



Aspen Decline on the Coconino National Forest

Mary Lou Fairweather¹, Brian W. Geils² and Mike Manthei³

Abstract

An accelerated decline of aspen occurred across the Coconino National Forest, in northern Arizona, following a frost event in June 1999, and a long-term drought that included an extremely dry and warm period from 2001 through 2002, and bouts of defoliation by the western tent caterpillar in 2004, 2005, and 2007. From 2003 to 2007, we monitored aspen mortality and regeneration, and measured associated stand and site variables on randomly-selected sites of the Coconino National Forest where aerial survey had detected dieback or decline. Year of death was observed or estimated since 2000. Xerophytic forests sustained greater mortality than mesophytic forests. Aspen on low-elevation xeric sites (<7500 ft) sustained 95% mortality since 2000. Mid-elevation sites (7500–8500 ft) lost 61% of aspen stems during the same time period; mortality is expected to continue in these sites because some remaining trees have 70 to 90% crown dieback. Less aspen mortality (16%) was observed on more mesic high-elevation sites (>8500 ft). Low-elevation sites are located on northerly aspects while mid- and high-elevation sites are located on various aspects. Overall, diameter distributions showed mortality was not skewed to any particular size class, however, trees with diameters >9 inches generally took longer to die than smaller size classes. Several insects and pathogens were associated with aspen mortality but appeared to be acting as secondary agents on stressed trees. Although aspen ramet production occurred to some degree on all sites with the death of mature trees, aspen sprouts were nearly nonexistent by the summer of 2007 due to browsing by elk and deer. None of the sites studied are grazed currently by domestic cattle. Widespread mortality of mature aspen trees, chronic browsing by ungulates, and advanced conifer reproduction is expected to result in rapid vegetation change of many ecologically unique and important sites.

Introduction

Severe dieback and mortality of aspen occurred over the past several years on the Coconino National Forest (NF) due to impacts from drought, frost, and insect defoliation (USDA Forest Service 2006). In 1999 frost

damage occurred on approximately 6,000 acres following a severe June snowstorm (Fairweather 1999, USDA Forest Service 2000), resulting in early defoliation and death of twigs and stems. Damage was greatest in aspen clones whose leaves were succulent and expanding. Although many afflicted clones produced new leaves, damage was severe enough to be detected during aerial detection surveys later that summer (USDA Forest Service 2000). Greater crown dieback and mortality of aspen occurred in 2002 and 2003, during one of the driest periods on record. Aerial surveyors mapped over 5,000 acres of aspen dieback and mortality in 2002 and 2003 (USDA Forest Service 2003, USDA Forest Service 2004). Defoliation by the western tent caterpillar (*Malacosoma californicum*) was observed in 2004, 2005, and 2007, including areas previously affected by drought and/or frost.

This paper presents the results of a monitoring project in which permanent plots were established to track dieback and mortality of aspen on the Coconino NF. The objectives were to describe the timing and distribution of mortality, assess regeneration, and identify stand and site factors related to dieback and mortality of aspen.

Methods

Areas with aspen crown dieback and mortality were randomly selected from the 2002 Arizona Zone-Forest Health Protection Office aerial detection survey. A series of 1/20th acre permanent plots were established on a grid of one plot for every five acres of an aspen delineated site. Plot data included slope, aspect, and elevation. Trees >5 inches diameter at breast height (dbh) were recorded. Information included species, status (live or dead), dbh, height, crown rating, and presence and severity of damage agents.

In: McWilliams, M.G. comp. 2008. Proceedings of the 55th Western International Forest Disease Work Conference; 2007 October 15-19; Sedona, AZ. Salem, OR: Oregon Department of Forestry.

¹Mary Lou Fairweather is a plant pathologist with the USDA Forest Service, Arizona Zone of Forest Health Protection, Flagstaff AZ. mfairweather@fs.fed.us.

²Brian W. Geils is a research plant pathologist with Rocky Mountain Research Station, Flagstaff AZ. bgeils@fs.fed.us.

³Mike Manthei is forest silviculturist with the Coconino National Forest, Flagstaff AZ.

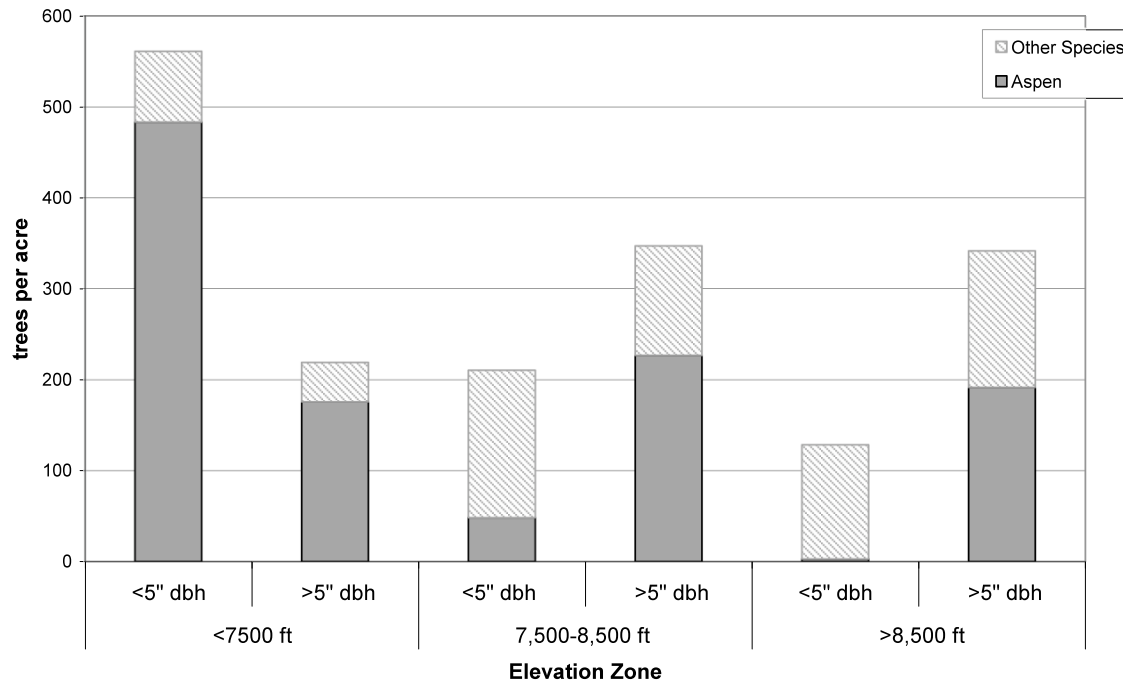


Figure 1—Stand composition in trees per acre, 2000.

During plot establishment, estimated year of death was determined by presence of leaves, buds, flowers, fine branches, and bark condition. Categories for year of death included current year, 1 year, 2 years, and more than 2 years.

In order to quantify branch dieback and decreases in leaf area of a live tree, percent live crown remaining was estimated for all live aspen. For example, a rating of 10% was given to a tree that had 90% recent branch mortality. All live aspen trees >5 inches dbh were tagged. Damage agents included borers, defoliators, canker fungi, decay fungi and ungulate damage. Tree heights were measured on the first two live aspen in each plot. Regeneration on 1/100th acre subplots was recorded by species, size, status, and damaging agent. Plots were reexamined through 2007.

Results

Site conditions were reconstructed to the year 2000 based on year-of-death estimates for 83 plots, and categorized into three elevational zones: <7500 ft, 7500–8500 ft, and >8500 ft (Figures 1 and 2). Aspen

was the dominant forest species in affected stands across all elevational zones; compared to other tree species, aspen trees (>5 inches dbh) were the most numerous and comprised the greatest volume. For all tree species combined, basal area increased with increasing elevation, ranging from approximately 110 to 240 ft²/ac. However, aspen basal area was nearly constant at 100 ft²/ac, regardless of elevation. Due to advanced decay, stem age could not be determined for most sampled trees; but those that were readable showed stand age to be about 100 years. Associate tree species at low-elevation sites include ponderosa pine and Gambel oak, at mid-elevation sites were ponderosa pine, Gambel oak, southwestern white pine, and Douglas fir, and at high-elevation sites were ponderosa pine, Douglas fir, white pine, white fir, subalpine fir, and spruce. Aspen was dominant in the understory only in low-elevation sites. There were 58 aspen snags per acre in low-elevation sites in 2000, while mid- and high-elevation sites had 15 and 14 snags per acre, respectively. Low-elevation, aspen sites were mostly restricted to northerly aspects; at higher elevations aspen sites occurred on all aspects.

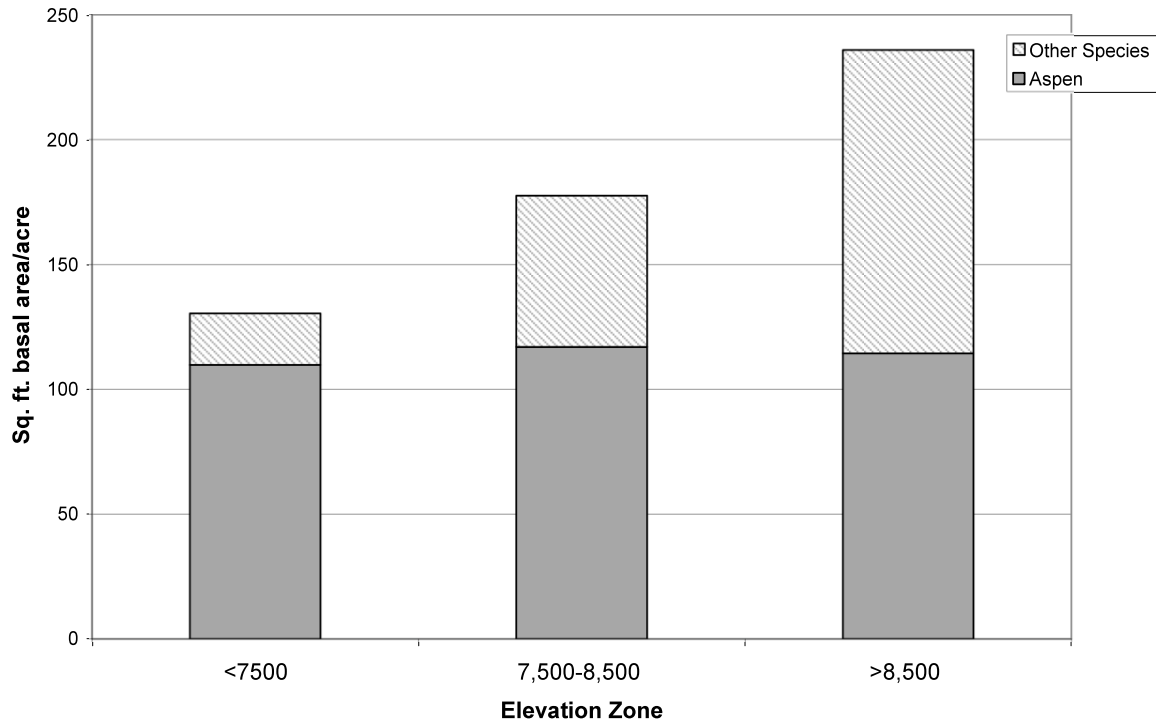


Figure 2—Stand composition in square ft. of basal area per acre, for live trees >5" dbh, 2000.

Stand composition changed considerably in affected stands since 2000 (Figure 3 and 4), particularly at low-elevation sites where aspen was completely removed from several stands and nearly eliminated from most others. Affected sites <7500 ft elevation experienced on average >95% aspen mortality by the summer of 2007; sites 7500–8500 ft had 61% mortality; and 16% mortality was observed >8500 ft (Figure 5). The annual mortality rate was near 20% from 2001 through 2004 in the low-elevation sites (Figure 6).

In general, mortality within each elevation zone was distributed among tree-size classes with little striking trends (Figure 7). At lower elevations, a higher percentage of saplings (<5 inches dbh) died than larger trees, while a lower percentage of mid-sized trees (5–9 inches dbh) died than smaller or larger trees. In mid-elevation sites, a different pattern was observed; percent mortality decreased by size class but with only a difference of 20% between the smallest and largest size classes. At the high-elevation sites, the difference in percent mortality between mid-sized trees and the larger trees was only about 10%; on these sites, there were only 3 saplings/ac to begin with and none died.

Overall, there was a linear relationship between crown rating and mortality, and no threshold crown rating determined likelihood of survival. Larger trees (>9 inch dbh) took longer to die than smaller trees. Trees with severe branch dieback and/or reduced foliage often produced enough green foliage to be rated as “live” rather than “dead”, even though death was probably imminent. Where low crown ratings were associated with western tent caterpillar activity, in the absence of prior decline, trees survived and the crown rating improved after insect populations declined. However, defoliation likely hastened death of many, previously stressed trees.

Several insects and pathogens were associated with aspen mortality but appeared to be acting as secondary agents on stressed trees (see Hinds 1985, Jones et al 1985). These agents include *Cytospora* canker (*Valsa sordida*), bronze poplar borer (*Agilus liragus*), aspen bark beetles (*Trypophloeus populi* and *Procryphalus mucronatus*), poplar borer (*Scperda calcarata*) and a clearwing moth (*Paranthrene robinae*). *Cytospora* canker was present to some degree on all sites, but the occurrence of other agents varied by location.

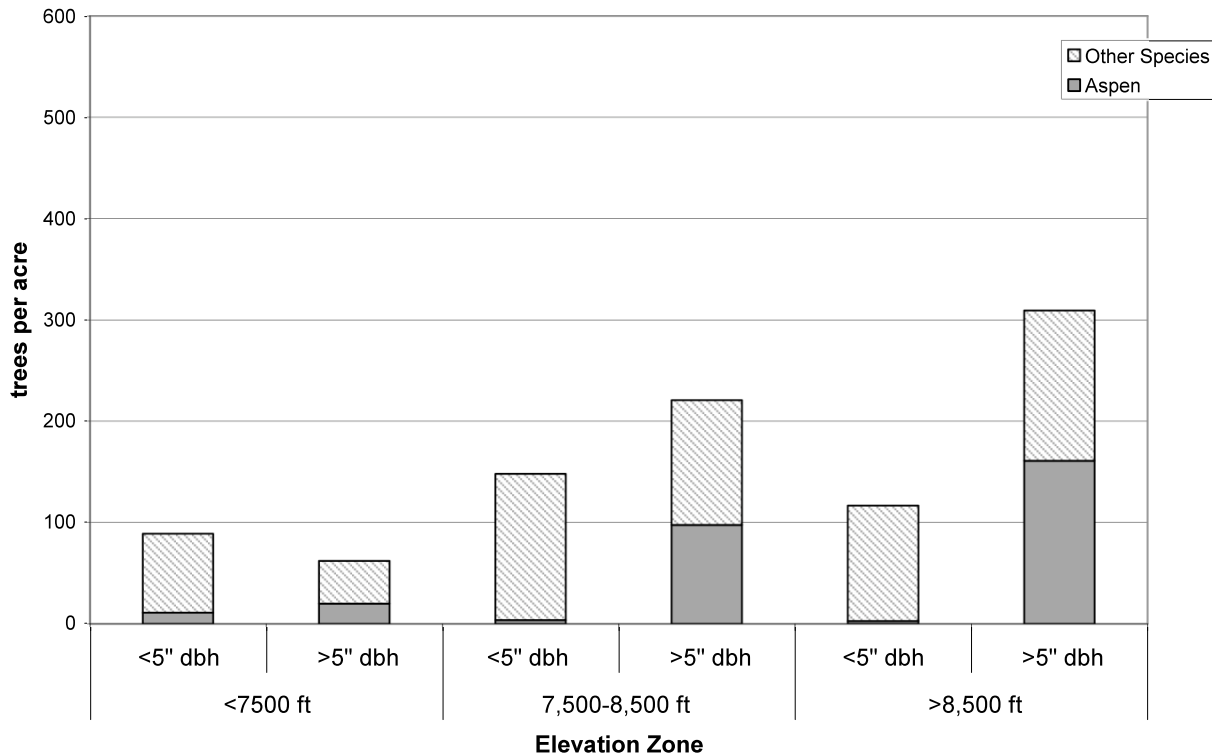


Figure 3—Stand composition in trees per acre in sites affected by aspen decline, 2007.

Western tent caterpillars severely defoliated aspen throughout northern Arizona in 2004, 2005, and 2007 and were the most consistent biotic agent contributing to aspen decline.

Reproduction by suckering was highest within the first few years of plot establishment and monitoring (Figure 8), reaching an average of 1,000 stems/ac on low- and high-elevation sites. Site averages varied from as low as 10 stems/ac to over 4,000 stems/ac. Nearly all ramets were browsed on an annual basis across the Forest and none exceeded a height of 2 ft.

Discussion

Aspen mortality observed over the past 7 years on the Coconino NF resembled a decline syndrome (Manion 1991) with various but identifiable predisposing, inciting, and contributing factors including site, climate, weather, insects, and pathogens. We detected substantial mortality as early as 2000 (58 snags in low-elevation sites), likely resulting from a frost event in 1999 (Fairweather 1999) and the stress of long-term drought beginning

in 1996. Mortality rates stayed high through the more severe drought years of 2002–2003 and the western tent caterpillar activity of 2004 to 2005. By 2007, affected sites <7500 ft elevation sustained 95% mortality; 61% mortality was observed at 7500–8500 ft; and 16% mortality in sites >8500 ft. This is much greater than damage reported by others. Gitlin et al (2006) found approximately 15% mortality associated with the 2002–2003 drought in a random sample of affected and non-affected aspen stands >7500 ft on the San Francisco Peaks, Coconino NF. Our greater mortality levels are likely due to several factors: observing cumulative mortality since 2000; including sites <7500 ft; monitoring sites detected to be in decline based on aerial detection surveys rather than including non-impacted sites; and capturing the slower mortality rates of larger trees by surveying sites through the summer of 2007. A recent study in southern Colorado reported 32% mortality from 2004 to 2006 (Worrall et al 2007), which was linked to a particularly dry, hot spring and early summer of 2005. Similar to the Coconino NF, aspen mortality was found to be inversely related to elevation.

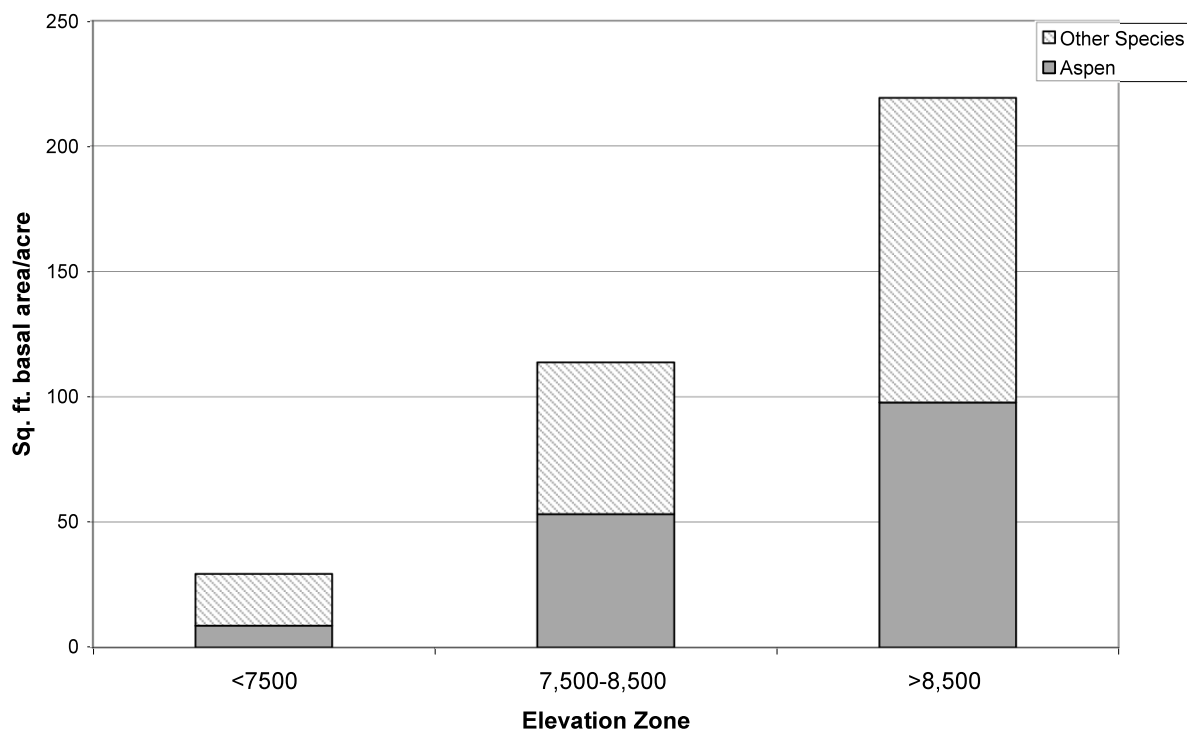


Figure 4—Stand composition in square ft. of basal area per acre, trees >5" dbh, in sites affected by aspen decline, 2007.

Aspen was not the only species affected by the severe drought of 2002–2003, as hundreds of thousands of acres of lower elevation piñon pine and ponderosa pine perished across northern Arizona; however, a different pattern of mortality occurred between conifer and aspen).

Stressed conifers either survived the drought or died as the result of bark beetle attack. The full impacts of the drought (and frost event) on aspen took much longer, 2–3 years, to materialize. A similar phenomenon was observed in Alberta and Saskatchewan, Canada, following the severe drought of 2001–2003 (Hogg et al 2006).

The decline of aspen reported here is distinct from the successional replacement of aspen by conifers. A decrease in the area dominated by aspen due to succession was addressed in Amendment 11 of the Coconino NF Forest Plan (USDA Forest Service 1996), but this recent and widespread mortality increases concern for the future of aspen on the Forest. The structural change in aspen forests is believed to be the result of: 1) altered fire regimes and livestock

grazing since European settlement which promoted succession to conifer forests (USDA Forest Service 1994, Dahms and Geils 1997, Cocks et al. 2005); and 2) heavy browsing of aspen suckers by large ungulates, especially Rocky Mountain elk (Shepherd and Fairweather 1994, Rolf 2001). Merriam (1890) describes the flora and fauna of the San Francisco Peaks, including distributions and correlations with climate, elevation and aspect. He characterizes aspen as common in forests above 8200 ft but descending “considerably” on mesic aspects and forming large groves of tall stems where fire had removed the conifers. Among the identified mammals, he lists the black-tailed deer as abundant, the mountain sheep as present; but gives no mention to any elk. Cocks et al (2005) report a 456% increase in basal area since 1876 in aspen forests on the San Francisco Peaks. The density of aspen in these forests decreased while conifer species increased. They report little evidence of aspen recruitment since the 1940s. Although some land managers think future large-scale fires will increase aspen regeneration across the landscape, it appears browsing impacts will limit any success.

Aspen typically sprout profusely following disturbance (upwards of 30,000 stems/ac), but the number of suckers produced by a clone maybe related to the levels of carbohydrate reserves and hormonal growth promoters in the roots (DeByle et al 1985). The substantial sprouting observed in the early stages of decline in some aspen sites in this study may have allowed for the production of a young stand of trees. Unfortunately, browsing by elk and deer (none of these sites were grazed by cattle), eliminated the potential.

Young aspen trees typically grow an average of 3 to 6 ft the first 2 years and a total of 9 to 15 ft in 5 years (Shepperd 1993 and Miller 1996), but in the 4 years since plot installation not a single sprout has grown over 2 ft in height. A similar scenario has occurred following disturbance by harvest or fire in aspen type across the Forest, where regeneration of aspen by suckering has not been successful unless well protected by fencing (Shepperd and Fairweather 1994, Rolf 2001, Bailey and Whitham 2002 and 2003). Aspen regeneration outside of protective fences is nearly non-existent—typically restricted to rocky areas or in steep terrain where ungulate activity is minimal.

Browsing of aspen regeneration from large ungulates, particularly elk has been a major concern since the 1960s when regeneration treatments failed because aspen sprouts were consumed in spite of attempts at protection with fencing suitable for cattle (Rolf 2001). Since the mid-1980s, forest managers have built 6½ ft tall fences around aspen regeneration to prevent elk browsing; but these fences are expensive to install and maintain. Although originally intended as a temporary measure until the trees obtained sufficient height to escape browse, it was soon realized that fences need to remain for a longer period (Shepperd and Fairweather 1994, Bailey and Whitham 2002). Rocky Mountain elk are the primary browser, and were introduced into the region after Merriam’s elk was extirpated in the early 1900s. Although Merriam’s elk were mainly

limited to the White Mountains of eastern Arizona, and the Mogollon and Sacramento Mountains of New Mexico, Rocky Mountain elk are now present in great abundance throughout Arizona (Truett 1996, Heffelfinger et al 2002). Although Merriam’s was considered a subspecies of Rocky Mountain elk, recent research suggests it may be a different species altogether (Heffelfinger et al 2002).

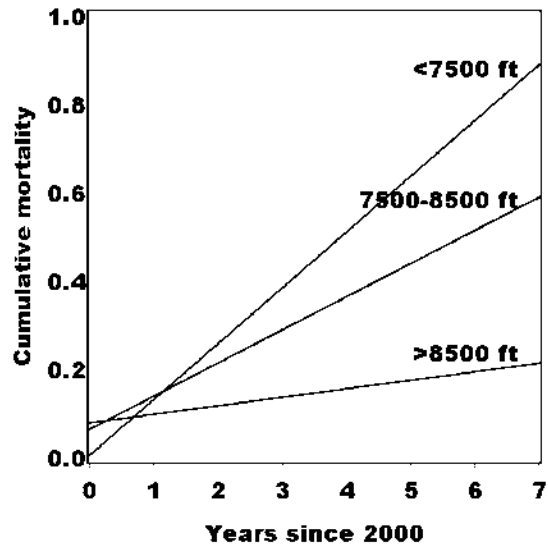


Figure 5—Cumulative mortality of aspen stems >5" dbh from 2000 to 2007 by elevation zone.

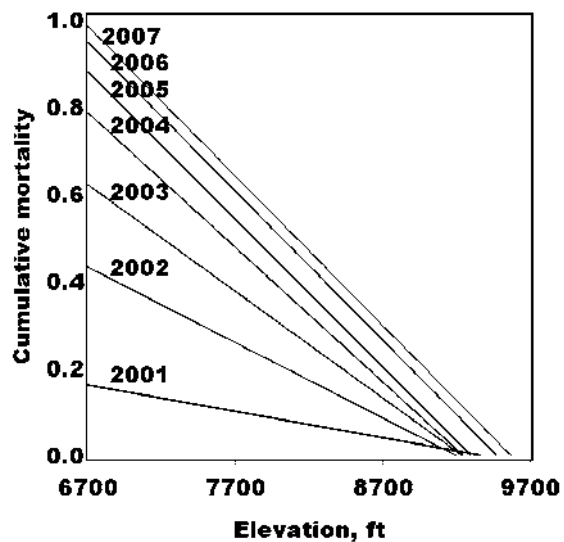


Figure 6—Cumulative mortality of aspen stems >5" dbh from 2001 to 2007 by elevation.

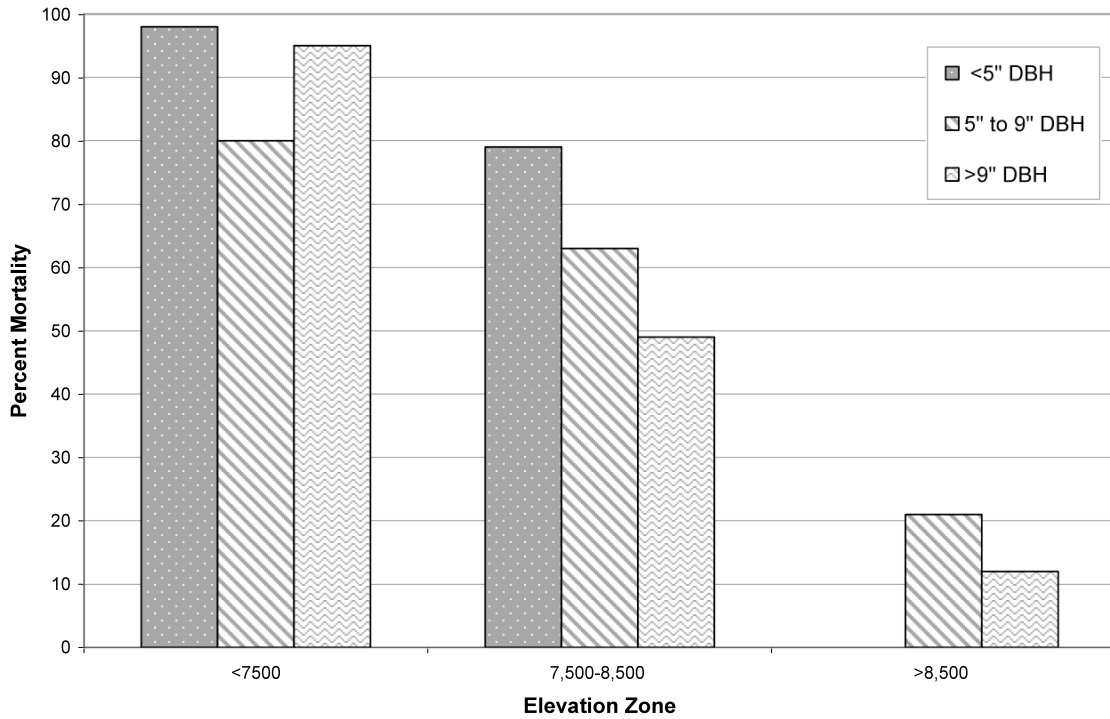


Figure 7. Cumulative percent mortality of aspen stems by size class and elevation zone, 2007.

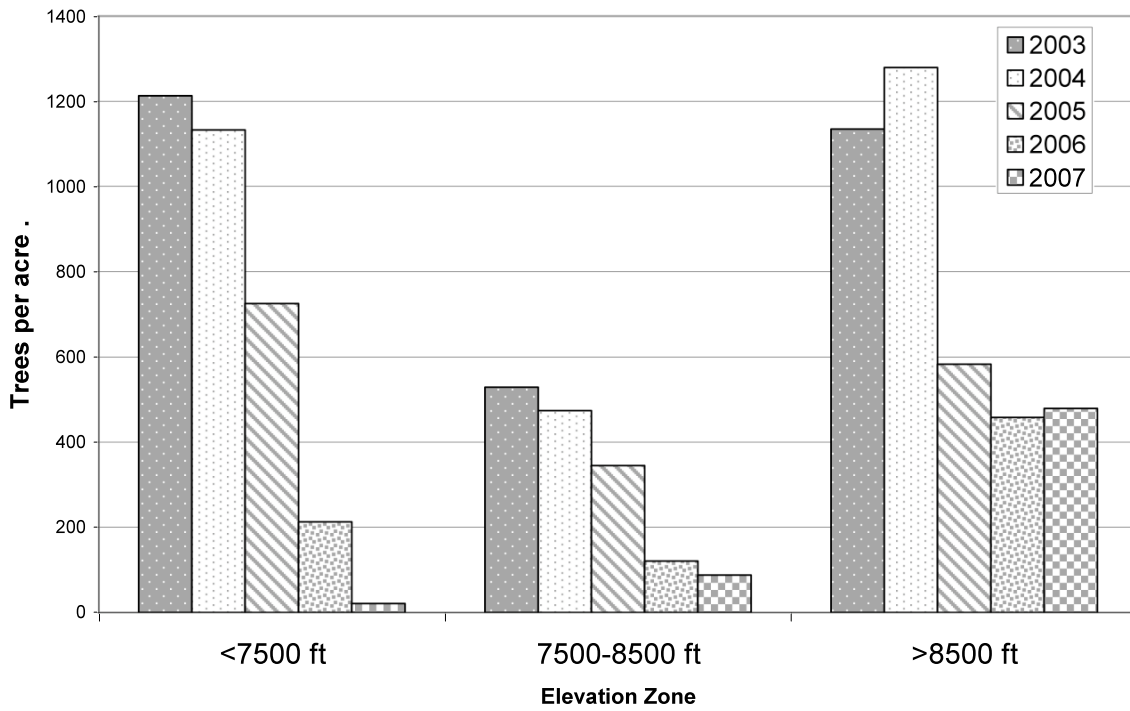


Figure 8—Aspen regeneration (stems less than 4.5 ft. high) by year and elevation zone.

Elk damage aspen in three ways: they browse new shoots, rub flexible saplings with antlers and gnaw or bark trees for phloem. The browsing of shoots is so prolific that it is rare to see these ramets survive more than a couple of years, and that only happens when the mature tree is still living. Barking and rubbing has been positively correlated to damage by secondary pathogenic fungi causing stem cankers and decay (DeByle 1985, Hinds 1985) that play a role in the death of trees. Stem decay fungi contribute to stem instability as the trees grow (Hinds 1985).

Permanent exclusion fences are required to allow for successful reproduction following silvicultural treatments or fire (Rolf 2001, Bailey and Whitham 2003, Fairweather et al. 2006). Coupled with the inability of aspen regeneration to survive browsing, the mortality events are resulting in virtually complete loss of aspen in many stands.

The mortality of aspen on the Coconino NF over a period of several years is similar to that observed recently in other parts of North America (Frey et al 2005, Worrall et al 2007), which were also linked to severe drought and defoliation. In Colorado, Worrall et al (2007) named the phenomena as Sudden Aspen Decline (SAD) to distinguish it from the gradual succession of aspen to conifer forests. A decline disease is defined as an interaction of three or more sets of abiotic and biotic factors to produce a gradual general deterioration often ending in tree death (Manion 1991). Although there are many possible factors, none can be shown to produce decline individually. The factors involved in declines are grouped into predisposing, inciting and contributing categories. Predisposing factors alter the trees' ability to withstand or respond to injury-inducing agents. In this case, affected stands were composed of mature aspen that were succeeding to conifer with little chance of recruitment. Inciting factors are short-term biotic or abiotic events that often result in branch dieback. Examples of incitants here include late spring frost, drought, and defoliators. Contributing factors are environmental factors or biotic agents that are able to act more aggressively on stressed trees. On the Coconino NF, canker fungi, wood boring insects, and bark beetles were some of the contributing factors associated with the death of

mature trees. Elk are contributing to the decline of aspen on the Forest, as they are not allowing newly sprouted ramets to grow and mature. Although death of large numbers of mature trees is a good thing that is required for proper development of the next generation of aspen, we observed no chance of survival of new sprouts.

Conclusion

Rapid and abundant mortality of aspen occurred on more xeric, aspen-dominated sites of the Coconino NF in response to several abiotic and biotic factors. Low and mid-elevation sites sustained 95% and 61% mortality, respectively. Affects of aspect were related to elevation; low-elevation sites are located on northerly aspects and aspect was variable for sites above 7500 ft. Larger trees took longer to die than smaller size classes. Although regeneration occurred following the death of overstory trees on some sites, successful regeneration of aspen is doubtful due to widespread browsing of young trees by elk and deer. Extensive mortality of mature aspen trees, chronic browsing by ungulates, and advanced conifer reproduction is expected to result in rapid vegetation change of many ecologically unique and important sites.

Acknowledgements

Funding for this project was provided in part by US Forest Service, Forest Health Protection, Forest Health Monitoring, Evaluation and Monitoring Program. The authors appreciate the assistance of Kelly Williams, Brian Howell, John Anhold, Alison Honahni, Melissa Fischer, Wes Sprinkle, Joleen Rosson-Atencio, Kevin Johnson, David Melville, Brandon Melville, and Bobbe Fitzgibbon.

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Proceedings of the 55th Annual Western International Forest Disease Work Conference

Radisson Poco Diablo Resort
Sedona, Arizona
October 15 to 19, 2007

Compiled by:

Michael McWilliams

Oregon Department of Forestry
Insect and Disease Section
Salem, Oregon

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Patsy Palacios

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