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Defoliators in Eastern Oregon and Washington

Abstract

Defoliating insects are major disturbance agents affecting forest health and productivity in eastern Oregon and Washington. Information on the four main defoliators of conifers in eastern Oregon and Washington is abundant. Because of concerns about growth suppression and mortality of trees during widespread defoliator outbreaks, much research effort has been focused on these species. They are western spruce budworm (*Choristoneura occidentalis*), Douglas-fir tussock moth (*Orgyia pseudotsugata*), pandora moth (*Coloradia pandora*), and larch casebearer (*Coleophora laricella*). Various interactions of defoliators with other system components and natural regulatory processes have been described, as have monitoring and suppression techniques using pheromone traps. Large-scale suppression projects using both chemical and biological materials have been used in attempts to control some defoliator outbreaks. While such suppression projects have prevented some tree mortality and growth loss, they have been largely ineffective in changing the outbreak behavior of these insects. Some suppression materials have undesirable side effects on non-target insects such as sensitive or endangered moths, butterflies, and skippers, or on other ecological processes. Successful control of larch casebearer has been achieved by introduction of parasitic wasps. For most defoliators, the recommended strategy is preventative: silvicultural treatment to promote a diversity of tree species, stand structures, and moderate stocking levels. Decision-support tools UPEST and UTOOLS analyze insect and disease risks, and the Forest Vegetation Simulator models effects of insects and disease on stand growth.

Effects of Defoliators

Defoliating insects are dominant agents of disturbance in east-side forests. About two dozen species of insects were listed by Furniss and Carolin (1977) as major forest insects in the montane West, including east-side forests. These were considered "major" on grounds that they disrupted management goals. In early western forestry, these goals were largely confined to timber production objectives. Goals of management now include a diverse array of resources that include visual, recreational, and ecological attributes. About half of the major insects listed by Furniss and Carolin (1977) may be broadly defined as defoliators. Defoliators are insects that eat, mine, or skeletonize the foliage of forest trees, and there are numerous species that cause only temporary, spotty episodes of defoliation or mortality in forest stands. Contrastingly, there are other species that sporadically erupt to outbreak proportions West-wide or over areas at regional or landscape scales. These outbreaks can be intense and cover millions of hectares (Dolph 1980, Sheehan 1996). It is those insects that erupt to outbreak proportions causing severe defoliation or widespread mortality regionally or landscape-wide that tend to galvanize the attention of the public at large, forest managers, and the media. Without question the two most important of these defoliators are the western spruce budworm, *Choristoneura occidentalis*, and the Douglas-fir tussock moth, *Orgyia pseudotsugata*. These defoliators cause widespread and significant disturbance in mixed-conifer forest types that are dominated by Douglas-fir and true firs. Two other defoliators that sporadically reach outbreak proportions are the pandora moth, *Coloradia pandora*, on pines, and the larch casebearer, *Coleophora laricella*, which mines and kills the needles of western larch. Thus, among these four defoliator species nearly all of the major east-side tree species and stand types may experience sporadic regional and landscape-level outbreaks that result in widespread disturbances causing ecological change, growth losses, and mortality.

The extent to which any individual tree or stand may be affected by defoliation, or whether mortality will occur depends on the tree species and age, species composition, the relative positions of trees within the stand, and the general health of trees or the stand in terms of other agents of disturbance like diseases or other insects, drought, or fire. In general, dominant, vigorous trees are more tolerant of defoliation than younger, suppressed trees. Outbreaks on the scale of those described above have both positive and negative effects depending upon whether they are viewed from an ecological or commodity standpoint. Characteristically, the degree of ecological effect from episodes of defoliation depends, in part, on interactions with other disturbance agents, notably other insects such as bark beetles, drought, and wildfire. Tree mortality associated with outbreaks can change successional trajectories and stocking levels, which affect predictions of commodity flow for industry, commerce, and timber-based communities. Conversely, it can be argued that these outbreaks are a part of how forests change over time, and provide the diversity of plant community structures and mosaics needed by a diverse flora and fauna (Gast et al. 1991, Hessburg et al. 1994, Johnson 1994, Jaindl and Quigley 1996, Youngblood and Wickman *In press*). Dendroecological analyses support the hypothesis that budworm outbreaks have increased in frequency and severity in the 20th century in northeastern Oregon (Swetnam and Lynch 1989, Swetnam et al. 1995). The consensus among most scientists dealing with disturbance processes in east-side forests is that fire exclusion and harvesting of ponderosa pine and larch as preferred timber species have led to profound changes in forest stand structure. This current structure is more vulnerable to extensive and more severe outbreaks of defoliating insects, particularly budworm and tussock moth. Research on arthropod and avian predators, and on parasitization of defoliators (Bellows et al. 1998) suggests that these predators and parasites have a regulatory effect on defoliator populations, helping to maintain these insects at low densities for long periods of time between outbreaks (Mason and Torgersen 1983b, 1987; Torgersen et al. 1984, 1990; Mason and Paul 1988; Torgersen 1994; Filip et al. 1996; Mason et al. 1997). Management options to restore east-side stands to more stable ecological systems include reintroduction of fire, restoring riparian corridors, enhancing biological diversity by practicing landscape ecological management, and emulating natural patterns on the landscape (Carlson et al. 1983; Wickman 1992; Mutch et al. 1993; Hessburg et al. 1994, 1999; Johnson 1994; Powell 1994; DellaSala et al. 1995; Jaindl and Quigley 1996).

Several computer-based software tools have been developed as decision support systems to help managers predict the outcome of insect outbreaks and the effects of selected management options used to mitigate losses. Two relevant examples of such predictive decision support systems have been developed. The Forest Vegetation Simulator (FVS) is a growth and yield model that has extensions that estimate the influence of agents such as insects and disease on stand growth (Crookston 1990, Teck et al. 1996, VanDyck 1999; see also www.fs.fed.us/fmsc/fvs/fvs_model.htm). UPEST and UTOOLS were developed with data from eastern Washington and Oregon, and analyze insect and disease risks for watershed analyses (Ager et al. 1995, Ager 1996, Ager and McGaughey 1997, Scott et al. 1998). Developments in remote sensing technologies offer managers the ability to monitor defoliator activity at stand and regional scales (Ciesla 2000).

Monitoring and Suppression Activities

Douglas-fir Tussock Moth

The Douglas-fir tussock moth is a major pest in the mixed-conifer stands of eastern Oregon and Washington. The principal tree hosts are Douglas-fir, grand fir, white fir, and subalpine fir. Larval feeding causes growth loss, top-kill, or tree mortality. The wingless females attract flying males by producing a sex pheromone that facilitates reproduction. This pheromone was chemically identified and synthesized in 1975 (Smith et al. 1975). This pheromone (Daterman et al. 1979) and predictive sampling techniques (Mason et al. 1993) have since been developed as tools to monitor incipient outbreaks of the tussock moth. Since 1980, a pheromone-based trapping system has been used annually in Oregon, Washington, Idaho, and California to provide early warning of outbreaks. This system has been successful in detecting impending outbreaks on a regional scale (Daterman et al. 1999). The sex pheromone has a potential as a suppression agent on high-value sites (Sower and Daterman 1977; Sower et al. 1979, 1983, 1990; Hulme and Gray 1994). Artificially-produced pheromone products have been an important element in the development of the monitoring and suppression technology for the tussock moth. Outbreaks occur at 7- to 10-year intervals, although longer intervals are known to occur. Once initiated, outbreaks last from 3 to 4 years, and are terminated as a result of natural mortality processes involving a nucleopolyhedrosis virus and starvation. Susceptibility to damage increases in multi-storied stands as areas with older-aged hosts increase, especially on drier, upper slopes where soils are shallow. Although chemical insecticides have been used in tussock moth suppression projects in the past, there is more general support for the use of biological insecticides containing the nucleopolyhedrosis virus of tussock moth, or the bacterium *Bacillus thuringiensis*. The short natural duration of tussock moth outbreaks makes the need for suppression projects less imperative, except in especially high-value stands. Long-term studies by Wickman (1963, 1978b, 1986, 1988) and Wickman et al. (1980) examined radial growth of grand fir and Douglas-fir in natural and thinned stands that had undergone severe outbreaks of tussock moth. Overall, post-outbreak radial increment of surviving trees increased to, or even surpassed pre-outbreak growth within 5-10 years after the outbreaks (Wickman and Starr 1990). See Gast et al. (1991), Fuxa et al. (1998), and Scott (2000) for more information on the biology and management of this defoliator.

Research effort on the Douglas-fir tussock moth and western spruce budworm has fluctuated synchronously with outbreaks of these defoliators. A major outbreak of Douglas-fir tussock moth in the early 1970s generated public concerns over the fate of mixed-conifer stands and timber-based economies in the West. These concerns culminated in an accelerated research program, the Expanded Douglas-fir Tussock Moth Research and Development Program, which greatly augmented knowledge about this insect. The research supported by that Program was compiled in a compendium of new knowledge about the population dynamics, management, and suppression of tussock moth outbreaks (Brookes et al. 1978). Arguably, three of the most significant research developments of that period were the identification and description of the insects' outbreak patterns (Wickman et al. 1973, Mason 1977b, Mason and Luck 1978, Mason and Wickman 1988), the identification and production of a naturally-occurring polyhedral virus disease of the tussock moth (Hughes and Addison 1970, Martignoni et al. 1971, Thompson and Martignoni 1978), and development of pheromones for monitoring and suppression (Sower and Daterman 1977, Daterman et al. 1979). Managers and scientists interested in early work on tussock moth and other *Orgyia* species are encouraged to examine the work of Campbell and Youngs (1978) who produced a cross-indexed annotated bibliography of 338 published and unpublished papers relating to studies done before 1977.

After the termination of the accelerated research program, publications relating to monitoring for identifying impending outbreaks continued to be produced (Mason 1977a, Wickman 1978a, Dewey 1978, Beckwith 1978, Daterman et al. 1979, Paul 1979, Stelzer 1979, Beckwith et al. 1982, Mason and Torgersen 1983a). The research of Mason (1996), which spanned 23 years, has added to our understanding of tussock moth outbreak and non-outbreak dynamics. Other management-related research and syntheses continued to flow from the accelerated tussock moth research program as well. Stand-outbreak models and management systems were described by Colbert and Wong (1979), Colbert et al. (1979), and Campbell and Stark (1980). Information on risk-rating of potential defoliation and tree damage appeared in Wickman (1979) and Heller and Sader (1980). Shepherd (1994) described management strategies for insect defoliators in British Columbia, but his concepts of timely monitoring, pre- and post-outbreak planning, and judicious use of insecticides are relevant to all defoliators in east-side forests. In a compendium that examined forest health issues in the National Forests of northeastern Oregon, Gast et al. (1991) presented excellent reviews on the ecology of western spruce budworm and Douglas-fir tussock moth. Although those descriptions were primarily intended to describe the activity of these defoliators in the Blue Mountains, they apply as well for these insects throughout east-side forests. The descriptions in Gast et al. (1991) contain information on hosts and plant community associations, biology, historical trends, population dynamics and damage simulation models, effects on resources, and suppression and other management options. More recently, Scott (2000) prepared a population analysis for tussock moth in which he re-examined earlier literature, and the most recent research on the population behavior and effects of tussock moth outbreaks. In combination, the works of Dewey and Bennett (1988), Gast et al. (1991), Hessburg et al. (1994), Jaindl and Quigley (1996), and Scott (2000) are excellent sources for the reader seeking a thorough grounding in the ecology of defoliators in east-side forests.

Western Spruce Budworm

The western spruce budworm, contrary to what its name implies, does not affect only spruce. Principal hosts of the budworm are Douglas-fir, the true firs (*Abies* spp.), and to a lesser extent, Engelmann spruce (*Picea engelmanni*) and western larch (*Larix occidentalis*) in both pure and mixed stands of these tree species. New buds and needles as well as pollen structures may be destroyed by the feeding larvae (Fellin and Dewey 1982). First-hand information about outbreaks in the West from 1922 to 1949 suggests that outbreaks were small, widely scattered, and subsided quickly from natural processes, generating little interest in suppression (Stipe 1987). In the latter half of the 1900s, and from 1944 in the Blue Mountains, outbreaks throughout the West appear to have become more severe, extensive, and longer-lasting (Dolph 1980, Anderson et al. 1987, Swetnam and Lynch 1989). As with Douglas-fir tussock moth, the intensity and extent of outbreaks of the budworm seem to be related to successional changes influenced by fire-control efforts and selective logging that have favored the dominance of shade-tolerant species of trees that are major budworm hosts. The above predisposing factors and characteristics of host vigor, and stand features are discussed in Brookes et al. (1985, 1987a, 1987b). Mesoscale changes in climate, mainly periods of cold, dry arctic weather patterns in spring that affect budworm outbreak dynamics are discussed by Kemp et al. (1985). The presence of landscape-scale outbreaks of the budworm is also commonly a precursor to large-scale bark beetle outbreaks that kill the defoliation-weakened trees (Gast et al. 1991). As for the Douglas-fir tussock moth, sex pheromones have been identified and synthesized for the western spruce budworm (Cory et al. 1982, Silk et al. 1982), as well as for other conifer-feeding *Choristoneura* species, like the Modoc budworm, *C. retiniana* (Walsingham) (Daterman et al. 1984, 1995). Technologies that employ life-table analyses and modeling (Campbell 1993) and pheromone-based traps have potential as management tools for monitoring and suppression of the western spruce budworm (Sartwell et al. 1985, Daterman et al. 1985), but additional research is needed before operational applications can be recommended. The synthesis of information on all aspects of budworm ecology and management by Gast et al. (1991), Powell (1994), Powell and DeBenedictis (1995), and Scott and Schmitt (1996), provide an excellent grounding in the literature through the mid-1990s.

Budworm suppression efforts in the mid-1940s were conducted with an eye toward outbreak control. By the early 1980s, it was apparent that suppression projects had generally not controlled or changed the course of regional outbreaks, or significantly improved the budworm problem in the West. The best that could be expected was to allow host trees and stands some temporary reduction in defoliation, and delaying some top-kill and mortality (Carlson et al. 1983, Mason et al. 1998). By the end of the budworm outbreak in eastern Oregon and Washington (1980-1992), it was apparent that suppression efforts had been ineffectual in changing either the outbreak dynamics or significantly altering the trajectory of defoliation, topkill, or host mortality (Powell 1994, Torgersen et al. 1995, Sheehan 1996, Mason and Paul 1996). In terms of acreages involved and number of projects, budworm control efforts from the early 1980s have used formulations of either carbaryl or *Bacillus thuringiensis* (Sheehan 1996). At least part of the rationale for using the biological insecticide, *Bacillus thuringiensis* (Bt), has been that it would have limited effect on most non-target insects. However, new concerns about threatened, endangered, and sensitive (TES) species have generated interest in the consequences of the use of Bt in areas inhabited by TES moths, butterflies, and skippers (Miller 1990, Fuxa et al. 1998, Scott 1999). Possibly the best advice for managers who want to reduce the potential hazard from future budworm outbreaks was set forth by Carlson et al. (1983, 1985), Carlson and Wulf (1989), and Gast et al. (1991), who prescribe silvicultural treatment to promote a diversity of tree species, stand structures, and stands with moderate stocking levels.

Pandora Moth

The pandora moth is an occasional, but spectacular defoliator of ponderosa and lodgepole pine in the east-side pine type. Speer et al. (*In press*) described the long-term dynamics of pandora moth West-wide. The 2-year life cycle of this insect usually means that even when defoliation is severe it occurs in alternate years. Because only old needles are destroyed, as opposed to buds and new needles, the alternating years of defoliation allow many of the trees to recover. Still, direct tree mortality does occur, and secondary attack of already weakened trees by bark beetles can result in additional mortality. Infections of dwarf mistletoe, *Arceuthobium* spp., predispose stands to greater mortality. However, except in severe outbreaks, mortality and losses in growth and height are often perceived as less significant than other attendant losses.

Public outcry about pandora moth outbreaks is commonly directed to the adverse impact on visual quality from the appearance of defoliated trees. Often, the nuisance generated by moths being attracted to artificial lighting in residential areas, high-use recreation sites, and commercial establishments causes the most concern (Carolin and Knopf 1968, Furniss and Carolin 1977, Bennett et al. 1987, Schmid and Bennett 1988, Miller and Wagner 1989).

Few options for managing pandora moth populations are available. Fall foliar application of the chemicals acephate or diflubenzuron may reduce larval densities and temporarily protect foliage, but direct suppression is unlikely to terminate an outbreak (Ragenovich et al. 1986, Schmid and Bennett 1988, Ross 1995). Prescribed fire in late June or early July can reduce the population of overwintering pupae in the soil, but other management considerations and the risk of loss of control of such fires have limited its application. Silvicultural treatments that maintain desirable stocking and reduce the incidence of dwarf mistletoe can mitigate growth losses from defoliation (Schmid and Bennett 1988, Cochran 1998).

Larch Casebearer

The most serious insect pest of western larch is the larch casebearer (Cochran and Seidel 1999). Repeated severe defoliation for several years reduces growth, but rarely results in tree mortality (Tunnock et al. 1969, Furniss and Carolin 1977). Growth reductions of 95% may occur after five years of severe defoliation (Tunnock and Ryan 1985). The casebearer was accidentally introduced into New England from Europe in the mid-1800s. By 1960, the casebearer had spread to eastern Washington and Oregon, and by 1982, half of all the range of western larch in the West was infested. A biological control program that ultimately resulted in the artificial establishment of two species of parasitic wasps from Europe has been pivotal in reducing casebearer populations (Ryan 1997, Bellows et al. 1998). Characteristically, casebearer populations will begin to erupt, but they are quickly regulated by the action of the introduced parasitic wasps. In addition to the regulatory action of predaceous birds and arthropods, two needle diseases—a *Hypodermella* blight, and *Meria laricis*, which act to limit viable foliage for the casebearer—aid in the collapse of casebearer outbreaks (Denton 1979, Tunnock and Ryan 1985). The cryptic habit of the casebearer to mine within needles, and to employ mined needles in which to protect themselves makes this insect relatively invulnerable to conventional insecticides. No operational suppression projects have been launched against the casebearer in the United States.

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Note

This special issue of *Northwest Science* is a set of papers reviewing the state of knowledge about disturbance processes in eastern Oregon and Washington, related management practices, and effects on key management issues.