

Aspen health and damage agents on national forests in northern Wyoming and western South Dakota

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Introduction:

Long-term monitoring plots (Shaw 2004) and aerial detection surveys (Worrall et al. 2008) suggest extensive sudden decline and deterioration of aspen forests in the Rocky Mountains. Changes to the fire regimes since European settlement and heavy browsing (Bartos and Campbell 1998; Kay 1997; Romme et al. 1995; Sheppard et al. 2006), drought (Hogg et al. 2008; Worrall et al. 2008), and climate change (Rehfeldt et al. 2009; Worrall et al. 2013) have been suggested as factors contributing to decline and mortality. Several diseases and insects are associated with aspen mortality (Dudley 2011; Fairweather et al. 2008; Frey et al. 2004; Guyon and Hoffman 2011; Hogg et al. 2008; Hogg and Michaelian 2014; Marchetti et al. 2011; Rehfeldt et al. 2009; Steed and Kearns 2010; Worrall et al. 2010, 2013). Aerial surveys in Wyoming provide general information regarding the extent and location aspen mortality, but not the condition of regeneration or specific damage agents associated with mortality.

In this study, damage agents and site variables were measured to determine factors contributing to aspen mortality. The objectives of the study were to: 1) evaluate tree and regeneration health, 2) quantify frequencies of damage agents, and 3) analyze tree mortality and regeneration stocking in relation to site, tree, climate, and damage agents.

Methods:

Permanent plots were selected in 2008/2009 in the Shoshone, Bighorn, and Black Hills National Forests (**Fig. 1**). Sites were initially selected systematically, sight unseen, using a geographic information system. Polygons (representing stands) were selected that were designated as $\geq 50\%$ aspen and ≥ 0.8 ha, with a minimum spacing among stands of 1.6 km. Stand size and composition were confirmed in the field. Three tree and three regeneration plots were installed per stand at 40 m spacing. For trees, 1/125 ha plots were used and 1/1250 ha plots were used for seedlings/saplings. Plots were reexamined in 2012.

Several variables were collected including location, altitude, slope, aspect, tree species and size, and percentage live crown. Trees were classified by condition (live, recent dead, or old dead). Recent dead trees had all their bark and at least some fine branches. Tree mortality rates per plot were calculated based on the number that died between 2008/2009 and 2012. A dominant or codominant tree at each plot was cored to determine approximate age, recent 10-year radial growth, and used to estimate site index. Eleven climate variables were derived using the Spline Model of Climate (Rehfeldt 2006) based on mean stand coordinates.

Damage agents were recorded for each live and recent dead aspen tree, and were summarized as percentage of stems per plot. For most damage agents, any amount of damage was recorded. Foliage diseases and defoliating insects were only recorded if they damaged $\geq 25\%$ of the crown. Animal and other physical damages to trees were only recorded if they damaged $\geq 25\%$ of the crown or stem. Root diseases were assessed differently than other damage agent given the potential damage to live trees and the time required to assess root systems for signs of disease.

Root disease pathogens were assessed as present or not found in 3 approximately 1/3 ha plots per stand, centered at tree plot centers. White mottled rot (*Ganoderma applanatum*) was confirmed by examining 10 recent dead trees (30 per stand) for the presence of conks. If recent dead trees were not present, trees with root disease symptoms were examined next and then healthy trees. *Armillaria* spp. were confirmed by examining three recent dead trees per plot (9 per stand) for the presence of mycelial fans and/or rhizomorphs. If found, root disease was confirmed by examining two live aspen trees per plot (6 per stand) for the presence of mycelial fans. Trees with root disease symptoms were preferentially selected.

Regeneration (seedling and sapling) was classified by species and host condition (living or dead); and were 30 cm high and < 7.6 cm DBH. Damage agents were tallied for both live and dead aspen regeneration.

Statistical analyses. Stand means were calculated from the three plots per stand. Data was analyzed by linear regression, using SAS release 9.4; for all tests $\alpha = 0.05$.

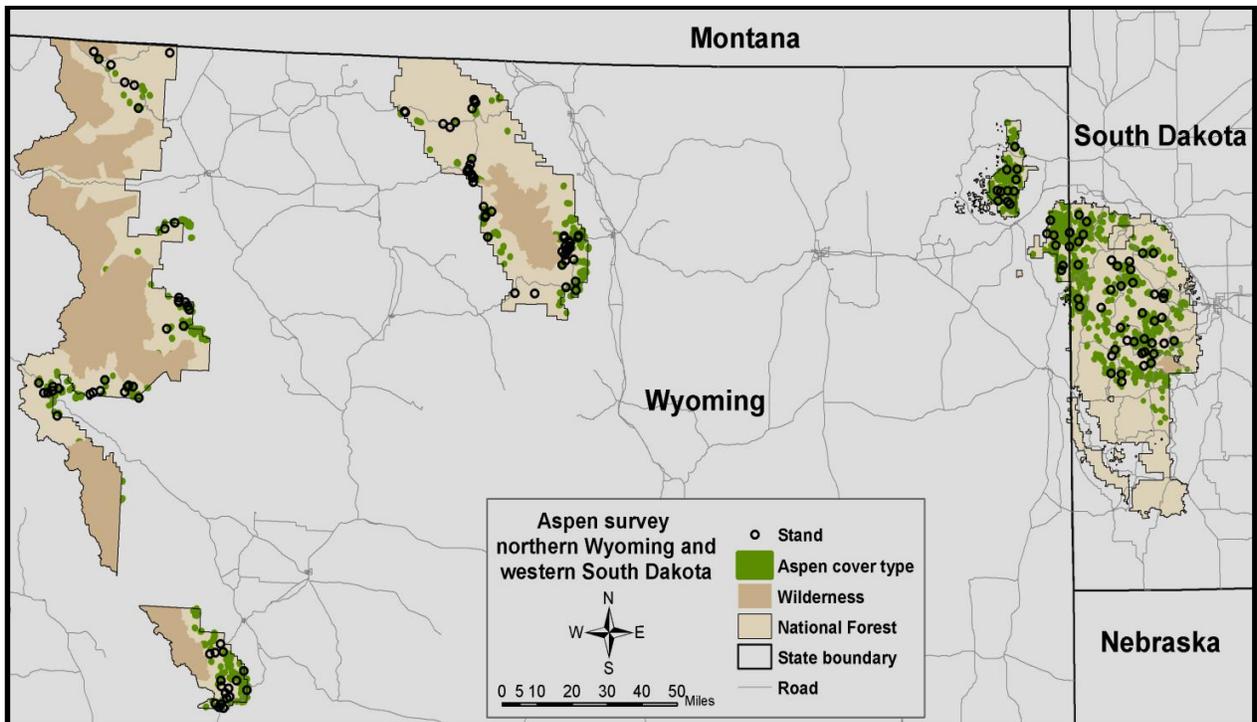


Figure 1. Location of stands and aspen cover type. Fifty, 45, and 60 stands were sampled in the Shoshone, Bighorn, and Black Hills National Forests, respectively.

Results:

Thirty three damage agents were found in trees with up to eight in an individual tree. However, most of these agents were found in <1% of the trees, thus were not contributing to significant mortality at the forest level. Only eight damage agents were common in the forests (**Table 1**). Mortality increased significantly with increasing levels of four of the common damage agents; however *R*-square values were small.

Thirty damage agents were found in regeneration with as many as seven in individual regeneration plots. Only three groups of damage agents were common in the forests (**Table 2**). None of the agents increased significantly with decreasing numbers of regeneration stems.

Mean aspen tree mortality rate was 6.2%/year (+/- 5.2% SD) and mean regeneration was 7708 stems/ha. White mottled rot (*G. applanatum*) was found in all forests (13% of stands). Mortality increased significantly with increasing levels of white mottled rot in both the Bighorn and Black Hills, but not the Shoshone, however the *R*-square value was very low (0.10). *Armillaria* spp. were common in all forests (55% of stands) and were found causing root disease in some stands, but the correlation with tree mortality was not significant.

Other variables with a low but significant correlation with 2012 aspen tree mortality were percentage live crown, 10-yr growth, and recent and old dead trees the first year (*R*-square = 0.75, 0.10, 0.26, and 0.12, respectively). Live crown and 10-yr growth were negatively correlated; recent and old dead trees the first year were positively correlated. The correlations were not significant between tree mortality and any other variable. None of the variables had a significant correlation with number of regeneration stems.

Table 1. Percentage of trees with damage agents^a in three National Forests

Damage agent	Shoshone (%)	Bighorn (%)	Black Hills (%)
Cytospora canker (<i>Cytospora</i> spp.)	51 (0.50) ^b	41 (0.30)	50 (0.38)
Sooty-bark canker (<i>Encoelia pruinosa</i>)	22 (0.23)	10 (0.14)	39 (0.51)
Aspen trunk rot (<i>Phellinus tremulae</i>)	9	7	28
Bronze poplar borer (<i>Agrilus liragus</i>)	17 (0.32)	3	18 (0.30)
Poplar borer (<i>Saperda calcarata</i>)	17	7	17
Animal debarking	5	20	1
Black canker (<i>Ceratocystis fimbriata</i>)	7	4	9
Cryptosphaeria canker (<i>Cryptosphaeria lignyota</i>)	7 (0.32)	2 (0.10)	4 (0.16)
All other agents ^c	15	10	8

^a Damage agents that could be rapidly assessed in individual trees. Root diseases were assessed by plot.

^b Numbers in brackets represent *R*-square values for relationships that were significant based on linear regression.

^c Twenty five damage agents found in <1% of the trees individually.

Table 2. Percentage of seedling and sapling stems with damage agents in three National Forests

Damage agent	Shoshone (%)	Bighorn (%)	Black Hills (%)
Animal browsing	10	27	32
Cankers	15	13	24
Foliage diseases	1	5	4
All other agents ^a	3	5	4

^a Twenty seven damage agents found in <1% of the trees individually.

Summary and Conclusion:

Most of the stands in the three forests are healthy. For trees, 75% of the stands had ≤8% mortality. Aspen mortality rates around 8% could be considered normal in mature stands, and most stands were close to the average (6%). Overall, aspen regeneration was common and relatively dense across the forests. For regeneration, 80% of the stands had ≥2500 stems/acre; many of the remaining 20% had high levels of competing vegetation (63%) and/or were very dense stands (53%). Regeneration levels of 2500 stems/acre could be considered high.

Many damage agents were observed, but only five agents were correlated with tree mortality (**Fig. 2**). The cankers and borer causing tree mortality in the three forests are associated with aspen mortality throughout the region (Dudley 2011; Guyon and Hoffman 2011; Fairweather et al. 2008; Marchetti et al. 2011; Steed and Kearns 2010).

Sooty-bark canker is likely the most damaging agent, but *Cytospora* canker, bronze poplar borer, and white mottled rot (*G. applanatum*) are contributing significantly to mortality. Sooty bark canker has been suggested as a major mortality agent in previous studies (Hinds 1985). Trees found with this disease during the first sampling year were often dead in 2012. Although *Cytospora* canker was more common and is causing mortality, the majority of the cankers were small, already healed, or likely to heal. Although not observed in all stands, white mottled rot was an important mortality agent of mature aspen, consistent with earlier findings (Ross 1976; Hinds 1985). Bronze poplar borer was a significant mortality agent in two of the forests, and is a common pest of stressed aspen (Furniss and Carolin 1977). Other damage agents did cause tree mortality, but their correlations with mortality were not significant or they were infrequent. Consequently, damage agent aggressiveness, tendency with mortality, and frequency should all be considered when determining potential impacts on forest health at the landscape level.

Although none of the damage agents were significantly correlated with the number of regeneration stems, browsing is often cited as a factor preventing successful aspen regeneration (Bartos and Campbell 1998; Kay 1997; Romme et al. 1995). Jacobi and Shepperd (1991) also found canker diseases to be a factor associated with low regeneration in clearcuts. Both of these damage agents were common on regeneration in the northern Rocky Mountain Region. In these forests, there was a high frequency of cankers in aspen regeneration. Most were associated with browsing damage. Thus, browsing damage is a likely entry point for the damaging canker pathogens.

The relationships (*R*-square) between mortality and damage agents were low. The low *R*-square values are likely due to: 1) multiple damage agents contributing to mortality, 2) different frequencies of damage agents in different stands, 3) low overall mortality in the forests, and 4) varying environmental conditions among stands (though no significant correlation was found for climate variables). Damage to live trees was included when tallying damage agents, which did not contribute to 2012 mortality. Therefore strong correlations were not expected. Still, five agents were significantly correlated with mortality, suggesting they contribute to mortality in the northern Rocky Mountain Region.

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Figure 2. The four most common damage agents correlated with tree mortality were *Cytospora* canker (*Cytospora* spp.), sooty-bark canker (*Encoelia pruinosa*), bronze poplar borer (*Agrilus liragus*), and white mottled rot (*Ganoderma applanatum*) from left to right, respectively.