbreaks in western Montana. Forest Ecology and Management 22:251-260.

Carlson, C. E., R. W. Campbell, L J. Theroux, and T. H. Egan. 1984. Ants and birds reduce western spruce budworm feeding in small Douglas-fir and western larch. Forest Ecology and Managememt. 9:185-192.

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

Fellin, D. G., R. C. Shearer, and C. E. Canson. 1983. Western spruce budworm in the Northern Rocky .:4 Mountains. Western Wildlands, A Natural Resource Journal 9(1):2-7.

Other Reading

(Continued from page 10)

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, University of Idaho, Moscow, Idaho. 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.

Ogden, R. M. 1988. Draft Environmental Impact Statement: Management of Western Spruce Budworm in Oregon and Washington. USDA Forest Service, Pacific Northwest Region.

Schmidt, W. C., D. G. Fellin, and C. E. Carlson. 1983. Alternatives to chemical insecticides in budworm-susceptible forests. Western Wildlands: A Natural Resource Journal 9 (1):13-19.

Swetnam, T. W., A. M. Lynch. 1993. Multi-century, regional scale patterns of western spruce budworm outbreaks. Ecot. Monographs 63(4) (399-424.

Torgersen, T. R., R. R. Mason. and R. W. Campbell. 1990. Predation by birds and ants on two forest insect pests in the Pacific Northwest. Studies in Avian Biology 13:14-19.

Western Spruce Budworm in the Northern Region: 1985 Situation Analysis. USDA Forest Service, Northern Region Rep. 86-12.

Forest Health Protection and State Forestry Organizations

Assistance on State And Private Lands

Montana: (406) 542-4300

Idaho: (208) 769-1525

Utah: (801) 538-5211

Nevada: (775) 684-2513

Wyoming: (307) 777-5659

Assistance on Federal Lands

US Forest Service
Region One
Missoula: (406) 329-3605
Coeur d’Alene: (208) 765-7342

US Forest Service
Region Four
Ogden: (801) 476-9720
Boise: (208) 373-4227