Monitoring High Severity Damages to Subalpine fir-Dominant Forests Caused by Balsam Woolly Adelgid on the Boise and Payette National Forests

Forest Health Protection, Boise Field Office

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Introduction

The balsam woolly adelgid (BWA) is a non-native piercing-sucking insect that infests all true firs of the United States and Canada. Introduced to the west coast in the 1920's, it continues to spread passively by wind eastward into the Rockies and beyond wherever there is available host and favorable conditions. True firs differ in susceptibility to the insect, with subalpine fir (SAF) being the least tolerant host (Mitchell 1966).

BWA infestations and symptoms can vary making it hard to quantify the presence of this pest until damages worsen. The insect damages the xylem water conducting tissues causing water stress issues that eventually lead to death of the tree. Symptoms of BWA can be similar for those associated with water stress including needles that change color from green to yellow to red and fall off the tree with older needle drop most noticeable in a thin crown, thinnest nearest the stem. Infestations can occur on the stem or crown. Stem infestations are observed as white "wool" in various levels in fissures/lenticels of bark leading to mortality in as little as 3 years (Mitchell 1966, Mitchell and Buffam 2001, Overhulser et al. 2004). Crown infestations are observed as white wool under branches at nodes or all around the entire branch with heavy populations. Abnormal growth of xylem cells cause node swelling, or "gout", and irregular branching patterns of twigs. Crown infestations can take several decades to kill a tree. Both types of infestations can occur on a tree, but climate is thought to influence the prevalence of crown or stem infestations (Greenbank 1970, Quiring et al. 2008). Other damages expected from BWA infestations are reduced cone production. Crown infestations are thought to be most common in maritime climates and stem infestations more prevalent in continental climates. In transitional climates like in central Idaho, where BWA outbreaks following warm winters and collapses during cold winters, there is a mix of stem and crown infestations (Greenbank 1970) . Colder temperatures kill adelgids in the winter above snowline and the populations have to grow again to re-infest the crown. In warmer areas, populations never get killed from within the crown or stem and populations can quickly expand to kill susceptible hosts.

The biology of BWA is amenable to rapid, continuous dispersal. BWA reproduces asexually with only one female needed to start an infestation since she can produce 50 to 100 eggs (Bryant 1974, Hain 1988). Temperatures influence the number of generations per year, but there are likely two generations per year in Idaho (Mitchell et al. 1961). Adults are present around June or July and again in late August through September. Only the 1st instar, or crawler stage, is mobile. Crawlers move up the stem toward

the crown to find a good location to insert the stylet and begin to suck sap from the tree. White waxy wool, "woollies", soon forms to protect the insect as it continues to develop and feed. A diapause is required for 1st instars of all generations, one in the summer and one over winter (Shooley and Bryant 1978). It is easiest to observe damages of BWA in the fall because signs and symptoms from two generations of feeding will have accumulated on the trees by that point prior to snowfall. Low level infestations must be detected through ground survey, making it difficult to track the range expansion through this vast, heavily roadless country.

BWA distribution and damage has been described to some extent in Idaho through ground and aerial surveys for over 30 years. Idaho's first record of BWA infestation on the ground was in 1983, documented for the first time in central Idaho in 2002, with further range determined in 2006-2011 (Livingston et al. 2000, Lowrey 2015). Additional ground investigations have involved a system of long-term monitoring plots established throughout Idaho in 2008 in low infestation levels only to monitor forest changes over time in many different habitat types (Davis, Fidgen, Lowrey, Pederson, in progress). Aerial Detection Survey (ADS) first used BWA signatures in central and southern Idaho in 2012 and records now occur throughout Idaho and into Wyoming (ADS 2012-2015, Lowrey 2015). ADS recorded 4,000 acres of damage in 2014 and 14,000 acres in 2015. ADS is flown mid-summer in Idaho when western spruce budworm (WSB) signatures can mask BWA signatures. Typically, only the worst impacted areas are captured by ADS, but we have not yet related the signature to what that means in terms of impacts to the forest.

Subalpine fir is host to a variety of insect and pathogens pests. Most notably are WSB, western balsam bark beetle (WBBB), root disease, cytospora bole canker and twig beetles. In central and southern Idaho, root disease is thought to be less prevalent than in wetter climates, such as northern Idaho, and is not an aggressive tree killer. This is important for BWA evaluations because root disease and BWA symptoms can look similar from the ground and in the air. WSB defoliation has been widespread across Idaho for over a decade and impacts most forests with SAF host to some degree. ADS data documenting BWA does not relate consistently to patterns of heavy or light WSB defoliation, nor are these areas mapped with concurrent WBBB damage (ADS data). Therefore, BWA can be approached as an aggressive tree killer of its own right, on par with bark beetles for their ability to kill trees. Interactions among these damaging agents needs to be further explored in the future.

Project Objectives: 1) To describe the damage and intensity of damage for SAF forests severely impacted by BWA and representative of areas mapped by ADS, and 2) to follow the decline of these stands over time to assess stand trajectories and ecological implications.

Methods

Three areas with high damage levels visible from the air and the ground were selected on the Boise and Payette National Forests (NF) to install long-term monitoring plots. Areas were chosen in close proximity to Boise to facilitate (bi)annual evaluations over the next 5 years and beyond. Recent ADS maps and roads were used to select plot locations on the Payette NF and ground surveys and a road GIS layer for Boise NF plot locations.

A field crew from Forest Health Protection, Boise Field Office consisting of Laura Lowrey (Entomologist), Kathleen Matthews (Aerial Survey Program Manager), Phil Mocettini (Biological Technician), Chad

Nelson (Aerial Survey Technician) visited Scott Mountain (Boise NF) on September 18 and 21, 2015, Mores Creek Summit (Boise NF) on September 23, 2015, and Hornet Reservoir (Payette NF) on October 14 and October 22, 2015. Four or five 1/10 acre (37.2 ft) fixed-radius plots were distributed at 3-5 chain (1 chain = 66 ft) intervals along linear transects laid out in a way to maximize the number of plots in the forested area, often along contour lines because of the steep terrain. Methods followed protocols for long-term monitoring plots established in 2008 (Davis, Lowrey, Pederson 2015). Plot one of each set was established in an area with at least three SAF over 5 inches diameter at breast height (DBH) with BWA infestations. All subsequent plots at each location had at least three SAF over 5 inches DBH. Additional chains were walked until this criterion was met. All trees over 5 inches DBH within the fixed plot were documented with numbered metal tags.

Mensurational data collected for each tree included species, DBH, crown status (live green, live with red needles, current dead, older dead). Tree age (number of growth rings from core) and growth (radial growth for the last 10 years in mm) were estimated with an increment borer for one SAF in each 5 inch size class. Information was collected for trees to describe presence of BWA gouting symptoms and BWA population information based on the level of stem infestations (low= 1 woolly, moderate= 1-10, heavy= over 10 per square foot on average) and crown infestations (low=over 25%, moderate=26-50%, and heavy = over 50% of nodes with visible adelgid or swelling). An additional regeneration 1/100 (16.8 ft) radius plot was installed 18.6 ft due North from plot center. Mensurational and BWA infestation data collected for each tree 1 to 4.9 inches DBH were the same for the large plot. Counts of regeneration 12 inches tall or more and less than 1 inch DBH were collected for all tree species as was live/dead tree status and presence/absence of woolly infestation or gouting. A picture was taken at each site to document visual plot conditions at the start of evaluations.

The number of BWA infested trees were summed for each transect, hereafter referred to as stand. To describe the susceptibility of stands to BWA infestation, stand survey data was entered into a spreadsheet and analyzed using the **F**orest **I**nsect and **D**isease **T**ally (FINDIT) program (McMahan and Zweifler 2014). The FINDIT program calculates metrics for up to three types of damages/codes. The FINDIT program calculated the following statistics to determine the level of BWA-caused mortality and other stand attributes:

a. Total trees/acre (TPA).
b. Total live and dead basal area (BA ft^2/ac).
c. Average live tree species quadratic mean diameter (QMD).
d. Live stand density index (SDI).
e. Number of dead and live trees/acre.
f. Percentage of each tree species, live and dead.
g. Percentage of basal area (BA) comprised of each tree species, live and dead.
h. BA impacted by each damage code/acre.

The following additional information was recorded and will be analyzed after future remeasurements. Live Crown, tree age and growth, tree vigor (% of crown exhibiting BWA symptoms of stunting, dead tips, needle discoloration and loss), BWA interaction with other agents (WSB, cytospora), presence or absence of BWA symptoms of stunting, dead tips, needle discoloration and loss, and habitat type.

Results and Discussion

The BWA damages observed within stands of Mores Creek Summit, Scott Mountain and Hornet Reservoir are representative of very widespread damages observed over the entire drainage. Table one shows that all three stands were comprised of nearly pure SAF in all size classes, diversity was especially low in the sapling and seedling size classes. SAF tree densities in all three locations were comparable, 118, 146 and 220 for Scott Mountain, Mores Creek Summit and Hornet Reservoir, respectively (Table 1). The percent live SAF basal area (BA) ranged from 53.9 to 73.1 with all mortality attributed to BWA as the primary tree killer (Table 1). The percent of live sapling regeneration ranged from 57 to 100 percent, nearly all of live SAF were infested (Tables 1, 2). All seedling regeneration was SAF and ranged from 82 to 92 percent live (Table 1) with 41 to 92 percent of live seedlings infested with BWA (Table 2).

Table 1. Stand summary information for the three high elevation locations evaluated for heavy BWA impacts on the Boise and Payette NF's, Idaho, broken into size classes (over 5 inches DBH, 1-4.9 inches DBH and less than 1 inch DBH and 12 inches tall), and based on data collected September through October, 2015.

		Trees over 5 inches DBH					Regen 1-4.9 in. DBH	Regen <1 in. DBH, >12 in. tall
Location; elevation (ft) decimal degrees	**Tree Sp.**	**QMD L/D**	**TPA (%)**	**TPA Live (%)**	**MBA (%)**	**Ba Live (%)**	**TPA Live/Dead**	**TPA Live/Dead**
Mores Creek Summit, Boise NF; 6,251;	SAF	14.7/8.0	117.5 (85.4)	70 (50.1)	99.3(64.8)	82.6 (53.9)	100/75	900/75
(N43.93143, W115.66687)	DF	22.7/21.8	20 (14.5)	10 (7.3)	54(35.2)	25.8 (16.8)	0/0	0
Scott Mountain, Boise NF; 7,263;	SAF	13.4/10.6	146 (100)	92 (63)	123 (100)	90 (73.1)	160/0	2300/280
(N44.16272, W115.71755)	WBP	0	0	0	0	0	20/0	0
Hornet Reservoir, Payette NF; 7,003;	SAF	12.2/10.1	220 (80.7)	162.5 (59.6)	164.8 (81.8)	132.6 (65.8)	375/100	900/200
(N44.80839, W116.72119)	LPP	9.7/12.2	52.5 (19.3)	20 (7.3)	36.6 (18.2)	10.3 (5.1)	25/0	0

***Tree Sp.** = SAF (subalpine fir), DF (Douglas-fir), LPP (lodgepole pine), WBP (whitebark pine); **TPA (%)** = trees per acre (live plus dead); **QMD**= quadradic mean diameter **(live residual trees/dead residual trees); MBA** (%) = mean basal area (ft^2 per acre) (live plus dead) and (percentage by tree species)

BWA impacts were severe specifically for trees larger than 5 inches DBH, although BWA-caused mortality and damage was observed for all size classes. Only three trees over 5 inches DBH in all plots of all locations were found to be free of BWA at the time of survey. BWA presence was indicated by crown and/or stem infestations which were very easy to see at nodes on the underside of branches and covering entire branches and upon stems. Stem infestations proved to be harder to observe at low infestation levels than crown infestation, especially for thicker barked/older trees. Usually we would look at the root collar or lower portion of stem in cracks to find low level stem infestations that survived winter dieback.

Gouting symptoms were very severe in all three of these locations, much more so than ever observed for SAF in central Idaho (Figure 1). Often entire crowns were full of round gouting nodules so that it is hard to imagine the tree ever growing new shoots or producing seed again. The percentage of trees

with gouting symptoms ranged from 56 to 98, 13 to 57, and 32 to 97 percent over the three locations for trees over 5 inches, saplings, and seedlings, respectively (Table 2).

Table 2. Balsam woolly adelgid damages to three size classes of nearly pure SAF forests in high elevations of southern Idaho, 2015, representative of heavily impacted areas that could be detected by Aerial Detection Survey; data represent only trees infested by BWA.

Tree Size Class	Damage	Mores Creek Summit		Scott Mountain		Hornet Reservoir	
		% SAF with damage (TPA)	% BA (BA) with damage	% SAF with damage (TPA)	% BA (BA) with damage	% SAF with damage (TPA)	% BA (BA) with damage
≥5 in. DBH (POST/POLE /MATURE)	**Dead-BWA**						
	Current dead-BWA	4.3 (50)	1.5 (1.5)	21.9 (320)	14.3 (21.9)	2.7 (50)	0.8 (1.4)
	Dead 1-3 years-BWA	36.2 (425)	15.3 (15.2)	15.1 (220)	12.6 (15.5)	23.9 (525)	18.7 (30.8)
	Live-BWA						
	Medium/High stem infestation	42.6 (500)	41.8 (41.5)	60.3 (880)	26.2 (32.9)	51.1 (1125)	45.0 (74.2)
	Low stem infestation	40.4 (475)	44.5 (44.2)	37.0 (540)	45.4 (55.9)	22.7 (500)	35.4 (58.4)
	Medium/High crown infestation	34.0 (500)	39.3 (39.1)	76.7 (1120)	49.9 (61.4)	42.0 (925)	43.8 (72.1)
	Low crown infestation	2.1 (25)	2.3 (2.3)	6.8 (100)	10.4 (12.8)	9.1 (200)	12.9 (21.2)
	Gouting	97.9 (900)	99.3 (98.7)	65.8 (960)	66.5 (81.8)	55.7 (1225)	59.8 (98.5)
	Secondary bark beetle/borers	19.1 (200)	8.6 (6.5)	2.7 (40)	3.7 (4.6)	1.1 (25)	1.2 (2)
1-4.9 in. DBH	**Dead-BWA**						
(SAPLINGS)	Current dead-BWA	0 (0)		0		5 (25)	
	Dead 1-3 years-BWA	42.9 (75)		0		20 (100)	
	Live-BWA						
	Medium/High stem infestation	57.1 (100)		12.5 (20)		50 (250)	
	Low stem infestation	0		12.5 (20)		0	
	Low crown infestation	0		12.5 (20)		10 (50)	
	M/H crown infestation	100 (175)		12.5 (20)		40 (200)	
	Gouting	57.1(100)		12.5 (20)		55 (275)	
>1 ft., < 1 in. DBH	**Dead**	7.7 (75)		10.9 (280)		17.8 (200)	
(SEEDLINGS)	**Live-BWA**						
	Stem/crown infestations	92.3 (900)		41.9 (1080)		58.3 (525)	
	Gouting	69.2 (675)		31.9 (820)		97.2 (875)	
	Live-no BWA	0		47.3 (1220)		2.8 (25)	

***Species** = SAF (subalpine fir); **TPA (%)** = live and dead; residual trees);

%BA (BA)= percent basal area (ft2) per acre (live and dead) for each damage category and (total basal area of each damage category)

The percentage of trees with both stem and crown infestations – the most damaging type of infestation – was 18 to 43 percent for trees over 5 inches DBH, and 53 to 76 percent if gouting was included as a surrogate measure of crown infestation. The percentage of trees with crown infestations alone ranged from 0 to 4 percent and 0 to 6 percent including gouting (Figure 1). The percentage of trees with only stem infestations ranged from 2 to 18 percent (Figure 1). It is sometimes very difficult to sample BWA woollies on the crown of tall trees even with binoculars, but branch gouting is easier to see from the ground. Future annual observations will determine if the type of infestation (low/moderate/high crown or stem) influences the speed of tree death at these locations over time.
BWA-caused mortality was substantial for all three size classes evaluated. BWA killed between 27 to 41 and 0 to 43 percent of trees per acre over 5 inches and saplings, respectively (Table 2). Between 8 to 18 percent of seedlings were dead, but it was harder to tell if death was solely attributable to BWA or to WSB and BWA. Secondary bark beetle galleries/wood boring beetle holes were observed on 1 to 20 percent of trees dead 1 to 3 years (Table 2). This has previously been recorded in other long-term permanent monitoring plots by year 2 or 3 post death attributable to BWA, i.e. the beetles fill in, and unseasoned observers may attribute tree death to beetles instead of BWA at this stage (Davis, Lowrey, Pederson, unpublished data). Finally, between 2 to 12 percent of trees recently killed by BWA (estimated within three years) had snapped off or fallen (Figure 1). A substantial amount of older dead (no bark or fine branching) was observed in all of the Hornet Reservoir plots and at least one of the Scott Mountain and Mores Creek plots. These trees were not tagged but likely attributable to BWA. No Brown's surface fuels transects were established to describe fuel loading, but may be included next year.

The ramifications of BWA in its new range of Idaho and beyond are largely unknown. SAF is the most intolerant true fir host species and we have an abundance of it in central/southern Idaho and western Wyoming, valued at $8 to $16 billion for Idaho alone in 2015 (Lowrey and Davis, unpublished). BWA impacts and kills all size classes of SAF, different from other true fir species where regeneration classes are spared. BWA killed 17 to 37 percent of BA per acre, an estimate equivalent to kill levels we see with landscape level, native bark beetle outbreaks. Outbreaks of Douglas-fir beetle and mountain pine beetle typically result in 20-60 and 20 to 90 percent BA killed per acre, respectively (Roe and Amman 1970, Negron et al. 1999). Since we think many of the older (4 plus years) trees on the ground were also killed by BWA the BA estimate could be greater and will continue to increase over time. Mortality of this level was not observed anywhere on the Boise NF ten years ago during the original detection surveys, and in only a few places on the Payette NF (Lowrey 2015). This loss of SAF would not be as significant if there were other trees to fill the ecological and recreation functions in the high country such as protection of snowpack, hydrological functions, or animal habitat. Regeneration size classes are at risk of further damage in these sites. Gouting symptoms were very high for regeneration size classes, especially for the seedling group; to the extent that it is unlikely they will ever successfully grow to larger size classes or reproduce. There is very little species diversity at these high elevation sites in central/southern Idaho and southward with two species being common, whitebark pine and subalpine fir. Whitebark pines have been decimated by mountain pine beetle and the regeneration is infected with white pine blister rust. BWA populations and impacts are likely to continue or increase as climates warm because winter mortality will be less for BWA populations and there is potential for an additional generation per year.

Figure 1. Heavy stem infestations (a), gouting of SAF branches (b), and accumulation of surface fuels (c) caused by Balsam woolly adelgid in nearly pure SAF forests in high elevations of southern Idaho, 2015, representative of heavily impacted areas that could be detected by Aerial Detection Survey.

(a)

(b)

(c)

This evaluation highlights the destructive and aggressive nature of BWA leading to heavy mortality within nearly pure SAF stands. Observations reported in this evaluation should be useful in both short-term and long-term planning efforts by the Forests. Future trajectories for SAF-dominated stands with damages similar to observed in this evaluation are unknown, but drainages once dominated by SAF may be converted to grass or shrub communities without restoration efforts. Tree planting prioritization and planting of white pine blister rust tolerant whitebark pine may be warranted in some of these sites. Additional concerns for managers could be fuel loading from BWA-killed SAF that will likely impact wildfire behavior on these very steep slopes. Assessments of potential wildfire behavior and advisement of firefighting crews about the potential for erratic fire behavior in these heavily impacted areas is recommended.

Please contact Laura Lowrey or Joel McMillin (Group Leader) with questions regarding this report or related assistance or concerns.

Sincerely,

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