**2013 FINAL REPORT**

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# APPLIED SILVICULTURAL ASSESSMENT: QUAKING ASPEN AFFECTED BY SUDDEN ASPEN DECLINE IN SOUTHWESTERN COLORADO

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**ROCKY MOUNTAIN RESEARCH STATION**
**ROCKY MOUNTAIN REGION, FOREST HEALTH PROTECTION**
**GRAND MESA, UNCOMPAHGRE, GUNNISON NF**

**IN COOPERATION WITH**

**COLORADO STATE UNIVERSITY**

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**ABSTRACT**

This report presents results from a research study conducted by Colorado State University under agreement with the U.S. Forest Service. This effort was an experimental assessment of using clearfell harvesting on an operational level to initiate a suckering response in forests affected by Sudden Aspen Decline (SAD). Nine aspen stands with various levels of mortality attributed to SAD were commercially harvested and aspen sucker response monitored for three subsequent growing seasons. Stands with the heaviest mortality exhibited the poorest subsequent sucker response. Stands with over half their original aspen stocking alive at the time of harvest produced levels of suckering which appear adequate for successful regeneration. Paired untreated stands exhibited very little sucker response, regardless of the initial overstory mortality level. These results indicate that management intervention can successfully regenerate aspen forests affected by SAD, provided treatment occurs before the majority of the aspen are dead.

Key words:, *Populus tremuloides*, Aspen Management, Sudden Aspen Decline, Applied Silviculture

## INTRODUCTION

Aspen (*Populus tremuloides* Michx.) is the most widely distributed tree species in North America (Shepperd et al., 2006), occurring from Alaska to New England and throughout mountainous areas of the west into Mexico. Since 2000, over 3.2 million ha of aspen decline have been mapped in North America (Worrall et al., 2013), including large areas of aspen decline in Ontario, Minnesota, Alberta, Saskatchewan, Utah , Arizona, and Colorado.

In Colorado, U.S. Forest Service Forest Health Management aerial surveys reported a rapid increase in aspen crown dieback and stem mortality. State wide aerial surveys between 2003 and 2008 estimate 220,000 ha (17% of the aspen cover type in the state) have been affected (Worrall et al., 2010), which has been corroborated by local field observations. Site specific data from the Mancos-Dolores Ranger District, San Juan National Forest showed a three to five-fold increase in aspen stem mortality from 2003 to 2006 (Worrall et al., 2008).

Sudden aspen decline is characterized by mortality of a majority of the mature overstory in an affected forest (Bartos and Shepperd, 2010) and the almost total lack of new aspen suckering following the overstory mortality. SAD is thought to have been initiated by severe drought and high temperatures that occurred in the early 2000's (Worrall et al., 2013) exacerbated by the following group of biotic agents: Cytospora stem canker (usually caused by the fungus *Valsa sordida* Nitschke), aspen bark beetles (*Trypophloeus populi* Hopkins, and *Procryphalus mucronatus* LeConte), poplar borer (*Saperda calcarata* Say), and bronze poplar borer (*Agrilus liragus* Barter and Brown), all of which typically affect stressed trees (Worrall et al., 2007). The rapid mortality of mature trees associated with SAD differs from other types of aspen declines attributed to fire exclusion and the associated succession of conifer species, and extreme browsing pressure from large ungulates like deer and elk (Romme et al., 1995; Kay, 1997; Bartos, 2001; Ripple and Larsen, 2000; Kulakowski et al., 2004; Kaye et al., 2005; Smith and Smith, 2005). Furthermore, SAD events may be the precursor of future changes in the location and distribution of aspen due to climate change (Rehfeldt et al., 2009).

The lack of new regeneration is a critical aspect of SAD. Healthy aspen typically regenerate by profuse root suckering following a disturbance that kills or removes the overstory. Sucker densities exceeding 10,000 stems $ha^{-1}$ are not uncommon following clearfell harvesting (Shepperd 1993). In contrast, uncut, intact aspen stands typically have about 2,500 suckers $ha^{-1}$ in southwestern Colorado (Crouch, 1983). In stands with heavy mortality attributed to SAD, Worrall et al. (2007) found sucker densities at or below the range typical of uncut stands, indicating that there had been little to no suckering response to the overstory mortality.

Additional work by Worrall et al. (2010) found aspen root mortality to be associated with SAD. The lack of a healthy root system raises questions regarding the ability of SAD-impacted stands to successfully regenerate. Complete root system mortality in stands affected by SAD, could result in entire aspen forests being permanently lost in a short amount of time. However, if SAD affected aspen could be stimulated to sucker before all overstory stems and their associated root systems are lost, it might be possible to establish new aspen forests on SAD affected sites.

In 2008, we initiated a research project in SAD-affected forests in western Colorado to determine if management intervention could result in adequate levels of suckering to regenerate fully stocked aspen stands. Specifically, we tested clearfell harvesting in stands affected with varying levels of overstory mortality attributed to SAD. Our goal was to identify a threshold level of overstory mortality where SAD-affected aspen stands could still be successfully regenerated and to develop management guidelines to prioritize aspen stands for treatment in future climate-induced mortality events.

## METHODS

### Study Area

The study area is located within the Terror Creek and Alder Creek watersheds of the Paonia Ranger District on the Gunnison National Forest in southwestern Colorado. This area was selected because lower portions of the watershed are dominated by pure aspen stands (no conifer species present) that have varying levels of SAD. This area also has had a 20+ year history of successful aspen regeneration following clearfell harvesting of commercial forest products, indicating that stand and site conditions were fully capable of regenerating new aspen forests prior to the occurrence of SAD.

### Study Design

Stands proposed for treatment were stratified into three categories of crown dieback and mortality (0-20%, 20-60% and 60 %+ ). Dieback categories were established by determining the percentage of the overstory basal area in each stand that had died or was in decline (thin crowns, small chlorotic leaves) at the initiation of the study in 2008. This was determined from a prism cruise tally of overstory trees (those larger than 13 cm in diameter at 1.4 m breast height [dbh]). Stands with existing understories (3000+ stems $ha^{-1}$ <12.9cm dbh) were not selected for treatment. The rationale behind this approach was to eliminate stands that exhibited a suckering response prior to the SAD outbreak in order to focus our efforts on determining whether non-regenerating aspen that are in decline can be stimulated to produce new suckers by a clearfell harvest of the remaining overstory.

A replicated paired study design was used. Three replications were chosen for each crown dieback category, which required a total of nine candidate stands. Replications One and Two were on southerly aspects and Replication Three was on a northeasterly aspect. All stands were between 2680 and 2840 m elevation. Selected stands within each replicated block were a minimum of ten acres, were located on similar soil types and were accessible for commercial harvest (Figure 1). Stands were assumed to contain a majority of a single aspen genotype, as identified by phenotypic characteristics, but recognizing that most aspen stands actually contain more than one genotype (Long and Mock, 2012). Stands selected for treatment were split, with half randomly selected for harvest treatment while the other remained untreated. This allowed testing of harvest treatment effects across the three crown dieback categories. Pairing minimized site and genetic (clonal) variation in treatment response, as variation in those factors was assumed to remain constant within a selected stand. After harvest treatments were randomly assigned, a minimum two ha monitoring area was delineated in each un-harvested and harvested treatment.

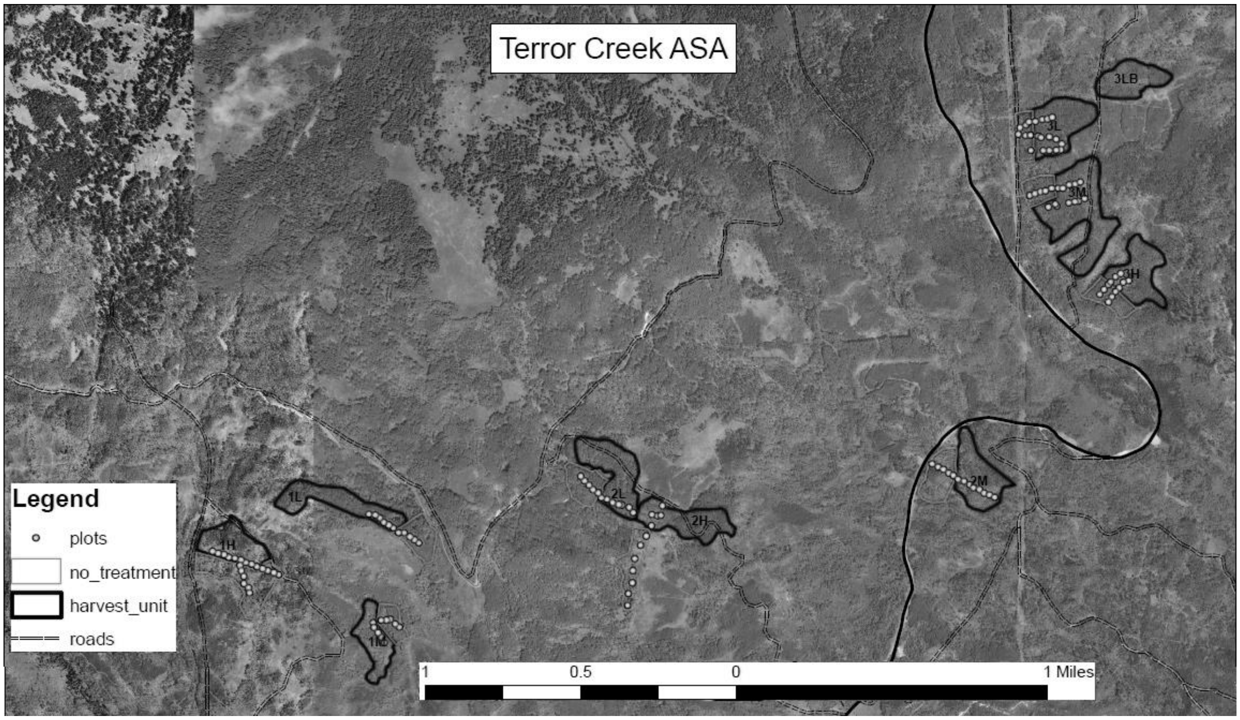


**Figure 1** – Stands within the Terror Creek Aspen Assessment Area (ASA) selected for this study. Numbers 1-3 = Replication, L = low (<30%), M = medium (30-60%) and H = high (60%+) overstory mortality present in 2008.

### Pre-harvest Data Collection

Within each monitoring area a minimum of five variable radius inventory plots were established using a basal area factor (BAF) = 4.59 $m^2$ $ha^{-1}$ (yielding an average of 4-10 trees/point). Plots were established by randomly locating an initial point near the edge of a monitoring area (walk 30 m into the stand, select a random distance and bearing from computer generated tables and navigate to the first point), with the remaining points placed on a systematic manner within the monitoring area on compass bearings at measured distances apart to insure complete coverage of the monitoring area. All plots were permanently staked and their positions recorded with a hand-held GPS receiver to facilitate relocation for post-harvest re-measurement.

The following data was collected for each "in" tree greater than 13 cm dbh: tree species, tree status (live, dead, or declining), dbh, height, % recent crown loss (on sampled stems), presence/absence of known aspen damaging agents. For dead trees, the estimated time since death (≤ 5 years [bark remaining], or > 5 years [no bark]) were recorded. Trees were measured beginning at true north and proceeding clockwise around each plot.

A 2.07 m fixed radius (13.5 $m^2$) plot was located at the center of each BAF plot to sample trees less than 13 cm inches dbh. Trees in these plots were tallied by tree status, size class and occurrence of damage agents that appeared to be affecting tree vigor. To further sample regeneration response, an additional ten 13.5 $m^2$ fixed radius plots were established midway between each pre-treatment overstory plot (with an additional plot located beyond the last pre-treatment plot) and marked as described above.

### Harvest Treatment

Designated units were clearfell harvested under a commercial timber sale contract. All units were winter logged using tracked feller-bunchers to cut trees and rubber-tire grapple skidders to move trees to landings. The over-snow logging left no evidence of skid trails or soil disturbance in any of the units following logging. Although it was intended that all treatment units be harvested in the same year, operational and economic conditions required two years to complete treatment of all units. Units in Replication 1 were harvested during the winter of 2008-2009 and Replications 2 and 3 were harvested the winter of 2009-2010.

### Post-harvest Field Data

All plots in the treated and untreated areas were re-sampled following the first full growing season after harvest and annually through 2012. All plots in harvested treatments were re-measured following criteria for the fixed-radius understory plots. Both overstory and understory plots were re-measured annually in un-harvested treatments to monitor overstory mortality and any subsequent suckering. All data was analyzed using SAS/STAT® software[1]

## RESULTS

### Treatment Response

While some new aspen suckers were evident in non-harvested control units, the harvest treatment produced greater numbers of suckers (Fig. 2).

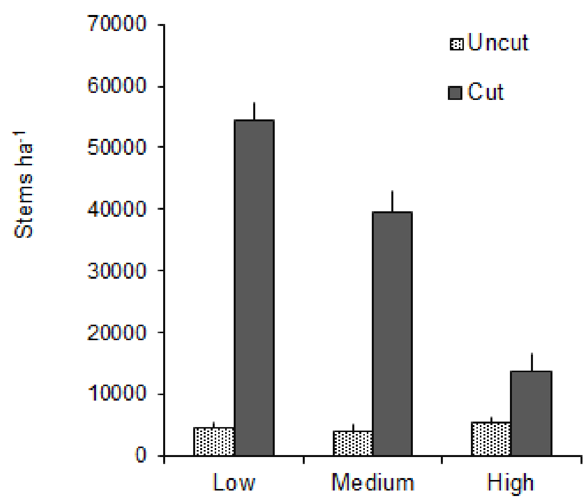


**Figure 2** – Average aspen sucker live stem density per hectare in 2012 by treatment, and overstory mortality class, with 95%CI bars.

One-way Analysis of Variance (Using proc GLM, with model livstm=level trt level*trt.) revealed that the Cut and Uncut treatments were significantly different in all 3 mortality levels ($p = 0.0001$). Sucker density declined with increasing levels of overstory in the original forest in Cut treatments ($p = 0.0001$), but the low sucker densities in the Uncut treatments did not vary significantly among overstory mortality levels.

Differences between replications were also apparent (Fig. 3). Cut units with Low and moderate overstory mortality levels exhibited markedly greater suckering than Uncut units in all reps, but the response was quite variable. High overstory mortality units on south and east facing aspects in Reps 1 and 2 had the poorest suckering response among the cut units. However, the high overstory mortality unit located on a north aspect in Rep 3 exhibited a better, but more variable suckering response following harvest (Fig. 3).

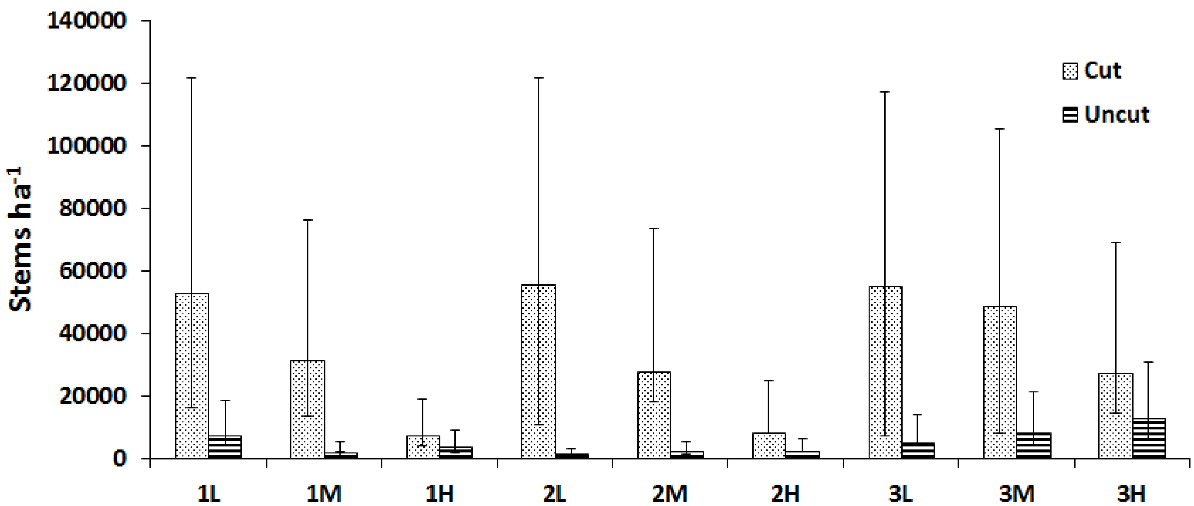


**Figure 3** – Average aspen suckers live stem density per hectare in 2012 by treatment, replication, and overstory mortality class, with 95% CI bars.

Average 2012 sucker density in cut units was linearly related to the average live overstory basal area present in 2009 in those units prior to harvest (Fig. 4). These 2009 basal area values differ somewhat from the overstory mortality level assigned to the units in 2008, which were based on the portion of original stand basal area that had died at that point in time.

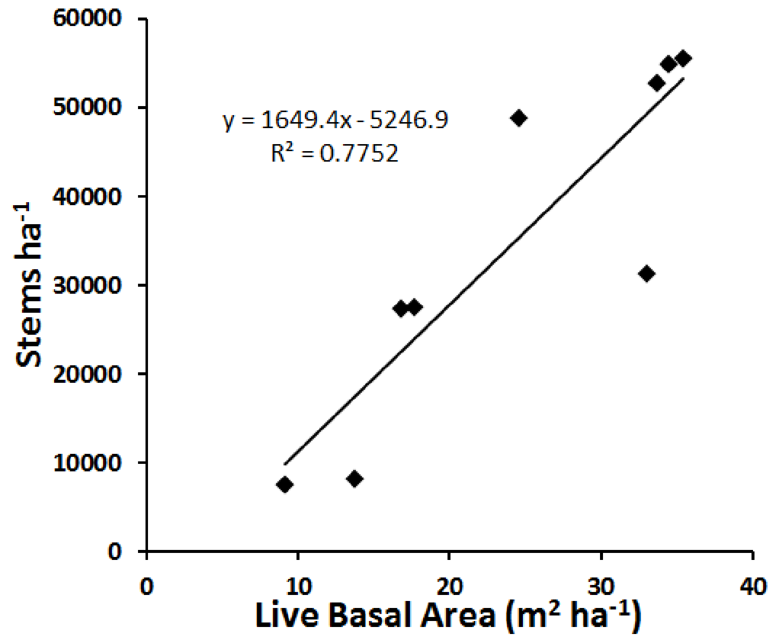


**Figure 4** – Relationship between live pre-harvest (2009) basal area and subsequent (2012) sucker production for the nine harvested units in the study.

### Sucker Damage

A number of damages to aspen suckers were observed in this study. Browsing (of terminal leaders), trampling by livestock (basal wound) and poor form (lack of a well-defined terminal leader)were the most commonly observed sucker damages in 2010 (Fig. 5). Browsing and basal wounds were less prevalent in 2011, but suckers with poor form increased, possibly as a result of the effects of the earlier browsing and basal wound damage. Several damages increased in 2012 including insect damage, dead leaders, disease (primarily foliar), and browsing. Mortality of stems from past damage also increased. In spite of these damages, the majority of aspen suckers sampled in 2012 appeared to be healthy and growing well (Fig. 5).

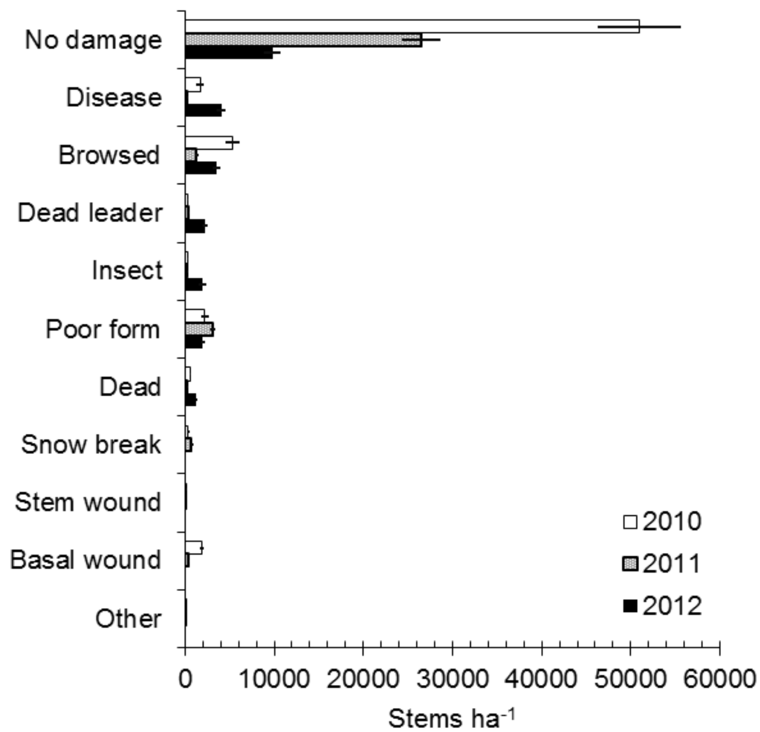


**Figure 5** – Average number of damaged suckers in all units by identifiable agent and year. Damage was coded if it was likely to affect the future growth and vigor of a tree.

### Sucker Height

The average heights of the tallest suckers found on each plot in 2012 ranged from 0.5 m to 2.75 m (Fig. 6). Suckers in Cut treatments were taller than those in Uncut treatments, with the exception of Replication 2, where high overstory mortality levels had the tallest suckers.

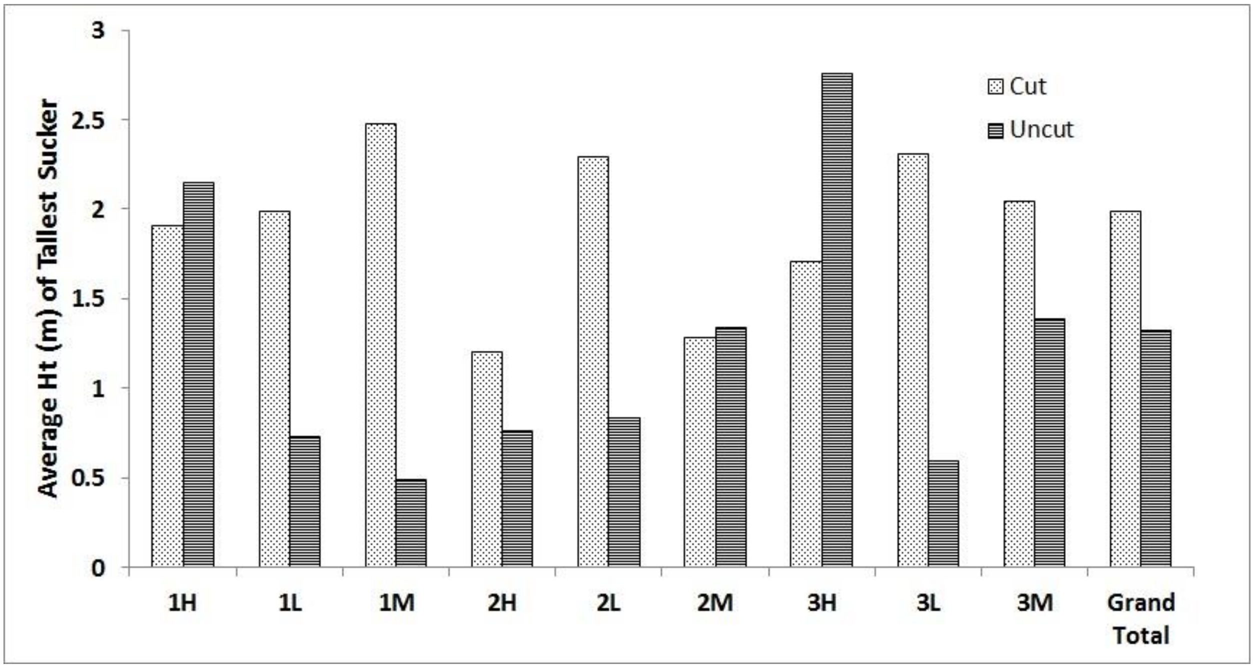


**Figure 6** – Average height of the tallest suckers on plots by Treatment, Replication and Overstory mortality level.

### Overstory Changes

A couple of important trends were noted in the remaining overstory in the un-harvested control plots as the study has progressed. Live stocking in the heavy mortality units has continued to decline over time (Fig. 7). However, mortality and trees exhibiting symptoms of fading in units with low and medium levels of SAD peaked in 2009 with some recovery apparent in 2010 and 2011 (Fig. 6). Dead aspen in the study area did not persist very long as standing snags. Regardless of the level of mortality, dead trees quickly lost their bark and fell down, usually within two years (Fig. 8)

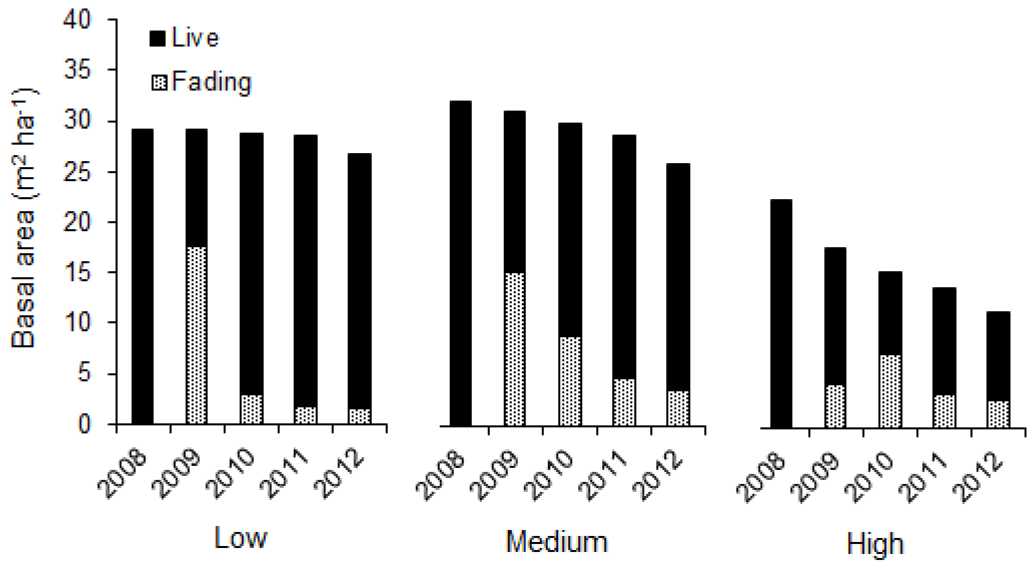


**Figure 7** – Basal area/acre in live vs. fading trees on uncut units by year and overstory mortality level.

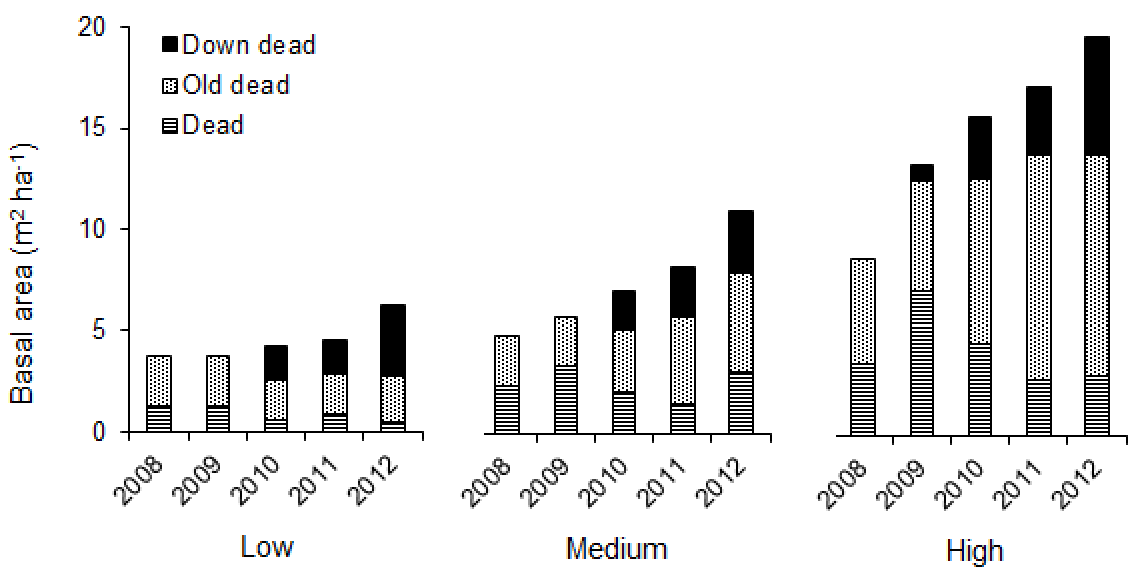


**Figure 8** – Basal area/acre in dead trees by condition category on uncut units by year and overstory mortality level.

## DISCUSSION

Based on the suckering response that we observed in this study it is apparent that aspen forests affected by SAD can be successfully regenerated by clearfell harvesting of overstory trees, provided such harvest is implemented before complete overstory mortality occurs. The best post-harvest suckering response in this study occurred in stands with low and moderate overstory mortality containing at least 15 $m^2 ha^{-1}$ live overstory basal area prior to harvest. These post-harvest sucker densities fall within the range of those previously reported for commercially harvested aspen in Colorado (Shepperd, 1993) and the heights of the tallest suckers are above the 2 m threshold needed to be out of reach of browsing domestic livestock (Shepperd et al., 2006).

The differential suckering response between units on southerly aspects in Replication 1 and those in Replication 3 on northerly aspects agrees with data previously reported by Worrall et al. (2008, 2010) The increased root mortality reported on southerly aspects in these studies could partially account for the differences in suckering that we observed here. The assumption that higher levels of overstory mortality would accompany higher levels of root mortality would also agree with the sucker responses that we observed here.

The types of damages we observed on aspen suckers in this study are similar to those reported in by Hinds and Shepperd (1987) in a survey of regenerated aspen in Colorado. However we found browsing to be more prevalent than what they observed in similar-aged stands. This might be due to heavier livestock use in our study area, or to somewhat lower sucker densities in our study that resulted in heavier utilization of suckers by livestock. The heights of the tallest suckers and the relatively low overall incidence of suckers with poor form in our study indicates that units with good stocking could be expected to grow into fully stocked aspen forests.

Yearly remeasurement of uncut overstory plots indicated that overstory mortality peaked in 2009, with some recovery of fading trees apparent. This is consistent with state-wide 2010 and 2011 aerial survey data in Colorado. One observation that did surprise us was how rapidly dead trees were deteriorating and falling. Many trees that we had recorded as live, but fading at the beginning of the study had fallen to the ground by 2012. This rapid progression means that SAD-killed standing trees are not available to cavity nesters and as perches for birds of prey for very long. It also means that SAD-affected forests will have heavy surface fuel loadings soon after the trees die.

## MANAGEMENT IMPLICATIONS

Although the current SAD outbreak in the western United States appears to be over, the results of this study will have implications in future aspen decline events that are likely to accompany climate change. In order to respond to these future events, managers will have to react quickly in order to implement clearfell treatments before too much mortality has occurred. We were fortunate to have found an area where SAD had not yet peaked and to have teamed with the Grand Mesa Uncompahgre Gunnison National Forest Staff in quickly planning and executing a commercial timber sale contract. A similar timely and efficient response will require fast tracking of environmental analysis, silviculture prescription development, sale layout, and contract advertisement, award and execution. Although this is potentially a daunting task, our experience demonstrates that it is possible for managers to successfully regenerate aspen forests affected by sudden aspen decline.

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**LITERATURE CITED**

Bartos, D.L., 2001. Landscape dynamics of aspen and conifer forest. pp. 5-14 in *Proc. of the Symposium on Sustaining Aspen in Western Landscapes, 13-15 June 2000; Grand Junction, CO.* Shepperd, W.D., Binkley, D., Bartos, D.L., Stohlgren, T.J., and L.G. Eskew, (eds.). USDA For. Serv. Proc. RMRS-P-18. 460p.

Bartos, D.L., and W.D. Shepperd, comps. 2010. *The aspen mortality summit; December 18 and 19, 2006; Salt Lake City, UT.* USDA For.Serv. Proc.RMRS-P-60WWW. 21 p. Available online at http://www.fs.fed.us/rm/pubs/rmrs_p060.pdf; last accessed June 24, 2013.

Hinds, T.E. and W.D. Shepperd. 1987. *Aspen sucker damage and defect in Colorado clearcut areas.* USDA For. Serv. Res. Pap. RM-278. 12p.

Kay, C.E. 1997. Is aspen doomed? *J. of For*. 95: 4-11.

Kaye, M.W., Binkley, D., and T.J. Stohlgren. 2005. Effects of conifers and elk browsing on quaking aspen forest in the central Rocky Mountains, USA. *Ecol. Appl.* 15, 1284-1295.

Kulakowski, D., Veblen, T.T., and S. Drinkwater. 2004. The persistence of quaking aspen (*Populus tremuloides* Michx.) in the Grand Mesa area Colorado. *Ecol. Appl.* 14, 1603-1614.

Long, J.N. and K. Mock. 2012. Changing perspectives on regeneration ecology and genetic diversity in western quaking aspen: implications for silviculture. *Can. J. For. Res.* 42: 2011–2021.

Rehfeldt, G.E., Ferguson, D.E. and N.L. Crookston. 2009. Aspen, climate, and sudden decline in western USA. *For. Ecol. Mgmt.* 258: 2353–2364.

Ripple, W.J., and E.J. Larsen. 2000. Historic aspen recruitment, elk, and wolves in northern Yellowstone National Park USA. *Biol. Conser.* 95, 361-370.

Romme, W.H., Turner, M.G., Wallace, L.L. and J.S. Walker. 1995. Aspen, elk, and fire in Northern Yellowstone National Park. *Ecology.* 76:2097-2106.

Shepperd, W.D. 1993. *Initial growth, development, and clonal dynamics of regenerated aspen in the Rocky Mountains.* USDA For. Serv. Res. Pap. RM 312. 8p.

Shepperd, W.D., Rogers, P.C., Burton, D., and D.L. Bartos. 2006*. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada.* USDA For. Serv. Gen. Tech. Rep. RMRS-GTR-178. 122p.

Smith, A.E., and F.W. Smith. 2005. Twenty-year change in aspen dominance in pure aspen and mixed aspen/conifer stands on the Uncompahgre Plateau, Colorado, USA. *For. Ecol. Mgmt.* 213, 338-348.

Worrall, J.J., Rehfeldt, G.E., Hamann, A., Hogg, E.H.,Marchetti, S.B., Michaelian, M., and L.K. Gray. 2013. Recent declines of Populus tremuloides in North America linked to climate. *For. Ecol. Mgmt*. 299:35-51.

Worrall, J.J., Marchetti, S.B., Egeland, L., Mask, R.A., Eager, T., and B. Howell. 2010. Effects and etiology of sudden aspen decline in southwestern Colorado, USA. *For.Ecol. Mgmt.* 260:638–648.

Worrall J.J., Egeland L., Eager T., Mask R.A., Johnson E.W., Kemp P.A., and W.D. Shepperd. 2008. Rapid mortality of Populus tremuloides in southwestern Colorado, USA. *For.Ecol. Mgmt.* 255: 686-696.

## ENDNOTES

[1] The data analysis for this paper was generated using SAS software. Copyright, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.