Aspen Mortality near the Southwestern Edge of its Range

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Introduction & Problem

Mortality of trembling aspen (*Populus tremuloides* Michx.) has rapidly increased over the past 15 years in western North America. This sudden and rapid loss of aspen represents a disproportionally high loss in the diversity of conifer-dominated western forests.

The factors responsible for rapid declines in aspen often fit the conceptual framework of a decline disease (Frey et al., 2004), where mortality is caused by the interacting effects of predisposing, inciting, and contributing factors.

Arizona contains the southwestern edge of contiguous aspen habitat in North America, and the forested regions of the state have experienced recent aspen damage over thousands of hectares (Fairweather et al., 2008). In this study, we characterized aspen mortality on the southern Kaibab National Forest, where the greatest amount of recent aspen damage has occurred (USDA, 2009).

Objectives

- Determine how predisposing site and stand factors and contributing damaging agents relate to aspen mortality near the southwestern edge of its range.

Methods & Analysis

Study area

Williams Ranger District of the Kaibab National Forest in northern Arizona, where aspen forest type occupies only ~970 ha in ~330 stands. Small, discontinuous stands occur in pine-oak type, while larger stands occur in mixed conifer (Fig. 1).

Stand and site selection

We stratified aspen stands by elevation, aspect, and slope. Stratified random sampling weighted by area was used to select field sites proportional to the occurrence of strata within aspen's distribution. We installed 48 sites in the summers of 2009 and 2010.

Tree ring sampling and dating

A sub-sample of 2-7 aspen cores per site were crossdated (Stokes and Smiley, 1968), then assembled into age distribution.

Analyses

Simple linear regression was used to evaluate univariate relationships. Stepwise-forward multiple linear regression was used to develop models for aspen mortality. Paired, two-tailed t-tests were used to compare live versus dead aspen density.

Table 1. Stand structure factors of 48 study sites on the Williams Ranger District, Kaibab National Forest, Arizona. Size classes = overstory (≥10.1 cm dbh); sapling (≥5.1 cm but <10.1 cm dbh); tall sucker (<5.1 cm dbh); and short sucker (<1.37 m tall).

Factor	Mean	S.D.
Overstory		
Aspen mortality (%)	50	25
Aspen mortality by BA (%)[a]	44	28
Aspen crown dieback >33% (%)	48	26
Conifer by BA (%)	67	26
Sites with live aspen (%)	98	--
Aspen age (years)	110	41
Sapling		
Aspen mortality (%)	82	29
Live aspen density[b]	25	56
Conifer (%)	85	30
Sites with live aspen (%)	25	--
Tall sucker		
Aspen mortality (%)	72	41
Live aspen density	145	529
Conifer (%)	89	28
Sites with live aspen (%)	21	--
Short sucker		
Aspen mortality (%)	16	19
Live aspen density	2550	3280
Conifer (%)	52	35
Sites with live aspen (%)	90	--

[a] BA = basal area (m^2 ha^{-1})
[b] Density = stems ha^{-1}

Table 2. Univariate relationships between aspen mortality and explanatory factors. The "sign" of a significant relationship (α = 0.05) was positive (+) or negative (-).

Factor	Sign	R^2	P-value
Overstory mortality by BA (%)[a]			
Elevation (m)	-	0.24	0.0004 *
Forest type [0-1][b]	-	0.10	0.0275 *
Conifer by BA (%)	+	0.43	<0.0001 *
Canker diseases (%)	+	0.18	0.0028 *
Wood-boring insects (%)	+	0.56	<0.0001 *
Sapling mortality (%)			
Conifer (%)	+	0.20	0.0187 *
Canker diseases (%)	+	0.16	0.0341 *
Tall sucker mortality (%)			
Elevation (m)	-	0.22	0.0201 *
Slope (%)	-	0.60	<0.0001 *
Heat load[c]	+	0.21	0.0238 *
Forest type (0-1)	-	0.17	0.0441 *
Canker diseases (%)	+	0.27	0.0091 *
Short sucker mortality (%)[d]			
Slope (%)	-	0.16	0.0182 *
Conifer (%)	+	0.16	0.0167 *
Animal damages (%)	+	0.15	0.0198 *

[a] BA = basal area (m^2 ha^{-1})
[b] 0 = pine-oak, 1 = mixed conifer
[c] Calculated; McCune and Keon (2002)
[d] Log (y)

Table 3. Multiple regression models for aspen mortality. All factors were significant at α = 0.05.

Factor	t-ratio	P-value
Overstory mortality by BA (%)[a,b]		
Forest type [0-1][c]	-2.43	0.0192*
Conifer by BA (%)	2.87	0.0063*
Canker diseases (%)	5.75	<0.0001*
Wood-boring insects (%)	5.77	<0.0001*
Log (short sucker mortality) (%)[d]		
Slope (%)	-2.21	0.0344*
Conifer (%)	2.24	0.0327*
Animal damages (%)	2.62	0.0136*

[a] n = 48; R^2 = 78% ($F_{4,43}$ = 41.47, P <0.0001)
[b] BA = basal area (m^2 ha^{-1})
[c] 0 = pine-oak, 1 = mixed conifer
[d] n = 35; R^2 = 34% ($F_{3,31}$ = 6.80, P = 0.0012)

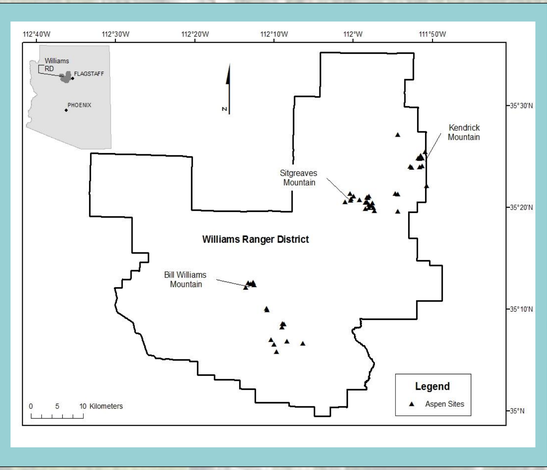

Figure 1. Locations of 48 aspen study sites on the Williams Ranger District, Kaibab National Forest, Arizona.

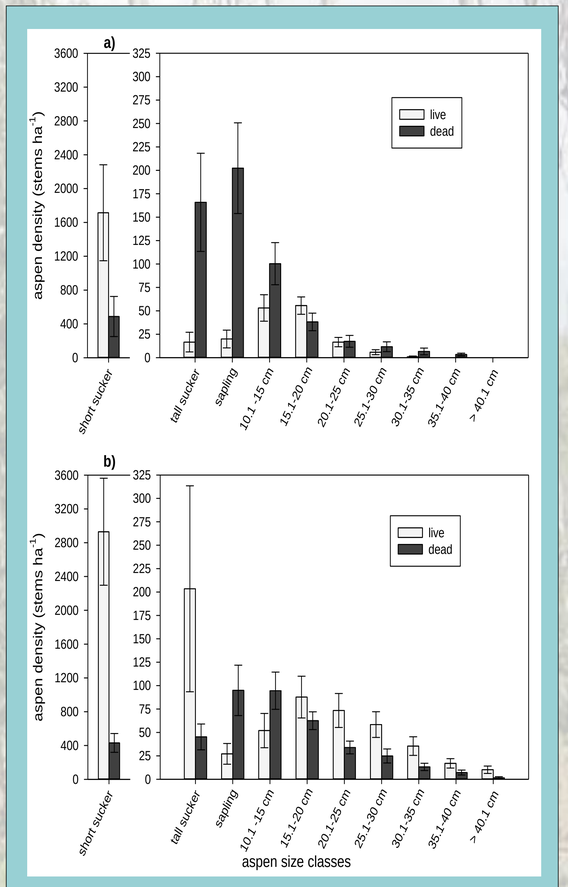

Figure 2. Size-density distribution of live and dead aspen stems by forest type: a) pine-oak type (n = 15) and b) mixed conifer type (n = 33). Error bars are +/- standard error.

Results

Structure

- high aspen mortality across all size classes except short suckers (Table 1)
- at least moderate crown dieback in roughly half of living overstory aspen stems
- all size classes had >50% conifer
- most sites did not have live sapling or tall sucker aspen
- stand age ranged 41-177 yrs, half were >100 yrs
- more mortality in pine-oak type (Fig. 2)
- lack of aspen recruitment into the overstory.

Simple Regression

- Percent conifer was significant across all size classes except tall suckers (Table 2)
- stand and damaging agent factors were more important in describing variation in overstory mortality than site factors
- wood-boring insects (*Agrilus liragus* and *Dicerca tenebrica*) were the most significant overstory factor
- significant site and stand relationships varied by regeneration size classes
- canker diseases (*Valsa sordida*) were significant for saplings and tall suckers, while animal damages (browsing) were significant for short suckers.

Multiple Regression

- overstory mortality decreased from pine-oak to mixed conifer and increased with increasing percent conifer and higher incidences of canker diseases and wood-boring insects (Table 3)
- short sucker mortality decreased with increasing slope and increased with increasing percent conifer and higher incidence of short sucker animal damages
- no significant models could be produced for saplings or tall suckers because of small sample size.

Discussion & Conclusions

Our results document extensive crown dieback and mortality of aspen in the pine-oak and mixed conifer forests of the Williams Ranger District, Kaibab National Forest. Predisposing stand factors were more important than site factors because aspen occurred on relatively similar sites. Contributing factors were insects and pathogens that tend to invade and kill stressed trees. Our results are similar to rapid declines reported elsewhere (Fairweather et al., 2008; Worrall, 2010). We suspect that the inciting factors were the droughts that occurred during the growing seasons from 1996 to 2007, especially the severe droughts in 2000 and 2002 (Breshears et al., 2005).

Future Work

Develop age structure for the full sample and analyze patterns in aspen annual growth rings and climate.

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