Balsam Woolly Adelgid Occurrence on True Fir in Oregon

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Introduction

Originally from Europe, the balsam woolly adelgid (*Adelges piceae*) was first observed infesting *Abies* in the eastern U.S. in the early 1900's. In the western U.S., it was found in California around 1928 and on grand fir (*Abies grandis*) near Salem, OR in 1930(Annand, 1928) (Keen, 1952). This adelgid is very small, 1mm or less in length, and relatively inconspicuous except for a covering of white wax-like threads that gives the insect its name. Two unique features of this adelgid are that all individuals are female, capable of starting a new infestation alone, and all are flightless. Dispersal of the balsam woolly adelgid nymphs is believed to be by wind or as hitchhikers on birds, mammals or infested nursery stock. Its hosts are *Abies* spp. where it feeds in areas of thin bark or in bark crevices by inserting a long stylet into living cells. While feeding, the adelgid injects through the stylet toxic saliva into the host that affects cell development and results in damage to the tree (Johnson and Wright, 1957) (Mitchell et al. 1970).

The principle hosts of balsam woolly adelgid in Oregon, in order of susceptibility, are subalpine fir (*A. lasiocarpa* (Hook.) Nutt.), Pacific silver fir (*A. amabilis* (Dougl.) Forbes) and grand fir (*A.grandis* (Dougl.) Lindl.). Other native true fir, noble fir (*A. procera* Rehd.), Shasta red fir (*A. magnifica* var. *shastensis* Lemm.) and white fir (*A*. concolor (Gord. & Glend.) Lindl.), appear generally resistant in native stands, but are often susceptible when growing among principal hosts or outside their native range. Balsam woolly adelgid (BWA) infestations take two forms that have different impacts on the tree. When adelgid populations concentrate on the outer branch nodes they produce gouting (Figure 1) that inhibits new growth. The inhibition of new growth from gouting coupled with the natural shedding of older needles eventually result in tree crowns having a thin, sickly appearance. Tree decline from branch gouting is slow, but persistent infestations of this type can kill trees. However in the first decades after BWA introduction in the West, tree mortality solely from gouting attack was described as insignificant. Gouts on branch tips and nodes persist on trees for many years and are a sensitive indicator of BWA presence. There is also evidence that BWA infestations on some hosts can affect cone crops and reduce the percent of filled seed (Fedde, 1973). The other more severe form of BWA attack is the stem infestation that involves higher population densities feeding on the tree's main bole (Figure 2). Severe stem infestations can kill trees in as little as three to five years. In Oregon, long-term impact plots established in BWA infested subalpine fir stands have shown 40% - 79% tree mortality over a 35-45 year period (Mitchell and Buffam, 2001). An interaction between elevation and the severity of BWA infestations in true fir exists in Europe and has been reported as occurring in the Pacific Northwest. Stem infestations and rapid tree death were reported as more common in the lower elevation ranges of host species in Oregon and Washington (Rudinsky, 1957) (Mitchell, 1966). Stem infestations come and go depending on conditions favorable to BWA populations, but BWA does not seem to completely disappear from a site as long as host trees are present (Johnson and Wright, 1957) (Mitchell, 1966)(Mitchell and Buffam, 2001).

Over the decades various types of surveys and ground observations have been used to monitor the spread of BWA in Oregon. Aerial surveys indirectly detect established BWA populations by the appearance of infested trees and have used fading crowns or branches as a signature. However, aerial surveys are not suited to detect the recent spread of BWA to new geographic areas. The preferred method to monitor spread is observing BWA symptoms on individual trees (Mitchell, 1966). Ground surveys have used the presence of branch gouting or stem infestations on highly susceptible trees, such as subalpine fir, as an indication of BWA presence. After the first detection of BWA in the Willamette Valley in 1930, it was not

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Figure 1. Twig gouts on true fir from balsam woolly adelgid (Rudinsky, 1957).

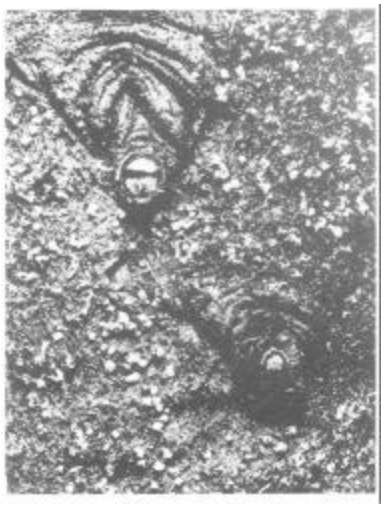

Figure 2. White wool-like spots on bark indicate an infestation (Rudinsky, 1957).

until 1955 that large areas of forest were reported infested in Oregon. Initially forestland on the westside of the Cascade Mountains was infested, but by 1956 BWA infestations were reported on the eastside of the Cascades in the Deschutes National Forest. The approximate boundaries of the BWA infestation in western Oregon during the 1960's extended from Crater Lake in the south to the Columbia River in the north. No further eastward movement of BWA was noted until 1974 when a small number of subalpine fir were reported infested on the Walla Walla Ranger District of the Umatilla National Forest. The 1974 BWA detection represented a roughly 180mile eastward extension of its range in Oregon. (USFS I&D Conditions Reports, 1938-1974). In 1983 BWA was detected farther to the east in Coeur d'Alene, Idaho and has since spread over millions of acres of subalpine fir forests in this state (Livingston et al. 2000). No updated information has been published about the spread of BWA through Oregon for almost three decades.

Methods

The objective of this survey was to examine true fir stands in Oregon for the presence of balsam woolly adelgid and to describe the current level of infestation in true fir species based on damage symptoms. The habitats examined for BWA infestations included general forest, agricultural land and urban areas, but the vast majority of sites, 98%, were located on forestland. Between 1998 – 2000 land managers provided the Oregon Department of Forestry with road maps that highlighted areas with true fir stands. Field crews drove along the marked roads and stopped at one-mile intervals to sample any true fir present. In most cases, the trees sampled were growing along the edge of a stand or open grown. The true firs examined were categorized into seedlings, saplings, and trees based on the criteria in the Region 6 Field Procedures Guide. At each stop one to twenty true fir were examined for symptoms of BWA infestation. Because of this insect's small size, it is very difficult to find in the field at low populations. For this reason its presence or absence on true fir was judged by looking for signs of gouting on branch tips. Stem infestations were also recorded if they were visible on seedlings or saplings. When there were questions on whether the gouting was caused by BWA, the branch tip was cut, bagged and returned to the Oregon Department of Forestry for a determination. At each plot the following data were collected; the site location using a GPS unit, the true fir species present, relative tree size, and the type of damage symptoms (i.e. gouting, stem infections, abnormal crowns, and BWA-caused mortality) if any. Only trees with gouts on branch tips and/or stem infections were counted as BWA infested. When a site had more than one true fir species present, data from each species were counted as separate plots with the same location. Plot elevations were

determined through a GIS program accurate to +_ 45 feet. A total of 857 roadside plots containing 14,221 true fir were examined in Oregon over a three-year period for signs of BWA infestation.

Results

The spread of BWA infestations through host stands in eastern Oregon since the 1970's has been relatively rapid (Figure 3). This is somewhat surprising since much of the true fir type in this area of the state is discontinuous with mountain ranges containing fir separated by high desert, farmland, or stands of non-host conifers. While having lower winter temperatures, many high elevation sites in eastern Oregon are generally drier and warmer than similar sites in the Cascades for much of the year. Based on the eastward

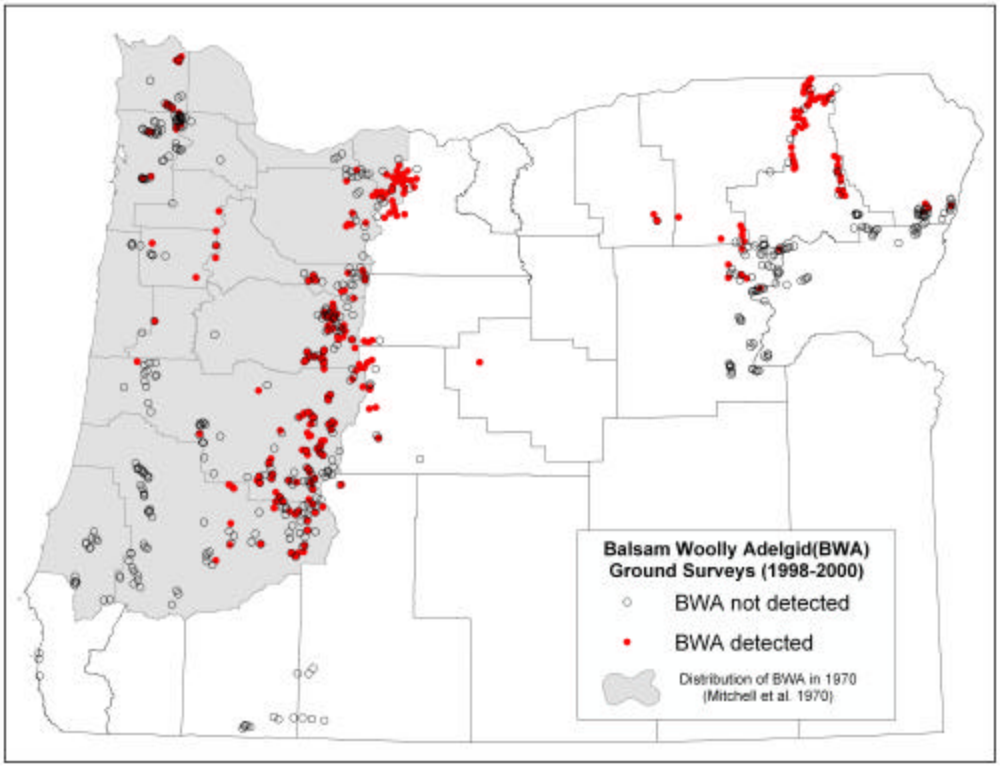

Figure 3. Balsam woolly adelgid distribution in the early 1970's and the locations of plots installed during the 1998-2000 survey.

spread of BWA, these conditions may be more favorable to BWA than once believed. In western Oregon, surveyors had a notably difficult time finding Pacific silver fir in northwest Oregon's coastal mountains, a part of its natural range. Most of the Pacific silver firs found in the coastal mountains were infested and had poor crowns and declining vigor.

A summary of the plot data taken during this survey for true fir species is shown in Table 1. Stem infections and tree mortality were encountered in some subalpine fir, but branch gouts were the most common symptom. While Pacific silver fir shows a high percentage of gouting, the number of trees with the more severe symptoms was small. On both sub alpine fir and Pacific silver fir plots, it appeared that

severe gouting attacks were leading to a decline in crown vigor and eventual mortality. Excluding the Willamette Valley, BWA infestations in grand fir plots were not impacting tree survival. In all cases gouting was not severe and did not impact crown vigor of noble fir. White fir displayed a low incidence of gouting and no stem infestations. When gouts were detected on white fir, the infestations were very light with no apparent affect on crown vigor. The small amount of mortality in the white fir sample is probably attributable to other biological agents. A few plots containing Shasta red fir were visited during the survey, but are not included in this table. No symptoms of BWA infestation were found on the Shasta red fir examined.

Table 1. Summary of plot data on balsam woolly adelgid damage symptoms occurring on true fir species in Oregon.

Species	Total Trees (all sizes)	Total Plots	Plots Infested	------- % Plots w/symptoms --------- Gouts	Stem Infestations	Mortality
Subalpine	2681	173	89	44.5	16.8	16.8
Pacific silver	5084	225	133	58.7	2.2	7.6
Grand	3957	223	71	28.7	1.8	0
Noble	1818	167	33	19.8	0	0
White	664	66	8	12.0	0	0

The occurrence of gouts on the branch tips of major BWA hosts did not showed some decrease with plot elevation. The range of elevation for plots with gouts was quite wide; subalpine fir (2,978 ft. – 7,160 ft.), Pacific silver fir (2,234 ft. – 6,426 ft.) and grand fir (148 ft. – 5,510 ft.). The percentage of plots with gouts in three elevation ranges for subalpine and Pacific silver fir is shown in Table 2. Stem infestations on subalpine fir occurred on 29 plots at elevations ranging from 4,211 ft – 7,511 ft. On Pacific silver fir, stem infestations occurred on 5 plots with elevations between 3,349 and 4,782 ft.

Table 2. Occurrence of gouts on subalpine fir and Pacific silver fir at three elevation ranges.

Plot Elvation(ft.)	Subalpine fir plots		Pacific silver fir plots	
	Total	% w/gouts	Total	% w/gouts
<3500	1	100	32	37.5
3500 – 5000	35	57.1	147	68.0
>5000	136	41.2	46	43.0

The majority of plots involving subalpine and Pacific silver fir were located in multistoried stands. The occurrence of gouts in these stands in relation to the amount of non-host trees present is shown in Table 3. It appeared that the amount of non-host trees present had little effect on the detection of gouts at these sites. The ability of BWA populations to infest trees in predominantly non-host stands implies an ability to reach even isolated pockets of susceptible hosts.

Table 3. Presence of gouts on subalpine fir and Pacific silver fir plots in multistoried stands having different species composition.

Composition	Subalpine fir plots		Pacific silver fir plots	
	Total	% w/gouts	Total	% w/gouts
Mostly Host	41	51.2	29	62.1
Mixed	78	41.0	65	60.0
Mostly Non-host	31	38.7	54	53.7

Summary and Discussion

Roadside surveys can detect the presence of BWA in new locations, but they cannot be used to describe impacts of BWA across the landscape. This is especially true in the case of subalpine fir where most high elevation sites are not accessible by roads. Although the analysis of roadside data have great limitations, the general trends of tree sensitivity to BWA infestation appear the same as those reported almost forty years a go by Mitchell (1966). However, the rapid tree mortality from stem infestations observed in sub-alpine fir during the 1950's and 1960's appears to be rare. Gouting attacks, described by Mitchell and Buffam (2001), that reduce tree vigor and can eventually kill trees appear to be the most common form of infestation now encountered. Gouts at branch tips and nodes were the most numerous BWA symptom observed during the survey. Pacific silver fir and subalpine fir were the species most susceptible to gouts. Stem infestations and tree mortality were more common in subalpine fir than in other species. The number of plots with gouts detected in noble fir was somewhat surprising given its perceived resistance over its natural range. Most of the infested noble fir plots had no more than occasional gout, which did not threaten, tree vigor. A couple of plots with BWA infested noble fir occurred in the Willamette Valley where off-site conditions predispose trees to BWA infestations. Other infested noble fir occurred in areas where subalpine fir was also present and possibly acting as a reservoir for BWA infection. But gouts on noble fir also occurred in other situations that were not easily explained. The results of this survey confirm the general resistance of noble fir, white fir and Shasta red fir to BWA infestation when grown in natural stands. Grand fir also appears resistant to BWA except when grown in low elevation areas of western Oregon, particularly the Willamette Valley.

It is important to note that approximately 50% of the subalpine fir and Pacific silver fir plots, the most susceptible hosts, did not show any symptoms of BWA infestation. This represents a large reservoir of apparently uninfected trees and shows the spotty nature of BWA infestations. Survey results support the idea that BWA impacts are not uniform, even on a single host, and factors affecting host susceptibility and the severity of infestations are not well understood.

There appeared to be a decrease in the percentage of plots with branch tip gouts with an increase in elevation similar to the pattern based on damage severity described by Mitchell (1966). However branch tip gouts were found at relatively high elevations and suggest a pattern of BWA occurrence that may not have existed in the 1950's and 1960's. Factors that may explain a weaker relationship with gout occurrence and elevation include higher temperatures in recent decades and the spread of BWA into high elevation sites in northeast Oregon with less snow pack and warmer temperatures during much of the year.

During its almost 80 years in Oregon, BWA has spread into virtually all of the highly susceptible host type. Oregon's relatively mild climate and the fact that both subalpine and Pacific silver are at the southern limits of their range may have contributed to this spread. Although many host trees did not show signs of BWA infestation in this survey, a number of observations support the proposition that BWA infestations are in fact changing the composition of forests in some areas. In our survey Pacific silver fir was difficult to locate in Oregon's Coast Range and it is likely that a combination of BWA infestations, logging, and lack

of regeneration, natural or planted, may eventually eliminate Pacific silver fir from this small part of its range. A decline in early and late succession Pacific silver fir stands in the Oregon Cascades has been documented (Regional Ecological Assessment Report, 1993). There is good reason to believe BWA has played a direct or indirect role in diminishing amount of silver fir type currently present in Oregon. Similar phenomena affecting grand fir in the Willamette Valley and sub-alpine fir growing on certain sites in the Cascades was described Mitchell and Buffam (2001). Regarding subalpine fir, warmer temperatures are known to favor BWA infestations (Mitchell and Buffam, 2001), adversely affect cone crop size and seed viability (Woodward et al, 1994), and reduce the establishment and survival of seedlings (Little et al. 1994). Climate warming could result in higher BWA populations affecting tree vigor, reducing the ability of sub-alpine fir to reproduce, and possibly increasing susceptibility to native pests. Defoliation by a native pest like the western spruce budworm could be particularly damaging in BWA infested stands since it further reduces crown vigor. Over many years branch gouts appear to cause a gradual decline in crown vigor and contribute to tree mortality. Scattered individual tree mortality in stands containing BWA hosts is not recorded by the annual cooperative insect and disease aerial survey. As a result we have a poor understanding of BWA impacts across the landscape**.** While current tree mortality from BWA in subalpine fir stands appears unspectacular on an annual basis, a combination of biotic and abiotic factors working over time could lead to the disappearance of subalpine fir from some sites in Oregon. There is continuing evidence that BWA is a significant disturbance agent in Oregon's high elevation forests as well as in grand fir stands located in the Willamette Valley.

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