

Scientific Note

Notes on balsam woolly adelgid, *Adelges piceae* (Ratzeburg, 1844) (Hemiptera: Adelgidae), range expansion in Idaho, Montana and Utah

The earliest reports of balsam woolly adelgid, *Adelges piceae* (Ratzeburg, 1844), in North America occurred in Maine in 1908 and California in 1928 (Kotinsky 1916, Annand 1928). By the late 1960s, this non-native pest was common throughout the ranges of native true fir species, *Abies* spp. (Pinaceae) in the eastern United States and along the Pacific Northwest coast. In the interior west, Livingston et al. (2000) detected balsam woolly adelgid in Idaho in 1983, then observed declining health and death of subalpine fir, *A. lasiocarpa* (Hooker) Nuttall, over the next 15 years, primarily in north-central Idaho. This seemingly slow invasion from the west coast to Idaho may be due, in part, to difficulty detecting an insect less than one millimeter in size. Another factor may have been a geographic barrier, the Columbia Basin, slowing the west to eastward dispersal between viable host trees. The distribution of true fir species from British Columbia through Idaho, western Montana, into western Wyoming, northern Utah and high elevations of Colorado present nearly continuous and abundant opportunity for passive dispersal of asexual first instars, called crawlers. Larger gaps exist in southern Utah, Nevada, Arizona, and New Mexico where host trees grow primarily in high elevation patches. Human or bird assisted movement are probable modes for balsam woolly adelgid to colonize those patches. Balsam woolly adelgid detection surveys continue along the known southern and eastern edges of its western range.

Multiple life stages of balsam woolly adelgid may be present throughout the growing season, and two or more generations are produced each year (Balch 1952). Adults, covered in woolly flocculence, are the only life stage generally visible with the naked eye, and these can be overlooked by the novice observer unless present in high density. Crawlers settle and insert their stylets along the main bole, often within fissures and lenticels, or at newly forming branch and bud nodes throughout the crown. Adelgid saliva causes a hormonal reaction and abnormal growth of xylem cells that appear as irregular swelling or gouting in the branches and as thickened reddish sections of growth rings (called rotholz), which functionally restrict water transport within the tree (Balch 1952, Balch et al. 1964). Gouting is a permanent and noticeable symptom indicating that balsam woolly adelgid feeding has occurred. There is a native western North American adelgid species, *Pineus abietinus* Underwood & Balch, 1964 that also settles on *Abies* bark and has a similar woolly appearance that may be confused with balsam woolly adelgid. However, *P. abietinus* does not cause gouting on branches (Johnson 1959).

Detection surveys occurred between July and November during 2006 through 2010 and 2017 through 2019 in Idaho; 2010, 2011, 2013, and 2015 in Montana; 2008, 2009, 2016, 2017, and 2019 in Wyoming; and 2017 through 2019 in Utah and Nevada. Roads and trails served as transects for survey points where subalpine fir dominated or was a major component of forest stands in Idaho, Montana, and Wyoming. In Utah, survey points included both subalpine and white fir, *A. concolor* (Gordon & Glend.) Lindley, and in Nevada, white fir was the only host. Survey points occurred along

one-mile intervals if host tree species composed less than 25 percent of the stand and at two-mile intervals if host tree species composed 25 percent or greater of the stand. Observers visually examined at least five host trees on the lower two meters of the bole. Gouting or woolly flocculence indicated likely presence of balsam woolly adelgid. A minimum of five minutes and maximum of ten minutes search was conducted. If there was no visual confirmation of adelgid, the stand was considered not infested. *Pineus abietinus* individuals cannot be readily distinguished from balsam woolly adelgid in the field (Underwood & Balch 1964). Adelgid specimens were therefore collected from each watershed, or at least each county, in Montana, Wyoming, Utah, Nevada and southern Idaho, and were slide-mounted and examined for species determination, and their DNA barcode sequences were compared to a reference database (Footitt et al. 2009) to confirm balsam woolly adelgid. Slide vouchers were deposited at the Yale Peabody Museum of Natural History, New Haven, Connecticut, and DNA sequences were deposited in GenBank.

Results of these surveys greatly expand the balsam woolly adelgid range reported by Livingston et al. (2000) (Figure 1). The range expanded over 400 kilometers eastward through western Montana and over 800 kilometers south into Utah. The highest elevations with balsam woolly adelgid populations were approximately 2700 and 3050 meters in Blaine County, Idaho and Duchesne County, Utah, respectively. Our surveys confirm balsam woolly adelgid occurs at variable population densities in most Idaho counties, except in the southernmost areas where systematic ground surveys were limited (Bannock, Bonneville, Camas, Cassia, Custer and Owyhee Counties) or did not occur (Butte, Gem, Madison, Oneida and Power Counties). Trained aerial observers annually record forest damage agents based on distinctive visual signatures across much of Idaho. Aerial detection surveys suggest Owyhee County may be the only county in Idaho with possible host trees not infested with balsam woolly adelgid. Ground surveys of areas identified as infested during aerial survey will continue in order to collect specimens and confirm balsam woolly adelgid presence. We suspect that balsam woolly adelgid had infested Adams and Valley Counties up to two decades before the first survey occurred in 2006 and Lemhi County up to seven years before first detection in 2010 based on the extent of damage on host trees. Surveys along the Idaho-Montana border in 2007 suggest balsam woolly adelgid was likely present in Montana. Insect samples collected in October 2007 by a Forest Inventory and Analysis crew in Ravalli County became the first record for Montana when Gary L. Miller, Systematic Entomology Laboratory, United States Department of Agriculture identified samples as balsam woolly adelgid in January 2008 (G. L. Miller, in litt.). The 2010 survey confirmed balsam woolly adelgid in five Montana counties (Lincoln, Sanders, Mineral, Missoula, and Ravalli) and four additional counties in 2011. The most eastward known infestation is in Gallatin County, Montana. Extensive surveys began in Utah in 2017, and balsam woolly adelgid was detected in seven counties (Boxelder, Davis, Morgan, Summit, Salt Lake, Rich and Weber) on both subalpine and white fir. Four additional county confirmations were made in 2018 (Cache, Duchesne, Uintah, and Utah). In 2018, the southernmost infestation was detected in Utah County. The 2017 subalpine fir mortality was extensive within several Utah canyons, suggesting balsam woolly adelgid may have been present for up to a decade before first ground detection. Surveying efforts through 2019 did not confirm balsam woolly adelgid in Nevada. Despite notable subalpine fir decline in western Wyoming, balsam woolly adelgid was not confirmed in Wyoming.

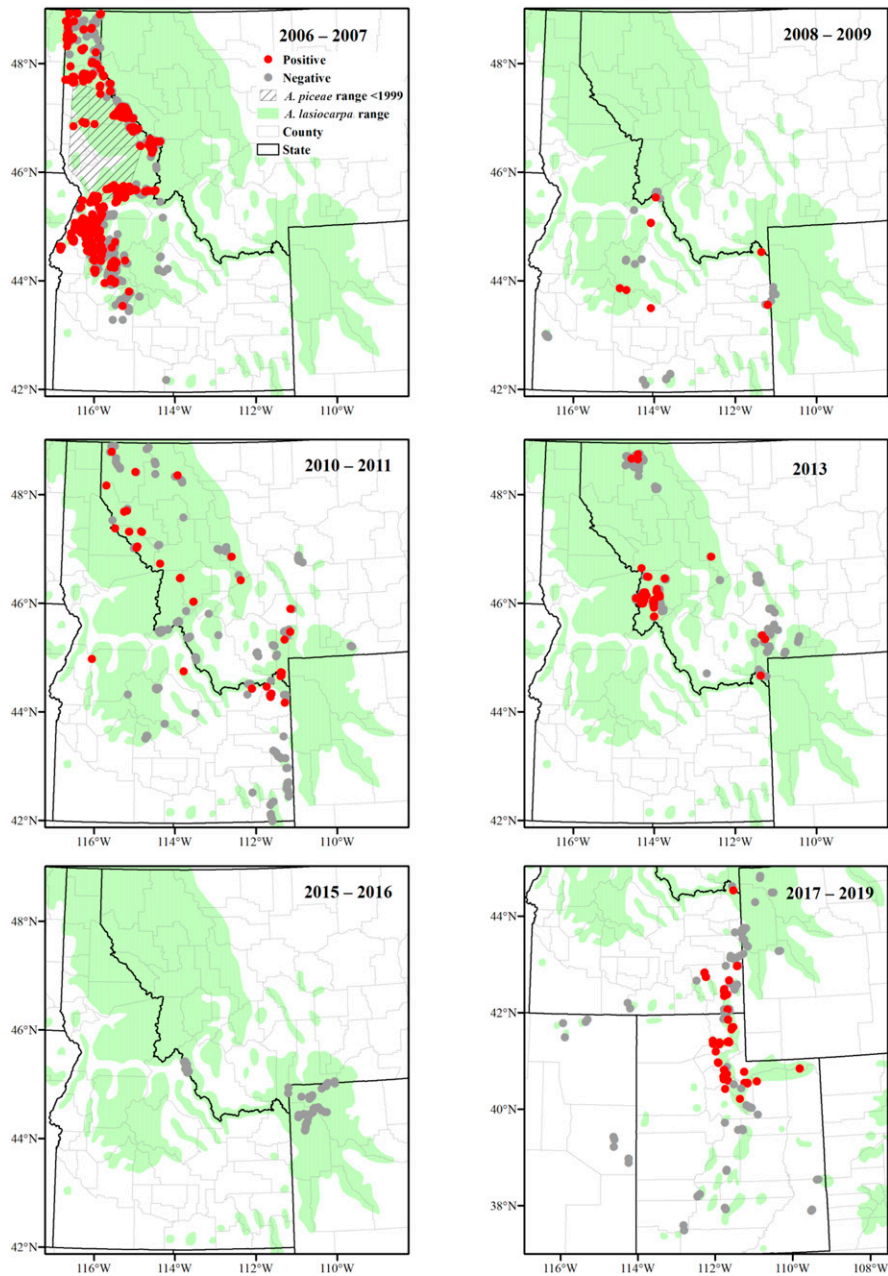


Figure 1. Points surveyed for balsam woolly adelgid by years surveyed.

Mitchell & Buffam (2001) showed that in Oregon and Washington, balsam woolly adelgid was prevalent on grand fir and Pacific silver fir only at low elevations but was found on subalpine fir at all elevations except possibly at the timberline. Our surveys found balsam woolly adelgid at elevations ranging from nearly 650 to 3050 meters. Since we surveyed in Wyoming on subalpine fir at points ranging from 2400 to 3000

meters in elevation, well below the timberline, it does not appear that that elevation explains why balsam woolly adelgid was not found in the state.

Small populations of this minute insect are difficult to detect, and ground surveys are generally limited to the lower bole and crown. Established populations may be difficult to locate, because they temporally and spatially fluctuate across the landscape in response to host quality, genetic variation and abiotic variables (Newton & Hain 2005). These challenges may explain why detection surveys in Wyoming remain negative, despite proximity to populations in Idaho, Montana and Utah.

Detection surveys are essential to inform management decisions before extensive tree mortality occurs. Based on lessons learned in Idaho, Montana, and Utah, we suggest implementing early detection surveys for this pest using established, standardized methods that will improve the efficiency of data management when multiple organizations and individuals conduct surveys across broad landscapes. We created a database and data collection system within Survey123 for ArcGIS (Environmental Systems Research Institute, Inc.) that ensures consistent data collection, efficiency by eliminating data entry from hand-written field notes and real-time spatial display of surveys. Further monitoring and studies are needed to predict the rate of host tree mortality in these newly invaded ecosystems and to better understand potential population regulation of balsam woolly adelgid toward developing effective management options. Increased outreach and education would raise awareness and may facilitate earlier detection within newly invaded environments.

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