

CHAPTER 5

West Coast Forest Insects

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This chapter describes seven projects focusing on the effects of defoliators, bark beetles, and the balsam woolly adelgid. Two of the defoliator projects addressed the effects of defoliation by the western spruce budworm (*Choristoneura occidentalis*), while a third developed methods for using satellite imagery to assess distribution of the aspen leaf miner (*Phyllocnistis populiella*) in Alaska. The budworm-related projects considered the effects on fire potential and on the unstable habitat of the northern spotted owl east of the Cascade Mountains. Three bark beetle projects dealt with the Douglas-fir beetle (*Dendroctonus pseudotsugae*), spruce beetle (*D. rufipennis*), and pine beetles in southern California. The Douglas-fir beetle project examined the accuracy of the Cooperative Aerial Detection Survey using the bark beetle as a test case for evaluating survey mapping. A spruce beetle outbreak led to significant changes in vegetation on the Kenai Peninsula, and its effects were studied by using data from forest inventory plots. In another project, bark beetle mortality in southern California was measured from plots of the Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, and compared to mortality mapped from aerial survey and other sources. One project used a ground survey approach to document current distribution and impacts of the nonnative balsam woolly adelgid (*Adelges piceae*) across Oregon and Washington.

Project WC-F-01-07: Changes in Fire Hazard Associated with Western Spruce Budworm Defoliation in the Eastern Cascades

Late Successional Reserves (LSRs) were established by the Northwest Forest Plan in order to provide habitat for late-seral species associated with the northern spotted owl. Many of these LSRs contain stands that are very dynamic and are vulnerable to various disturbances such as insects, disease, and wildfire. As such, land managers face large challenges

in carrying out the mandate to provide habitat under these unstable conditions.

The purpose of this 2-year project (2000-2001) was to examine the effects of defoliation by the western spruce budworm on changes in fire hazard within northern spotted owl habitat. The study was carried out on Smith Butte in the Gotchen Late Successional Reserve (Gifford Pinchot National Forest) where the budworm had been in outbreak status since 1995. The author measured several stand attributes including canopy cover, levels of down wood, and basal area of budworm host species. Specific fire parameters being evaluated included severity of surface fire, torching potential, and crown fire potential at the stand and landscape levels.

Sources of data included the Continuous Vegetation Survey (CVS) plots (1992), a local Research Natural Area, and Region 6 Timber Stand Exam procedures. These data sources represented pre-outbreak and during-outbreak information that could be compared to identify changes brought about by the budworm infestation. The data from these sources were also loaded into the Forest Vegetation Simulator (FVS) and the Fire and Fuels Extension to FVS (FFE-FVS) in order to model the contribution of each stand attribute to various aspects of wildfire.

Results from the first year indicated that canopy cover in defoliated stands was reduced by roughly half and that down wood levels doubled between 1992 and 2000 (from 18 to 35 tons per acre).

In the second year of the study, the data were processed through a number of fire models (FFE-FVS, BEHAVE, FOFEM) in order to describe how several aspects of wildfire would be affected by the budworm outbreak. The predicted average flame length derived from fire models increased from 4.5 to 6 feet given 95 percent weather [95 percent percentile of extreme weather conditions and perhaps footnote those elements that go into the equation (humidity, fuel moisture, temperature, wind)], while changes in torching potential and independent crown fire behavior were not significant. Current debris loads, although quite high, were not predicted to result in stand replacement fires. In fact, even though absolute stand density and basal areas were greater in 1992 than in 2000, the proportional loss to fire did not differ between the two periods.

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Utilization of project results—The peer-reviewed paper resulting from this study (Hummel and Agee 2003) has been cited in at least three District Environmental Impact Statement/Environmental Assessment planning documents in Region 6 and a dozen other scientific papers (with a geographic range across the Western United States and Canada). Results from this FHM-supported study were incorporated, for example, in the Gotchen Risk Reduction and Restoration Final Environmental Impact Statement (2004). Landscape-scale treatments began in 2005.

Suggestions for further investigation—The authors (Hummel and Agee 2003) pointed out that the predictions of fire behavior were derived from the best fire models available, but that each of these contains certain assumptions and therefore the results should be applied with caution. Their work described the stand conditions following 6 years of outbreak and as they appropriately suggest, additional work should be done in later years once the full effect of the budworm outbreak has been expressed. In the coming years, there will be more fuels accumulated as the small dead trees fall and add to the surface fuel bed. Other vegetative changes will occur over time and may alter the predicted fire behavior even more than suggested in this study. Another important avenue of study is how to manage these ephemeral habitats over time and across the landscape in such a way that they can be buffered from large-scale disturbances, be they insects, diseases, or fire. Research that evaluates various treatment alternatives for maintenance and/or recruitment of certain vegetative conditions associated with late-successional species would be very appropriate.

The Cold Springs wildfire burned through the northern portion of the Gotchen LSR in summer 2008. It stopped north of the Smith Butte plots measured for this project of the national Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture. But the fire burned through some that were remeasured in 2005 as part of a different FHM project (McDonald Ridge). The 2008 Cold Springs wildfire comprised stand-replacement, mixed-severity fire effects, and low-severity fire effects. It would be timely to remeasure both the Smith Butte (unburned) and the McDonald Ridge (burned or re-burned) plots to validate the earlier fire behavior model predictions.

Projects WC-EM-05-02, WC-EM-06-01: Effects of Western Spruce Budworm Defoliation on the Northern Spotted Owl and its Habitat in South Central Washington

The objective of the project was to investigate the landscape-level effects of a lengthy western spruce budworm outbreak (*Choristoneura occidentalis*) on the quality of habitat and

demography of the northern spotted owl (*Strix occidentalis caurina*). Issues are extremely complex in this dry forest setting, with owls occupying habitats that are prone to rapid deterioration yet expected to be managed for sustained late-successional conditions under the Northwest Forest Plan. The spruce budworm represents one of the important disturbance agents that make management of LSRs in dry forest ecosystems extremely challenging.

The study was designed to utilize numerous tools and procedures including satellite imagery of vegetation for the area (LANDSAT 5 TM), annual aerial survey maps of budworm defoliation, data from the CVS and FIA plots, remeasurement of spruce budworm impact plot data collected over several years, Washington forest permit application data, and owl demographic data from field monitoring surveys. Ground validation and remeasurement work was time-consuming due to difficult access of remote locations across multiple ownerships, and, therefore, the study was extended to include a second season of field work.

The study area was defined by using GIS overlays of northern spotted owl habitat, aerial survey maps of budworm defoliation, and topographic features of southwestern Washington. The satellite imagery, available for pre-outbreak (1985) and ongoing or post-outbreak (2003) conditions, was used for change detection. To verify the satellite classifications of defoliation levels, 219 ground sample points (1/4-acre fixed-area plots) were used (112 defoliated points and 107 undefoliated points). Post-outbreak defoliation impact data were collected from sites previously measured during early- or mid-outbreak periods to assess stand-level changes. Owl populations were to be assessed using assorted demographic data gathered since 1985. Finally, the trends and associations would be evaluated among severity of budworm defoliation and vegetative conditions, owl demography, and other disturbances.

In the first year of the study, preliminary work included sampling 88 ground plots. In the second year, an additional 131 fixed-area ground plots were sampled and results were summarized into three categories: (1) host-type with defoliation, (2) host-type with no defoliation, and (3) non-host with no defoliation. Plots were rated as host plots if they contained more than 30 percent trees per acre of true firs, Douglas-fir, and spruce. Preliminary results indicated a strong association between western spruce budworm defoliation and subsequent tree mortality. The tree mortality for host-defoliation plots averaged about twice as much as for host-no defoliation plots. Canopy cover, an important component of owl habitat, was also substantially reduced in the host-defoliation plots.

In the third year, the ground verification plot data were applied in geospatial models creating preliminary study area surfaces for

basal area, stem count, tree mortality, and owl habitat (modeled as a function of basal area standard deviation). Study area CVS/FIA plot data were summarized, and data on budworm suppression and harvest activities were compiled for use in further refining and expanding the models and examining relationships to owl demographics. Preliminary analysis of the CVS/FIA inventory data showed higher levels of crown cover and stocking, and of larger-diameter live and dead trees on forested plots categorized as budworm host type as opposed to non-host type plots. Further results from this ongoing project were still being analyzed at the time of this review.

Suggestions for further investigation—Greater understanding is needed of the effects and interactions of natural and human-influenced disturbance in unstable forests. Resource managers who deal with lands on the eastern slope of the Cascade Mountains are faced with the challenge of managing unstable forest conditions, most of which are considered critical habitat for species such as the northern spotted owl. As portions of these unstable conditions change due to various disturbance agents, similar conditions need to be recruited to replace what has been lost. The trade-off between managing these forest conditions versus leaving them alone is a fertile topic for investigation. Future studies would need to take a landscape level approach, as this one has done, to address ever changing conditions over the landscape and over time, and how to manage for those changes.

Project WC-EM-07-02: Assessment of Aspen Leaf Miner Distribution in Alaska Using Satellite Imagery

Due to the immense size of the State of Alaska, yearly comprehensive aerial forest pest detection surveys using fixed-wing aircraft are impractical. Annual aerial detection surveys typically cover a relatively small percentage of Alaska's total forested acres, providing only a partial indicator of insect occurrence and severity in any given year. If conditions in unsurveyed areas could be consistently assessed using another complementary method, annual pest impact and trend assessments would be greatly improved because they would more closely reflect total insect activity for the State.

The objective of this project was to develop a technique for using satellite imagery to predict pest presence and severity in areas not covered by aerial detection surveys. It focused on assessing the distribution of a single insect species within a delimited study area. Spatial statistical methods previously developed in studies of bark beetles and diseases in South Dakota (Reich and others 2004), Colorado, and New Mexico (Lundquist and Reich 2006) were applied to the aspen leaf miner in a 19 981 ha study area near Fairbanks, AK. The

aspen leaf miner is a widely distributed, native defoliating insect. Larvae tunnel through quaking aspen leaf tissues, causing the foliage of affected trees to turn a distinctive grayish-silver color that is visible from the air. Population levels of aspen leaf miner in Alaska increased dramatically over the 5- to 10-year period prior to 2007.

Within the study area, 206 ground verification plots were sampled in five vegetation types: spruce, birch, noninfested aspen, infested aspen, and open areas. Verification plot data, high-resolution Quickbird satellite imagery, and various other existing spatially referenced auxiliary data were used to develop predictive spatial models for basal area, canopy closure, and vegetation type. Healthy aspen and birch vegetation types were ultimately combined into a birch/noninfested aspen vegetation type, as the scarcity of noninfested aspen stands in the study area resulted in insufficient data to successfully differentiate the two. The resulting models generated probability maps of the distribution and severity of the aspen leaf miner over the study area. The final model mapped aspen infested with leaf miner (i.e., "infested aspen" vegetation type) at an 80 percent accuracy level, accounted for 45 percent of the variability in canopy closure, provided unbiased variance estimates, and yielded prediction and confidence coverage rates close to 0.95.

Suggestions for further investigation—With continued refinement and expansion to include other disturbance agents, the methods and models initiated in this project could enable comprehensive assessment of insect (and some disease) activity across the entire State of Alaska. Further work could be done in this regard to accurately predict the total array of vegetation types and disturbance agent activity in Alaska. New types of satellite imagery and spatial statistical techniques could be tested and incorporated as they become available. Future studies utilizing the refined and expanded methods and models could focus upon the effects of climate change on disturbance agents and forest conditions in Alaska.

Project WC-EM-01-02: Ground Checking Aerial Survey Polygons Identified as Douglas-Fir Beetle Caused Damage in Washington in 2001 and 2002

Each year, the Pacific Northwest Region conducts an aerial detection survey to map insect damage that occurred in the previous year. These map products are important tools for resource managers, and they provide an important historical perspective on insect activity. Ground checks are typically carried out to assess the accuracy of the mapping effort, but these checks have usually been random and not necessarily focused or comprehensive.

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The objective of this project was to conduct a systematic ground survey of aerial survey polygons in order to evaluate their accuracy and provide feedback to the aerial observers. The ground survey concentrated on polygons mapped as mortality caused by the Douglas-fir beetle, an important and commonly identified damage agent in the aerial survey.

The project concentrated on a Douglas-fir beetle (DFB) outbreak that began in 1998 around Republic, WA. This area was chosen because of good road access and a high likelihood that the outbreak would be mapped in 2001 and 2002 aerial surveys. In the summers of 2001 and 2002, aerial surveyors sketchmapped insect and disease activity in the project area using a digitally assisted sketchmapping system with GeoLink software while flying the standard four-mile grid pattern.³ In the autumns of 2001 and 2002, 117 DFB polygons were evaluated, either chosen from that season's map and then visited on the ground, or located on the ground and then sought on the most current map. The evaluator recorded how the polygon was selected (from the map or from the ground); how it was evaluated (from a distance, from the perimeter, from within); the number, species and size of trees of affected trees; and actual mortality causal agent. Fifty-three of the plots were located on the aerial survey map and then visited on the ground; fifty-three areas of damage were viewed from the road and then matched to a polygon on the map; four polygons were located with a combination of methods; and the locating method was not recorded for seven polygons.

Of the polygons evaluated, 60 were mapped in the correct place and 14 mapped polygons were less than half of a mile from the damage on the ground. One polygon depicted on the map (covering 30 acres with 10 trees per acre affected) could not be located; no dead trees were in the nearby area. Three mapped polygons were shown more than half of a mile from the damage on the ground. Thirty-nine damaged areas viewed from the ground did not correspond to mapped polygons. The polygons seen from the ground but unmapped were fairly small, discrete groups of trees (the average number of trees per polygon was 21.64). When only polygons with more than 100 dead trees indicated on the survey map ($n = 27$) are considered, 22 were in the correct location, four were mapped within half a mile of the correct location, and one could not be found at all.

The success rate (i.e., correctly mapping damage polygons within half a mile of the actual damage) identified in this study is 63 percent. Groups of more than 100 dead trees were successfully mapped 96 percent of the time. Success rates

were high for mapping of polygon shapes (74 percent accurate) and causal agent (96 percent correct).

Direct numbers of dead trees were compared between the maps and ground surveys. For smaller polygons (where actual numbers of trees are usually indicated) there was a tendency to overcount dead trees on the aerial survey map as compared to the ground survey. This could have been related to accumulations of older dead trees in the area making an impression on the aerial surveyors, in contrast to challenges in seeing even all the most recent "current" dead trees in the vicinity from a ground vantage.

The authors identified certain challenges associated with ground verification of mapped polygons. Complex topography and the limitations of a partial view from the ground make assessment of an aerial view difficult. Polygons attributed as "trees per acre" are also extremely difficult to evaluate.

Suggestions for further investigation—The aerial detection survey gathers an extraordinary amount of information at a relatively small cost. The 100 percent coverage of forested lands in the region means that there are potentially many users of this information and many types of questions that can be answered. Further work could be done along the same lines of accuracy assessment, but with other species of trees and other damage agents. A calibration of the recorded tree mortality under different conditions could produce a good index of the reliability of different attributes that are mapped in the aerial survey and conclusions could be drawn about the utility of these data in the management of our forests.

Project WC-F-01-09: Broad-Scale Spruce Forest Change, Kenai Peninsula, Alaska 1987-2000

Researchers reported on a number of vegetative changes that have occurred in the forests of the Kenai Peninsula as a result of a long-term spruce beetle epidemic. In 1987, FIA conducted a special inventory designed to assess the impact of the spruce beetle on the timberland resources of the Kenai Peninsula. This inventory provided the baseline for a remeasurement conducted in 1999-2000 after the spruce beetle had affected most of the stands on the Peninsula.

This project involved the resampling of 127 ground plots from a pool of 1,216 FIA plots classified as productive forest in 1987. Five-point variable-radius cluster plots were used to collect tree information. Understory vegetation and seedlings were sampled from small fixed-radius plots. Down woody material was determined from 11.3-m transects.

³ Personal communication. 2009. Julie Johnson, GIS Analyst, U.S. Forest Service, Pacific Northwest Region, 333 SW First Street, Portland, OR 97204.

Results for vegetative changes differed between the four distinct forested zones of the Kenai Peninsula (southern lowlands, Kenai Mountains, coastal forests, mid- to northern Kenai). The forests of the southern lowlands experienced the greatest change in vegetative composition, with high spruce mortality and increases in bluejoint grass and fireweed. Other significant vegetation changes occurred in the Kenai Mountains where mountain hemlock, tall blueberry, and rusty menziesia all increased over 1987 levels. The coastal and mid-northern Kenai forests showed no consistent changes in vegetative composition between the 1987 inventory and the revisit in 2000.

Tree mortality was greatest in the southern Kenai lowlands within the white spruce forest type. These stands experienced a substantial reduction in size class; poletimber was reduced to a smaller size (or to non-stocked) on 36,000 acres and sawtimber was down to pole-sized or smaller size class on 136,000 acres. During the period between 1987 and 2000, cubic foot volumes were reduced by half on productive forest land and mortality exceeded growth by a ratio of more than 2 to 1. Spruce reproduction (as measured by presence of seedlings) either improved or stayed the same on most sample plots.

Down woody material of all size classes increased during the sampling period. Fuels averaged slightly less than 5 tons per acre for all plots. Salvage logging of dead spruce did not significantly reduce large sound fuels; in fact, 10- and 100-hour fuels increased after harvest.

Suggestions for further investigation—A logical next step would be to identify resource issues that have arisen from these dramatic landscape-level changes in forest structure. Effects on recreation, hydrology, wildlife habitat, and perhaps wildfire risk might be expected. Clearly, not all resources are likely to be affected in the same way, but a quantification of the most dramatic effects or impacts might enable managers to evaluate mitigative measures for future events that will surely occur in other mature spruce stands.

Project WC-F-04-03: Southern California Forest Health Assessment—Analysis of Status and Trend, Post Drought-Induced Bark Beetle Mortality Events of 2002-2003

The study area covered more than 980,000 acres of forested lands on the San Bernardino, Angeles, and Cleveland National Forests in southern California. This project involved the remeasurement of FIA plots within areas affected by bark beetles in 2002 and 2003 in order to develop statistical estimates of tree mortality by species, size and volume. Recent tree mortality was determined using several data sources

including recent aerial photography, Landsat Thematic Mapper satellite imagery and aerial survey data. One hundred FIA plots were remeasured, and mortality was recorded by tree species and size class. This plot information was stratified by mortality level and vegetation type using remote sensing and aerial survey data. Statistical analyses of the FIA data provided information on the levels of beetle-caused mortality by forest type, tree size, and ownership.

Suggestions for further investigation—A comparison of aerial survey data with FIA ground plot data could be a useful calibration of the survey in order to generate timely reports of tree mortality that could be applicable to current issues.

Projects WC-EM-98-02, WC-EM-99-03, WC-EM-00-02: Balsam Woolly Adelgid Survey for Occurrence and Impacts

The first documented incidence of balsam woolly adelgid in Oregon or Washington occurred in Oregon's Willamette Valley in 1930. By the late 1950s and 1960s, the balsam woolly adelgid was causing extensive and fairly rapid tree mortality in the region, primarily in the Cascade Mountains. By the late 1970s, it had colonized most of the available sites in the western valleys and along the Cascade and Coast ranges of Oregon, Washington, and British Columbia. The initial wave of mortality was distinctive and well-recorded in annual aerial detection surveys. Since that time, an apparent shift from bole infestations that cause rapid and obvious tree death towards chronic crown infestations that cause a slow decline and can eventually kill trees has resulted in an associated shift towards a more subtle and less identifiable detection signature. As a result, balsam woolly adelgid occurrence and damage have often been missed or misidentified during annual aerial detection and ground surveys.

The primary objectives of this 3-year project were to conduct a ground-based survey in Oregon and Washington for the presence of balsam woolly adelgid, describe the current level of infestation in true fir species based on damage symptoms, and determine the effects of balsam woolly adelgid on host species and changes in local ecosystems (Overhulser and others 2004, Ragenovich and others 2002). In the ground survey, trained crews drove along roads adjacent to areas known to have true fir present and stopped to sample at 1-mile intervals. At each stop, 1 to 20 true fir trees were examined for indications of balsam woolly adelgid infestation. Only trees with gouts on branch tips, or with branch or stem infestations were counted as infested. Other plot data collected at each stop included damage type (gouting, abnormal crowns, balsam woolly adelgid-caused mortality) relative tree size, tree species, site characteristics, and location.

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Ground survey data were collected on 1,038 plots. About 44 percent of the plots were determined to be infested with balsam woolly adelgid. The majority of sites examined were forest lands, but some were located in urban areas and on agricultural lands. A major limitation of the roadside survey method was the inability to access unroaded high elevation sites, restricting sampling of the highly susceptible subalpine fir type. Nevertheless, the investigators found evidence that balsam woolly adelgid has spread into virtually all of the highly susceptible host type (subalpine fir, Pacific silver fir, and grand fir). Since the 1970s, it has spread rapidly through host stands in eastern Oregon. Distribution of detected infestations was spotty. Distinctive swellings on branch tips and nodes indicating balsam woolly adelgid infestation (called gouting) were found most commonly on Pacific silver fir and subalpine fir. Crown infestations that reduce tree vigor and can eventually kill trees was the most common form of infestation. Stem infestations that cause rapid tree mortality appeared to be relatively rare, but were more common in subalpine fir than in other species. Survey results confirmed the general resistance of noble fir, white fir and Shasta red fir when growing in natural stands.

A series of seven trend plots established between 1959 and 1965 were revisited in 1998 to collect long-term trend information on infestation characteristics and mortality. Among their findings, investigators reported that tree damage had been most severe during the first decade of infestation; once present, the insect never seemed to disappear from a stand; higher mortality occurred on wet sites and at lower elevations; and grand fir and subalpine fir were being slowly eliminated from certain environments and landscapes within their respective ranges (Mitchell and Buffam 2001).

Suggestions for further investigation—This study's finding that balsam woolly adelgid has spread throughout much of the highly susceptible host type in Oregon and Washington is a matter of concern, due to the balsam woolly

adelgid's potential for causing significant long-term ecosystem effects. Further investigation of balsam woolly adelgid occurrence and impacts could be focused upon specific ecosystems, or expanded to areas not covered in this roadside survey, as the picture is not yet complete and may continue to change over time. Studies on the interactions of balsam woolly adelgid and other disturbance agents or management practices are lacking, and could provide some much needed insight for forest land managers. As warmer temperatures are known to favor balsam woolly adelgid infestations, another important topic for investigation would be potential effects of climate change upon the balsam woolly adelgid, its predators and hosts, and host ecosystems.

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