

INTRODUCTION

Balsam woolly adelgid (BWA) (*Adelges piceae*) is an exotic, aphid-like sucking insect originally from Europe that feeds only on *Abies* species. North American species are particularly susceptible, with the apparently most susceptible being subalpine (*A. lasiocarpa*), Frasier (*A. fraseri*), and balsam fir (*A. balsamea*) (Newton and Hain 2005). The BWA feeds directly through the bark on stems, branches, and buds, causing swelling at the buds and branch nodes (“gouting”), dieback, and tree death. During feeding, the insect injects a salivary substance into the host tree, causing branch calluses and abnormal wood formation. Heavy bole infestations usually kill the tree. Branch and twig infestations cause gouting, which progressively weakens the tree. Infestations can occur at any point in a tree. This results in topkill, top curl, dead branches in the middle, or random dead branches throughout the crown (fig. 12.1).

The BWA was first found infesting balsam fir in North America around 1900 in New England and northeastern Canada (Balch 1952). It was documented west of the Cascades in Oregon in about 1930 and Washington in 1952 (Livingston and others 2000). It was first found east of the Cascades in 1972 near Walla Walla in southeastern Washington (Curtis and Johnson 1975) and by 1999 could be found throughout Idaho on subalpine fir (Livingston and others 2000).



Figure 12.1—Subalpine fir on left has thinning crown due to infestation by balsam woolly adelgid. Subalpine fir on right appears healthy. (Photo by Lia Speigel, U.S. Department of Agriculture Forest Service).

CHAPTER 12.

Assessment of Balsam Woolly Adelgid Damage to Eastern Washington and Oregon Subalpine Fir (Project WC-F-07-01)

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The adelgid has a complex, two-host lifecycle that includes a sexual stage on spruce and a parthenogenetic stage (reproduction without male fertilization) on true firs. In North America and much of Europe, it is known only from its fir hosts. The females can produce more than one generation a year of 30 to 100 eggs each (Mitchell 1966), and, because it takes just one female to initiate a population, populations can quickly establish and expand.

The BWA has been studied intensely in the Eastern United States, where it has decimated Fraser fir, and in the Western United States, west of the Cascades, where it has nearly eliminated old grand firs in low elevations. But its impact on high elevation subalpine fir is not well understood. In recent years, much of the BWA mortality documented in aerial surveys has occurred east of the Cascades in subalpine firs. The pattern of mortality to larger trees seen in both Fraser and grand fir (Ragenovich and Mitchell 2006) appears to hold for subalpine firs as well; however, this has not been well documented.

Surveys conducted in 1998 to 2000 in Oregon and Washington revealed several areas in northeastern Oregon and central Washington, where there were no BWA symptoms and the adelgids could not be found.

This project established long-term monitoring plots in subalpine fir stands throughout eastern Oregon and Washington. These plots are in a range of elevations, in areas that encompass both long-established adelgid populations and areas

that had not had adelgids 10 years prior. The extent and severity of damage and mortality to subalpine fir and other true firs from BWA were measured and will be monitored in the future. In addition, we assessed management options to ensure the long-term viability of subalpine fir on the landscape.

METHODS

Permanent plots were installed in 26 sites on the Okanogan, Wenatchee, Deschutes, Ochoco, Malheur, Wallowa-Whitman, and Umatilla national forests east of the Cascades in Oregon and Washington, and in Mt. Rainier National Park in Washington. We established 8 to 12 plots at each location. Data on trees 5 inches in diameter and larger were recorded on 0.1-acre plots, data on trees down to 1 foot tall were recorded on nested 0.02-acre plots. All green trees including blown down trees were measured. Dead standing trees were also measured to facilitate remeasurement in 5 to 10 years.

Three measures of BWA damage and abundance were developed to characterize the infestation in east-side true firs. Bole infestation was recorded, gouting severity was measured, and a BWA rating (BWAR) system captured crown damage in the form of dieback and dead branches.

The BWAR system is an adaptation of the white pine blister rust severity rapid rating system developed by Six and Newcomb (2005) and based on the Hawksworth (1977) dwarf

mistletoe rating system. As in the Hawksworth system, tree crowns are divided into equal thirds. Each crown third received a rating of 0-4, with 0 meaning no visible damage, 1 meaning < 25 percent of crown third infested/affected or dead, 2 meaning 25-49 percent of crown third infested/affected or dead, 3 meaning $\geq$ 50 percent of crown third infested/affected or dead, and 4 meaning no live branches. These numbers are summed for an individual whole tree rating. This also allows tracking of crown thirds over time since BWA damage can manifest in sudden dead tops, individual dead branches, dead sections, or overall decline, depending on where trees are attacked and the severity of attack.

Gouting severity is a measure of infestation evident on branches. Feeding by the adelgid causes branch nodes and terminal and lateral buds to swell. This reduces branch elongation and new foliage and cone production. We counted the maximum number of gouted branch nodes visible on each tree to characterize gouting damage.

Bole infestation was recorded as an estimated density of BWA individuals visible on the bole (up to about 6 feet in height), assigning a rating of 0-4, where 0 means no adelgids present, 1 means a light infestation of fewer than one adelgid per square foot, 2 means a moderate infestation with 1 to 10 adelgids per square foot, 3 means a heavy infestation of 11 to 100 adelgids per square foot, and 4 means a very heavy infestation at more than 100 adelgids per square foot. Bole infestations lead to branch dieback and whole tree mortality.

RESULTS AND DISCUSSION

The BWA is not yet present in north-central Washington. Recent increased mortality there was caused by a combination of *Cytospora* canker and *Pityokteines minutus*, which seemed to be acting as a tree killer in drought-affected stands.

All areas of northeastern Oregon previously without BWA in the 1998 to 2000 surveys are now infested, with some of the more recently infested areas experiencing some of the higher current mortality.

Because BWA symptoms are often difficult to distinguish, stem infestations are corroboration that the insect is present on a site. Two sites in central Oregon did not have stem infestations. However, gouting and crown decline (BWAR) were fairly severe. We suspect the woolly material was not detected on these sites due to low densities or infestations higher than the 6 feet we could inspect on the bole. BWA insects on branches are very difficult to detect and in fact we saw them very rarely there. Two sites in Washington also did not have stem infestations. These sites had very little gouting and crown decline and thus presence of BWA on these sites is not confirmed. Further monitoring at these sites in particular is needed.

Cause of subalpine fir mortality was difficult to determine. We did not confirm the presence of rotholtz (compression-like wood caused by adelgid feeding), few trees had evidence of gouting, no old adelgid wool was found and so we cannot definitively attribute cause of death to

BWA. A few trees had evidence of fir engraver, *Scolytus ventralis*, but most had no signs of bark beetles. However, the widespread presence of BWA in most of the plots indicates BWA is likely involved in much of the subalpine fir mortality.

Mortality at many sites was much higher in subalpine fir than other species. Exceptions were plots where bark beetles had been active recently killing lodgepole pine or Engelmann spruce or a few sites where overall mortality was fairly low.

Mortality at all sites of subalpine firs larger than 1 inch diameter at breast height (d.b.h.) varied from 52 percent at one site in Central Oregon to 4 percent in northeastern Oregon. Overall mean mortality was 23 percent. Trees smaller than 1 inch d.b.h. had very little gouting or other evidence of BWA and almost no mortality (fig. 12.2). All but four sites had higher subalpine fir mortality in the 5-inch d.b.h. and larger trees than the trees 1-inch to 4.9-inch d.b.h. Mortality of subalpine fir over 5 inches in d.b.h. was over 45 percent on three sites in central Oregon and the Blue Mountains (northeastern Oregon and southeastern Washington). These findings agree with those in other areas that indicate older, mature trees are more susceptible to BWA (Ragenovich and Mitchell 2006).

BWAR and gouting varied together between plots with generally more gouting coinciding with more heavily impacted crowns (fig. 12.3, Kendall's $\tau = 0.4545$, $\alpha < 0.01$). This agrees with previous reports that crown dieback and thinning occur where branch infestations are

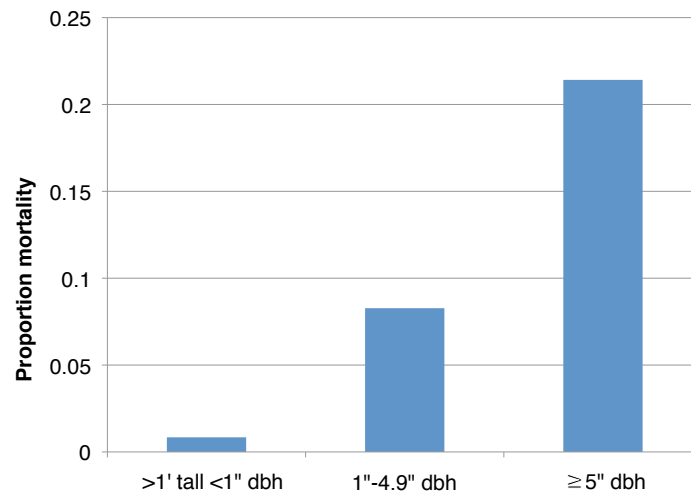


Figure 12.2—Proportion mortality in subalpine fir > 1 foot tall but < 1 inch d.b.h., 1–4.9 inches d.b.h. and ≥ 5 inches d.b.h., averaged across all sites. Larger trees experienced much greater mortality at some sites.

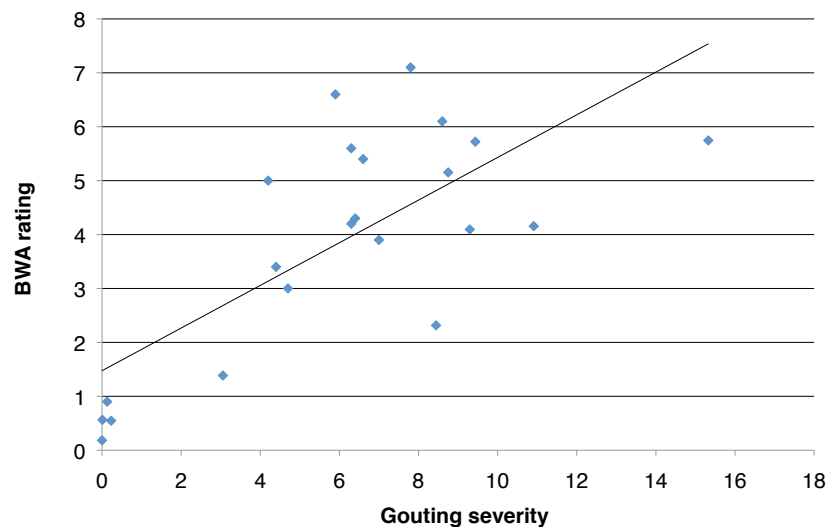


Figure 12.3—Gouting severity varied with balsam woolly adelgid rating (BWAR) crown rating. Gouting severity is the mean of the maximum number of branch nodes exhibiting gouting at each site.

heavy enough to impact growth but not so heavy as to cause outright branch death (Balch 1952).

Stem infestation measures correlated with BWAR (fig. 12.4, Kendall's $\tau = 0.4632$, $\alpha < 0.01$) but not with gouting (Kendall's $\tau = 0.134$, $\alpha > 0.1$). This is as expected as stem infestations affect crown growth and form but are somewhat independent of gouting as they are two different sites of attack. Stem infestations frequently are associated with sudden tree mortality while branch infestations result more commonly in gouting and stunted growth that results in the slow decline of the tree over many years (Ragenovich and Mitchell 2006).

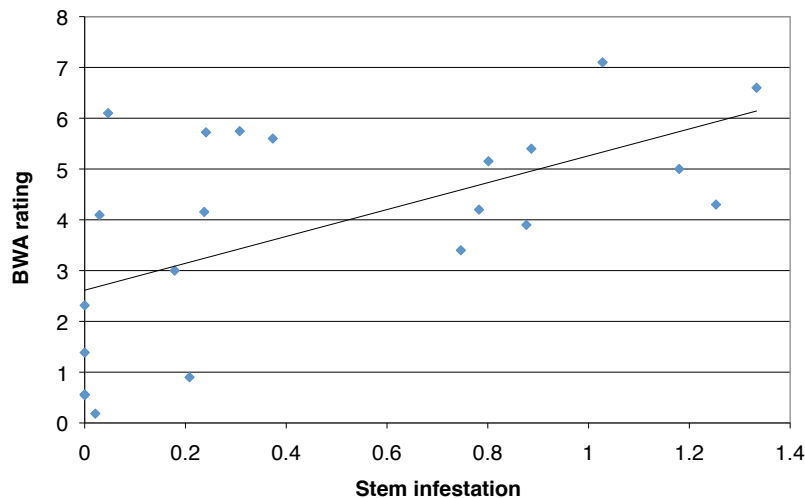


Figure 12.4—The balsam woolly adelgid rating (BWAR) crown rating varied with the stem infestation measurements.

Both BWAR and gouting were low to absent in Washington. Gouting was more severe in central Oregon than the Blue Mountains, while the BWAR's were similar. Very few trees had any crown thirds with no live branches (a BWAR of 4). The poorest crowns occurred at one plot in northeastern Oregon on the Umatilla National Forest, where nearly every crown third of every tree had damage and where BWA has been present for at least 10 years.

CONCLUSIONS

Occurrence and effects of BWA were more widespread and severe in central Oregon and the Blue Mountains than anticipated. The opposite was true in central Washington with some locations having no adelgids present where they were expected.

Once present at a site, BWA remains, with populations apparently fluctuating with the weather (Balch 1952, Mitchell 2001). Previous research has indicated that environmental factors appear to be the prime regulators in the abundance of this insect, with warmer conditions favoring population increases (Mitchell 2001). If a long-term trend of warmer summer temperatures occurs, this insect will likely expand to higher subalpine elevations and new habitats. A landscape analysis of BWA occurrence and severity by site factors such as elevation and precipitation is planned.

When BWA first colonizes a stand, the more vigorous, open grown or edge trees are the first to be attacked (Mitchell 1966). In

subalpine fir, attacks typically begin in the upper crown and move down, while in grand fir they typically begin in the lower crown and move up (Mitchell 1966). The smaller trees in stands are frequently suppressed, growing under overstory infested trees. As the overstory trees are killed, the understory trees are released and grow into susceptibility. How an individual tree's susceptibility changes with stand changes is not understood but appears to be related to the nutrients available to the adelgid at specific feeding sites. Continued monitoring of these sites will shed some light on these relationships.

Effects of BWA on subalpine stand dynamics are still not clear, now 30 to 40 years after establishment. Much subalpine fir east of the Cascades in Oregon and Washington occurs in mixed stands. These will probably become more dominated by overstory lodgepole pine and Engelmann spruce, depending on site conditions, if the older subalpine firs die and are not replaced. Currently understory firs are abundant and declines in recruitment were not yet detected.

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