

The Aspen Mortality Summit

December 18 and 19, 2006
Salt Lake City, Utah



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Abstract

The USDA Forest Service Rocky Mountain Research Station sponsored an aspen summit meeting in Salt Lake City, Utah, on December 18 and 19, 2006, to discuss the rapidly increasing mortality of aspen (*Populus tremuloides*) throughout the western United States. Selected scientists, university faculty, and managers from Federal, State, and non-profit agencies with experience working with aspen were invited. Participants were first asked to share information on recent aspen mortality. Subject matter working groups were then asked to determine factors associated with recent aspen mortality, recommend research needs, and organize those needs into testable questions and hypotheses. This report documents their findings, and will serve as a platform for Resource Managers to address the Sudden Aspen Decline issue.

Keywords: aspen, *Populus tremuloides*, Sudden Aspen Decline, aspen mortality, aspen diseases, aspen ecology

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The Aspen Mortality Summit

December 18 And 19, 2006
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Introduction

Quaking aspen (*Populus tremuloides*) are the most widespread tree species throughout North America and is found in the Rocky Mountains from Canada through the United States and into northern Mexico. In the western United States, aspen are most abundant in Colorado and Utah. Across its western range, aspen are a mid-elevation, shade-intolerant species that occupies a wide variety of sites.

Aspen are one of the few broad-leaved hardwood trees found in many western forests. It is a valuable ecological component of many landscapes, occurring in pure forests as well as growing in association with many conifers and other hardwood species. While aspen provides desirable scenic value, the diversity of understory plants that occur in the filtered light under the aspen canopy supply critical wild-life habitat, valuable grazing resources, and protection for soil and water. Aspen provides critical biodiversity where it occurs.

Aspen thrive where regular and frequent disturbance (typically fire in many western landscapes) promotes vegetative regeneration through root suckers that rise from lateral roots that lie within 6 inches of the soil surface (DeByle and Winokur 1985). Aspen sprout profusely (up to 500,000 stems per acre) following a disturbance that kills or removes overstory trees. These high numbers of aspen suckers typically grow very rapidly and self-thin following a negative exponential decay model. Most losses occur in the first few years (Shepperd 1993). Management activities rely on this process to regenerate and restore aspen forests in the western United States. The most current literature pertaining to aspen ecology and management was summarized by Shepperd and others (2006) for the Sierra Nevada area, but it would pertain to most western aspen.

Compared to conifers, aspen are relatively short-lived. The oldest known aspen stems are only about 300 years of age (Shepperd and others 2006). Most aspen were unlikely to live much beyond 100 years under the natural fire regimes that existed prior to settlement of the West. However, due to the absence of fire over the past century, aspen in many areas are older today, have succeeded to mixed conifer/aspen forests, and are gradually losing mature stems as the stands age. Additionally, heavy grazing from both native and wild ungulates has damaged many aspen forests by eliminating or damaging aspen suckers that are produced to replace overstory trees as they age and die (DeByle and Winokur 1985). Techniques to identify and restore aspen in these conditions have been developed (Shepperd and others 2006) and are being put into practice throughout the West.

Issue

Recent reports of dying aspen have caused concern about the future of some aspen forests. This mortality differs from normal aspen vegetative succession (fig. 1) or age-related reduction in stocking. Mature trees are dying at an accelerated rate with little or no new sprouts occurring, indicating that the lateral roots may also be affected (fig. 2). If this is the case, then affected aspen will not be able to produce new suckers and aspen groves that have existed for hundreds and perhaps thousands of years could disappear (fig. 3).

This rapid death of aspen trees seems to begin in epicenters and spread radially through an affected aspen stand. Stands on all topographic positions, moisture regimes, and soil types are affected and the phenomenon has been reported throughout the West, from Arizona into Alberta, Canada. However, specific causes of aspen mortality may differ from area to area and we do not assume, at this point, that a uniform syndrome is involved everywhere. Generally, the rapid mortality can affect one aspen grove, leaving others nearby untouched. Younger age classes and pre-existing sprouts are often not affected to the same extent as mature overstory trees. *Cytospora* cankers, poplar borers, and other damage or stress agents are often associated with die-off epicenters; however, the possibility of a yet-unknown invasive disease or insect cause still exists.



Figure 1. An aspen stand in southeast Idaho where mature aspen trees died but sufficient aspen regeneration exists to restore the stand.



Figure 2. Dying aspen stand in the summer of 1990 on Cedar Mountain in southern Utah (photo by James Bowns, see Ohms 2003).



Figure 3. Same stand as shown in figure 2 during the summer of 2002. Few living trees remain and no regeneration is present (photo by Seth Ohms, see Ohms 2003).

Accelerated rates of aspen mortality have been reported for several years in Utah and Arizona, but only recently have these rates become apparent in Colorado. Aerial surveys, conducted by Forest Health Management, USFS Region 2, indicated that nearly 140,000 acres were affected by aspen decline in Colorado in 2006; and by 2009, that area was in excess of 500,000 acres (see http://www.aspensite.org/SAD/sad_faqs.pdf). The apparent lack of a suckering response in some cases is disturbing, as aspen must sprout back if it is to persist. Mortality of this magnitude raises concerns about the future of aspen forests in some areas and justifies a comprehensive investigation into the phenomenon.

Aspen Summit Meeting

The USDA Forest Service Rocky Mountain Research Station invited selected scientists, university faculty, and managers from Federal, State, and non-profit agencies with experience working on aspen to an aspen summit meeting in Salt Lake City, Utah, on December 18 and 19, 2006. Participants were asked to share information about recent accelerated aspen mortality. Over a dozen participants from throughout the West presented descriptions and examples of dying aspen. Participants were then assigned to the following subject matter groups:

- Forest Health (pathologists, entomologists)
- Forest Ecology
- Wildlife Ecology
- Genetics
- Silviculture/Management

Each group was asked to discuss the following topic outline and make recommendations to address the aspen mortality phenomenon:

- a. Determine factors associated with aspen die-off.
- b. Determine research needs—factors and questions that need to be studied.
- c. Organize research needs into testable questions/hypotheses with budgets.

Broad guidelines were given to the groups; however, no universal protocol was suggested as to how the various groups should report their efforts. Each subject matter group produced outline notes from its discussions and presented them to all participants. Transcribed notes were then used to produce the narrative reports presented below.

Forest Health Working Group Report

Clarification of Terminology

The Forest Health group had concerns about the terminology used in discussing the aspen mortality problem. The four terms of major concern were: decline, die-back, die-off, and succession. These words mean different things to different people. The following definitions exist from a forest health perspective:

- Decline is the result of a forest disease that involves multiple specifically ordered, interchangeable and interacting factors (Manion 1981). The classic definition of a forest decline typically involves predisposing, inciting, and contributing factors (table 1).
- Die-back is a symptom characterized by death of parts of a plant. It is often present as part of forest decline. The term may be appropriate to describe death of stems in a clonal plant, such as aspen, when roots remain alive and are able to sucker.
- Die-off is characterized by mortality of aspen trees with no regeneration to restore the stand.

Table 1—Factors potentially involved in aspen decline.

Predisposing	Inciting	Contributing
Marginal sites	Frost	Animal damage
Old age	Acute drought	Canker fungi
Water tables	Sucker mortality from browsing	Borers
Succession	Defoliation event	Beetles
Genetic mutation		
Increased temperatures		

- Succession (a sequence of changes in a plant community) is a separate process from decline. Forest succession could play a role in causing trees to decline, but forest decline can occur with or without succession.

Commonly recognized definitions are needed so that participants can effectively communicate (for example, the Silviculture/Management Working Group used the terms die, die-off, and die-back in their summary later in this section). The Forest Health Working Group constructed table 1 to illustrate how factors affecting aspen might fit into the pathological definition of decline.

Research Needs

There is a need to identify causal agents in the aspen mortality phenomenon that we are currently observing. To understand this phenomenon and make recommendations, we need to know what agents and stresses are involved, (biotic, abiotic, and site factors) and to distinguish various interactions that are occurring.

Biotic Factors—To fully understand this mortality, specific biotic agents that are involved need to be identified. This may include various diseases, insects, and the impacts of ungulates. Some of these biotic factors will play major roles in aspen mortality while others will be superfluous. The role of ungulates will undoubtedly be a major factor in certain areas of the West. What is the maximum population level of wild ungulates that would allow us to still grow an aspen tree from a sucker? When do domestic livestock negatively impact aspen regeneration and can we develop guidelines for the manager to address this problem?

Abiotic Factors—These factors are probably the most significant contributors to the aspen mortality problem. The most prevalent factor could be drought and its effects on the aspen clone. How does drought impact the aspen overstory as well as the regeneration? Does drought act as a stressor to stimulate regeneration in addition to killing mature trees?

Site Factors—Additionally, the roles of various site factors need to be better understood. Factors such as elevation, topography, and soils are all an integral part of the aspen ecosystem. What part do these factors play and how do they interact in the demise of the aspen? Worrall and others (2008), in a quantitative study of numerous affected aspen sites in western Colorado, stated: “Our data are consistent with a hypothesis that (a) predisposing factors include stand maturation, low density, southern aspects and low elevations; (b) a major inciting factor was the recent, acute drought accompanied by high temperatures, and; (c) contributing factors and proximate agents of mortality are the common biotic agents observed.”

Testable Questions

- What is the magnitude and extent of aspen mortality in the Rocky Mountains?
- What site and biotic factors are associated with aspen mortality in the western United States?
- What meteorological factors are associated with aspen mortality?
- What are the long-term effects of diseases and insects on the aspen ecosystem?

Partners

Long-term research is needed to address various aspects of aspen mortality. This will allow for the development of monitoring protocols and management techniques.

Numerous partners have been identified to contribute to these long-term efforts: the Forest Restoration Institute at CSU, the proposed Center of Excellence (since morphed into the Western Aspen Alliance) at USU, and the U.S. Forest Service FIA/Forest Health Monitoring.

Forest Ecology Working Group Report

Our current knowledge of aspen ecology should be useful in understanding the extensive aspen mortality that is occurring in the Rocky Mountains. However, there is missing information concerning the ecology of aspen that would help decipher this mortality. This group approached their subject in two parts: (1) suspected factors contributing to the aspen mortality, and (2) significant questions that need to be evaluated.

Mortality Factors

A rapid assessment methodology must be developed to define the magnitude and extent of the aspen mortality problem. This method must be useful to resource managers and applicable throughout the western United States. The first step in achieving this goal may be to adapt the model specified in the Silviculture/Management breakout group. In addition, a remote sensing technique could be coupled with the rapid assessment to more precisely determine this mortality and better define the extent or patchy nature of the problem.

Drought has profound impacts on most vegetation systems. Does drought contribute significantly to the current aspen mortality? How does this moisture stress relate to elevation, aspect, etc.? Recently, Worrall and others (2008) found that aspen mortality, or Sudden Aspen Death (SAD), was more prevalent in situations where drought was more pronounced.

Aspen are a sun-loving, disturbance-dependent pioneer species that quickly re-colonizes a site following fire but will eventually be replaced by more shade tolerant conifers if a suitable conifer seed source is available. Given enough time, most aspen will eventually succeed to a conifer dominated system, but a third of the aspen in the West can be considered “climax” or stable for management purposes (Mueggler 1989), since no conifers are currently present. SAD is currently affecting both stable and successional aspen (fig. 4) and will undoubtedly affect the future character of both types of aspen.



Figure 4. Mortality of mature aspen in a mixed conifer/aspen stand on the Gunnison National Forest 2006.

Succession is usually affected by fire. Historically, many sites burned on a regular basis, so conifer regeneration was removed and the stands reverted to being aspen dominated. Because fire has diminished in these systems, aspen trees are becoming mature or over-mature. A stressor such as drought would give rise to the possibility of more incidences of diseases and insects. In addition to fire, numerous other factors can contribute to the rejuvenation of “stable” aspen.

Aspen usually regenerates in the western United States by vegetative means. Seedlings do occur but not on a level that would mean wide expansion of aspen seedlings across the landscape. However, with recent developments in the field of genetics, there is more incidence of regeneration by seeds than was originally thought (see Genetics group report).

In certain areas of the West, there is high incidence of herbivory of aspen by both domestic livestock and wild ungulates. These herbivores can have a severe impact on aspen regeneration and on mature trees in some cases. Some aspen clones/stands have been eliminated from the landscape by excessive ungulate use. What role do ungulates play in the current mortality being observed? Is excessive use by ungulates removing the regeneration from fading mature aspen stands causing some of the mortality we are experiencing?

Quaking aspen in the western United States occurs over a wide amplitude of conditions, from shrub/woodland ecotone on the lower end of its range to tree line at the upper limits. Will the projected climate change have a profound change in aspen distribution? It is believed that climate change might cause aspen to recede from drier sites at the lower extremes of aspen’s occurrence.

Aspen Ecology Questions

- Are aspen roots dying? If so, why? If disease or insects are present, are they girdling the parent tree and causing the root system to die? Are the roots being girdled and causing the roots to die?
- Does herbivory act as a vector for pathogens? Do herbivores transfer pathogens?
- Terminology needs to be clarified. How does decline differ from die-off/die-back? We should use less confusing terms that refer just to aspen mortality. Specific additional words need to be defined, such as stable aspen, clone, stand (grove), succession, and disturbance species.
- Questions attributed to Wayne Shepperd (given in his opening remarks):
 - Is mortality (die-off) a normal event?
 - Are there new diseases or insects present?
 - Can this mortality be predicted by stand age, growth rate, stocking, or other metrics?
 - Is climate involved?
 - How long will this mortality continue?
 - What can (or should) be done about this mortality?
- Is this current phenomenon just a return to historic conditions? If so, should we be concerned about it?
- Is there a means to “age” clones (see Genetics group report)? Does disease become a larger player as trees (clones) age?
- How can we build public support (for treatment) to stop the loss of aspen in critical areas? What are the economics associated with this mortality? What are the impacts on the public as a result of diminished fall colors?
- Should we mimic disturbance effects in order to prevent the loss of some aspen clones from the landscape? Should treated sites be protected from herbivores? What new and innovative techniques could be used to keep herbivores from eliminating aspen regeneration (for example, hinging, slash piling, and harassing animals)?
- What happens after mortality? What are the long-term impacts of this mortality on aspen clones, understory vegetation, soils, scenic and recreation resources, and animal habitats?
- Why are some clones affected while adjacent ones are not? Are some clones genetically predisposed to this mortality or is it just a random occurrence?

Specific Questions and Approximate Costs

- Quantify the magnitude and extent of the mortality issue (\$200K).
- Define the problem and terminology; review and synthesize literature; communicate research needs; and define pertinent questions to be addressed (\$50K).
- Develop a die-off risk assessment and a key (decision tree) to identify stands at risk and which would be most economical to treat (\$50K).
- Determine causes of die-off (\$200K):
 - Are elevation, aspect, and insect and disease stresses responsible?

- What is the role of stand age, drought, and herbivory?
 - Identify primary versus secondary agents, including genetics.
 - Is ungulate saliva a vector for disease transmission?
- Determine the known Natural Range of Variability (NRV) of aspen and test for a precedence of die-off (\$50K).
- Determine the regional effects of aspen mortality (\$1.5M).
 - Inter-clonal interactions
 - Successional trajectory
 - Erosion
 - Alleopathy
 - Pathogen accumulation
 - Insect accumulation
 - Water availability
- Identify and test techniques to protect regeneration and restore “fading” stands that are treated (\$100K).

Wildlife Ecology Working Group Report

Key Questions

The Wildlife Ecology group identified several key questions to address potential changes in wildlife habitat resulting from the loss of aspen. First, the current status and projected trends of the aspen resource need to be determined and how these changes might affect wildlife at different scales needs to be established.

- What implications will these trends have for different species of wildlife associated with aspen?
- What species might be most affected by loss of aspen?
- What effects would the loss of large aspen trees have compared to complete loss of aspen?
- At what scales would loss of aspen be critical to wildlife species?

Understanding the role of fire in shaping the aspen resource of the future is also critical. Re-establishing the predominance of fire on the landscape might offer opportunities for aspen re-colonization that could potentially compensate for the current loss of aspen, but it is unclear how these future scenarios might play out for wildlife species. Changing the spatial and structural distribution of aspen on landscapes will undoubtedly affect wildlife habitat. Gaining specific knowledge of how wildlife species use aspen habitat will help managers understand how to minimize conflicts, predict the effects of current aspen loss, and plan future management actions.

Determining the seriousness of the current loss of aspen and how it will affect population levels of elk (*Cervus elaphus*) and moose (*Alces alces*) is critical. These species use aspen for forage and cover and, consequently, may affect the health and vigor of aspen populations. Gaining a better understanding of the dynamics of this interaction will aid managers in understanding how they can build provisions for sustainable aspen health into integrated vegetation management strategies.

The goals for these strategies should be designed to achieve desired future conditions for aspen, wildlife, and other resource objectives.

Another critical need is learning how to transfer knowledge about aspen/wildlife interactions from one region to another. This requires detailed information on the features that are both common and different to these areas. We also need to understand how easily the results obtained from specific sites and scales can be parlayed into broader scale vegetation management goals and strategies. Similarly, we need to determine how to assemble and synthesize elements of the aspen problem from different disciplines and assess the known and unknowns in future scenarios.

Actions Needed

The Wildlife Ecology group suggests that several immediate actions are needed to deal with the current aspen mortality issue with respect to wildlife resources. First, a review and summary of statewide (wildlife and fish) comprehensive plans and The Nature Conservancy eco-regional assessments should be conducted to more completely ascertain specific questions and needs related to aspen and wildlife. In addition, the USFS project planning and appeals database Schedule of Proposed Actions (SOPA) should be reviewed to identify trends and critical issues associated with planning and implementing vegetation management projects involving aspen and wildlife. This comprehensive database describes proposed vegetation management projects on Forest Service lands and would provide a means of identifying potential projects that could be monitored or studied to learn more about wildlife and aspen interaction (as well as gain knowledge about other aspects of the effects of management activities on the aspen resource).

The group also recommends that a multi-partner workshop be organized that would

- increase understanding of aspen,
- identify research needs for aspen/wildlife interactions, and
- develop an action plan for aspen conservation and management that could be used to guide forest planning and integrated vegetation management.

Genetics Working Group Report

Overarching Need

A critical need to understanding the current aspen mortality phenomenon is to consider the clone-specific effects when investigating die-offs and treatment effects and when conducting trend monitoring. The need to clearly define phenomena and terms in this process should be emphasized. For example, the following phenomena may be the result of very different processes occurring in aspen stands:

- overstory tree mortality without regeneration,
- mortality of all age classes without regeneration,
- displacement by conifers,
- overstory mortality followed by ephemeral regeneration, and
- overstory mortality followed by regeneration of different genets (clones).

It is also critical to identify the genetic factors and issues associated with the current aspen die-off. Potential factors at the genet level include a genetic susceptibility and/or low fitness of particular genets that is now being expressed under changing climates. Given the suspected age of some aspen clones, another factor might be the accumulation of deleterious mutations in older genets that have existed on-site for many years. Earlier research has shown differences in growth and development in aspen that can be attributed to the gender in this predominately dioecious species. Gender could also play a role in the distribution and occurrence of aspen mortality. Inbreeding depression could also be a factor, as could the lack of phenotypic plasticity in particular genets.

Potential factors that might be operating at either a stand or landscape scale might include low numbers of genets in a stand, low genetic diversity among genets in the stand, a high degree of relatedness within a stand, and low levels of sexual reproduction in some genotypes or under specific ecologic conditions.

Research Needs

Genetic research needs include establishing the clonal boundaries within stands being studied so that the existence of different genotypes is known with respect to the occurrence of aspen mortality. Such genotype mapping should accompany research into aspen regeneration treatments and assessments to determine or measure the role of genetics in observed responses. This should also be a component of inventory and monitoring of aspen.

Identifying genetic traits that might be associated with die-off is important as well. This could involve learning what tradeoffs might exist among traits (for example, chemical defense versus growth) that might be contributing to aspen mortality and identifying whether these traits are heritable or plastic. Potential traits of interest possibly related to die-off susceptibility include differences in cavitation potential among genotypes and physiology with respect to above- versus below-ground viability. Genetic differences in root death rate and secondary chemistry (herbivory resistance) could influence suckering rate and sucker survivability and, therefore, might affect susceptibility to and the ultimate outcome of mortality events. The role of genetics in tree structure, pathogen resistance, drought resistance, and flooding resistance might also influence the outcome of aspen mortality events.

Other useful information might include determining the extent that root grafting occurs among different genets and quantifying whether losses in aspen coverage are congruent with losses in the number of genets in aspen populations. Determining how aspen stands transform from monotypic to diverse and back (in other words, clonal dynamics) may also be very useful in explaining the aspen mortality phenomenon. Although it may not be directly related to the current aspen mortality issue, determining to what extent genet diversity influences the diversity of understory plants, insects, and so forth in an aspen population could be enlightening. This is the concept of “extended phenotype” described by Whitham and others (2003).

In addition to genetic information, knowing what environmental conditions are associated with die-offs is also important. Factors such as soils, slope, aspect, grazing/browsing, other tree/shrub presence, climate history, and disease occurrence should also be recorded in any aspen assessment.

Testable Hypotheses

The following hypotheses need to be tested with respect to aspen genetics and current aspen mortality:

Hypothesis 1: The number of genets in western landscapes is declining (a separate phenomenon from decreases in spatial coverage).

Test by: Collecting genetics data in conjunction with establishing sampling plots for long-term monitoring in conjunction with FIA at a broad geographic scale.

Hypothesis 2: Aspen mortality is genet-specific within stands (H_A : Die-off is across genets).

Test by: Establishing sampling plots and collecting genetics data for long-term monitoring at a fine-scale resolution (fewer plots but more dense sampling than H1), focusing on areas experiencing die-off.

Hypothesis 3: Loss of aspen are related to maladaptation in the face of climate change.

Test by: Using a common “garden” approach to assess fitness of genotypes from different environments (clone-specific effects).

Additional basic research needs that don’t fit neatly into the above hypotheses testing include determining the extent of sexual reproduction among aspen genotypes and studying mutation accumulation and fitness among aspen. Developing more efficient ways of sexing and aging aspen clones and quantifying the extent of root grafting would be useful, as would investigating “extended phenotype” effects or the ecological effects of aspen genetic diversity within landscapes.

Silviculture/Management Working Group Report

Define and Clarify Terminology

There is a critical need to define and clarify terminology associated with the rapid mortality of aspen. A first step is to identify whether the current mortality is truly a crisis or just a normal or accelerated mortality of old trees. Identifying any relationships between ramet age and occurrence of mortality is crucial. Second, there is a need to identify and quantify any differences in mortality between affected stands with conifer encroachment and those where conifer encroachment is not occurring. If mortality is indeed stress related, then the presence of conifer should contribute to either the rate or incidence of mortality. Finally, any common factors that might be related to causality need to be identified.

The Silviculture/Management group identified three distinct conditions that can be associated with aspen mortality:

- Overstory mortality where regeneration of aspen are occurring
- Overstory mortality without successful regeneration of aspen
- Overstory mortality of aspen where conifer regeneration is present, but aspen regeneration is not or is insufficient to maintain the presence of aspen on the site

The Silviculture group concluded that there was no cause for concern, from an ecologic standpoint, if sufficient aspen regeneration is occurring, or already present, to develop into a fully stocked aspen stand. While the loss of a mature overstory might be regrettable from an aesthetic or wildlife habitat standpoint, it is within the expected range of natural conditions for a disturbance-dependent relatively short-lived tree species that vegetatively regenerates. However, if regeneration is not occurring the situation becomes more critical. If sprouting is occurring but not successful, the reasons need to be identified and corrected. If sprouting is not occurring, the reasons need to be identified. If roots have died, we have to accept the loss of aspen on the site and concentrate our management efforts on areas where the potential to regenerate aspen still exists.

Critical Research Questions

Several questions must be answered in situations where mature aspen trees have died but successful regeneration is occurring:

- When regeneration (aspen) is occurring under a dead overstory, how old is the understory?
- Does the regeneration pre-date the overstory mortality (e.g., was the stand regenerating prior to the onset of overstory mortality)?
- If so, what factors triggered the regeneration response?
- If not, why were these stands able to initiate regeneration when others were not?
- Could pressure from browsing animals be a factor?

Several questions must be answered where mature aspen stands have died and regeneration is absent:

- Did the stands attempt to regenerate but something killed the sprouts?
- Was the overstory too weak to sprout?
- Had too much time elapsed since the last disturbance to initiate sprouting?
- Did lateral roots die when overstory stems died (or conversely, did roots die first and cause the overstory mortality)?

Where conifers are present in affected aspen stands, their contribution to the conditions leading to aspen mortality needs to be identified:

- Did they out-compete the aspen for moisture, nutrients, or light and thus initiate aspen mortality?
- Did their presence contribute to the lack of aspen sprouting by shading the soils?

Since live roots are the key to the aspen suckering process, it is critical to:

- identify how aspen roots are affected;
- find ways of assessing aspen root condition prior to, during, and after overstory mortality has occurred; and
- relate root condition to any factors that might be identified as contributing to this rapid mortality phenomenon.

In addition to answering the above questions, it is critical to identify Intermountain West biodiversity hotspots where maintenance of aspen in landscapes is critical to ecosystems and to develop a means to prioritize the need for management intervention. To facilitate this process, the following terminology might be adopted to help differentiate between various aspects of aspen succession and clonal turnover.

Terminology

Die: when ≥ 80 percent of the overstory stems in a clone die within 3 to 5 years.

Die-off: not enough regeneration (suckering) to perpetuate stand due to

- a) a physiological failure of the aspen to respond, or
- b) the vegetative reproduction system is “turned off.”

Die-back: regeneration is sufficient to perpetuate the clone

- a) with prior regeneration present, or
- b) when regeneration coincides with overstory mortality, or
- c) when there is a gradual overstory decrease in stands with or without conifers.

Both die-off and die-back can be a part of the pathologic definition of “decline,” but both occur very rapidly. We prefer that the term “decline” be used to refer to the gradual death of aspen overstory in either pure aspen stands, or in conjunction with conifer invasion in mixed aspen/conifer stands, which is descriptive of an ecologic rather than pathologic process¹.

Additional Questions Associated With This Classification

- Is the mechanism for overstory mortality the same whether or not aspen regeneration occurs, or whether or not conifers are present?
- What are the patterns of mortality progression associated with rapid mortality of aspen?
- Does mortality radiate from a central point or occur simultaneously throughout the stand?
- Is mortality limited to one genotype at a specific site or does it cross clonal boundaries?
- Is the above definition of rapid death valid (for example, 3 to 5 years from onset to complete overstory mortality)?

Assessment Needs

It is important to gather consistent information to accurately assess what is happening to aspen throughout the West and compile consistent data that can be used

¹ Compilers Note: In the time since the meeting, the term “Sudden Aspen Decline” (SAD) has been used to describe conditions associated with the rapid mortality of aspen trees. Within this context, we feel the distinctions made by the “die-off” versus “die-back” definitions formulated by the Silviculture Working Group above are still valid and should be considered, regardless of the terminology used to describe the overall rapid aspen mortality process.

to answer the above questions. Assessment protocols should be developed to survey aspen mortality that falls into the categories previously described.

Categories to survey:

- 1) die-off (no regeneration present)
- 2) die-back
 - a. prior regeneration (existed before mortality started)
 - b. coincidental regeneration (initiated by the overstory mortality event)

The survey should define how many acres of each exist and list other factors that may be associated with each category, such as:

- insect and disease occurrence, especially *Cytospora*,
- elevation,
- aspect,
- ungulate pressure,
- drought,
- current vegetation (habitat types),
- current vegetation (soils), and
- treatments (if any) used to deal with aspen mortality and their apparent effectiveness.

A template for providing consistent treatment application and monitoring throughout the West should be developed. Coincidentally, a mechanism should be developed to facilitate collaboration and communication among all aspen managers in the West

Suggestions for Initial Research and Inventory

1. In each of the three die-off/die-back categories, determine the number of acres in landscapes containing aspen that are affected by rapid aspen mortality. This task could be done by the Forest Service's Forest Inventory and Analysis (FIA) and Forest Health Management (FHM) using the FIA database and existing FHM insect and disease survey techniques.
2. Quantify biotic factors and abiotic stand characteristics associated with each of the three die-off/die-back categories. This would most likely involve collaboration among FHM, university, and Forest Service researchers.
3. Determine the causal agents behind rapid aspen mortality (for example, the responsible mechanisms or factors). Again, data sharing and a multi-disciplinary approach will likely be needed.
4. To deal with the phenomenon, test management actions and determine an effective management time frame for action. This could best be accomplished by managers working collaboratively with university and/or Forest Service researchers.

In the short-term, the development of a common protocol for treatment execution and monitoring is essential in both the early and late stages of aspen mortality. This would include a pre-treatment stand assessment inventory protocol to assess and quantify the condition of the stands before they are treated, as well as common metrics to assess the effectiveness of treatment.

Another critical short-term need is to establish a clearinghouse or a lead organization to ensure collaboration and provide feedback among managers and researchers. This would include sharing of inventory and monitoring data and pre-publication sharing and review of research data. The clearinghouse should have an official data steward to build and maintain data sets, maintain and disseminate website information, and ensure data compatibility and security. The clearinghouse should also have a point person or facilitator who would interact with stakeholders (managers, universities, researchers) to secure an earmark for funding to deal with the aspen mortality issue.

Overall Needs

Definition of Terms

Several critical needs and themes were evident across the working groups. Foremost was the need for clarification of the terminology used to refer to the types of aspen mortality that have been observed and reported. All groups emphasized the need for clear and succinct definitions of the phenomena and the terms used to define the current mortality of aspen. Subsequently, we endorse the explanation and terminology presented by the Forest Health Working Group to describe decline in organisms. However, this model is still inadequate to describe the situation occurring in aspen populations at landscape scales. Terms previously used to refer to aspen mortality are also inadequate and caused considerable confusion during meeting discussions. During his summary remarks, David Cleaves, Director of the USDA Forest Service Rocky Mountain Research Station [currently Associate Deputy Chief, WO], suggested the acronym “SAM” for Sudden Aspen Mortality be used to avoid the value-laden connotations associated with “die-off” and “die-back” and the confusion with the classic pathologic definition of “decline.”²

However, Sudden Aspen Mortality does not cover all of the conditions reported and discussed at the meeting. An additional classification is needed to differentiate among specific mortality events that have been observed and reported. Two alternative lists of conditions were suggested by the working groups. We suggest adopting the following word model modified from the Silviculture and Management group. It provides a framework for distinguishing among mortality events and allows a means of investigating specific questions related to the events:

1. Overstory mortality where regeneration of aspen are occurring
2. Stand (clone?) mortality—Overstory mortality without sufficient aspen regeneration to maintain aspen on the site.
 - o Conifer regeneration is largely absent
 - o Conifer regeneration is present

² Compiler’s note: In the time since the meeting this term has morphed into “Sudden Aspen Decline,” which is consistent with the pathologic definition of decline presented earlier.

This model is consistent with the definitions proposed by the Forest Health group, as “die-back” could refer to the death of a part of an aspen genotype existing on a site, and the mortality of a stand or clone could be considered to be the result of a “decline.” Many critical knowledge needs and questions posed by the working groups could fit within this classification. Most groups called for the need to identify and quantify site and biotic factors associated with aspen mortality. Additionally, suggestions were offered to quantify climatic and meteorological factors associated with mortality, including site factors such as soil, physiographic position, aspect, and associate vegetation. Investigation is also needed into the role that climate change might play in the aspen mortality phenomenon, specific relationships between drought and moisture stress, and long term disease and insect effects. Better knowledge of the relationships between changes in fire regimes and current aspen mortality was identified as yet another critical need.

The Role of Herbivores

Several working groups discussed the need to learn more about the role of herbivores in aspen mortality events. Specific needs include aspen/herbivore interactions and inter-dependency, whether herbivores can be a vector for pathogens that can infect aspen, and identification of circumstances where aspen need protection from herbivores. Especially important is the need to learn at what scales and under what conditions herbivores become problematic in aspen forests.

The Role of Aspen Roots

The need to learn more about the role that aspen roots play in the various mortality scenarios was mentioned repeatedly. Are aspen roots really dead in situations where sprouting does not occur? If so, are they dying before or after the overstory trees die? Does root grafting play a role in avoiding or contributing to complete stand mortality?

Genetics

A lack of key genetic knowledge was identified. What role does genetics play in the mortality process? Can susceptible genotypes that are predisposed to mortality be identified? Is clone age (the amount of time a genotype has existed on a site) related to mortality occurrence? Are male or female clones more susceptible to mortality?

Rapid Assessment

A theme common to all working groups, and subsequent discussions by the entire group, is the need for a rapid assessment of aspen throughout the West to (1) determine the current status and projected trends of aspen forests and (2) more accurately quantify the magnitude and extent of mortality. The need to estimate the duration of mortality and project the economic and ecologic effects associated with it is especially critical to managers. Identifying stocking metrics associated with mortality would be very useful, especially if aspen loss could be associated with age, growth rate, stocking conditions, or other biotic factors.

Recommended Actions

Although workshop participants identified a number of research and management needs that could improve our understanding of the processes involved in the current aspen mortality events, we suggest that the most critical need is to develop a common rapid assessment protocol that could provide comparable data that would meet both management and research objectives. With that in mind, we recommend the following actions:

- Form a multi-agency task force to develop a common rapid assessment protocol that combines remote sensing and ground based data about the current condition of aspen forests and includes methodology and data needed to monitor and assess mortality events. The task force, after considering specific data needs outlined in the working group reports, should recommend a specific protocol template that will allow consistent treatment application and monitoring of the aspen resource throughout the West and provide information to plan future management and research activities. Subsequent research has used similar protocols; however no universal one has been adapted.
- Hold a future multi-partner workshop after the 2007 field season to re-assess the current state of aspen resources throughout the West. This workshop should be a vehicle to share information collected during the 2007 field season, identify additional research needs, and recommend management actions based on the new information. [Update: A Sudden Aspen Decline (SAD) meeting was held February 12-13, 2008, in Fort. Collins, CO. This meeting reported efforts concerning SAD for the 2007 field season. A wide variety of studies and issues were presented and discussed. An unedited summary of this meeting, compiled by Paul Rogers, can be found at <http://www.western-aspen-alliance.org/>. The summary can be found by activating “Links” on the left sidebar and opening “Summary of the Sudden Aspen Death (SAD)...2/08.”]
- Review state-wide wildlife and fish comprehensive plans and TNC ecoregional assessments to identify aspen-related issues, trends, and needs. The Forest Service SOPA documents database should be reviewed to identify specific sites where vegetation management projects are planned or have been completed in aspen forests. This information will be very useful in targeting research and monitoring to ascertain how particular management activities affect the aspen resource.
- Develop a mechanism to facilitate collaboration and communication among all aspen managers and researchers in the western United States. This could take the form of a university or agency funded institute or an informal collaborative working group that would serve as a clearing house for information and discussion concerning aspen. An integral part of this organization would be to serve as a conduit of information between interested parties, providing assistance, consulting services, and disseminating information through the internet or other informal outlets. [Update: A joint effort between Rocky Mountain Research Station (RMRS) and Utah State University (USU) has resulted in the Western Aspen Alliance (WAA) being formed. A formal Memorandum of Understanding (MOU) has been established between RMRS

and USU to validate this Alliance. The WAA is a consortium of researchers and managers who will coordinate and facilitate advances in aspen ecology in western North America. The WAA prospectus (fig. 5) and web site (<http://www.western-aspen-alliance.org/>) contain additional information on the Alliance.]



Promoting Sustainable Aspen Ecosystems in Western North America

Quaking aspen (*Populus tremuloides*) is known throughout the West as an icon of mountain scenery, and among managers and scientists, aspen is revered for its resource value and important contribution to regional biodiversity. Recent documentation of cover loss and sudden decline of stands has raised concern about the future of aspen on the landscape and values associated with these communities. Management practices and recent drought are thought to have contributed to declines. However, much is still unknown about aspen systems and, in turn, appropriate management to sustain these communities.

Utah State University's College of Natural Resources and the USDA Forest Service, Rocky Mountain Research Station have formed an alliance to facilitate and coordinate research issues related to aspen communities of the West. The Western Aspen Alliance (WAA – pronounced “way”) will facilitate cooperative research and disseminate state-of-the-science aspen information to interested managers, researchers, the public, and other entities.

The overall goal of the Western Aspen Alliance is to facilitate effective and appropriate management of aspen ecosystems in the Western US through coordinated scientific efforts and shared information. The following WAA objectives may be modified with greater participant input and as research progresses:

1. **Communication:** develop needs/expertise network, technology transfer, workshops/conferences, and publications.
2. **Spatial Assessments:** determine the geographic extent of Sudden Aspen Decline (SAD), seral/stable aspen stands, and historic aspen coverage.
3. **Basic Research:** stand structure, community composition, genetics, herbivory (wild/domestic), water yield, and biodiversity/trophic interactions issues.
4. **Management/Monitoring:** approaches to sustainability, developing aspen-specific monitoring protocols, and utilizing existing monitoring databases.
5. **Social:** catalog aspen resources, evaluate economic contributions and potentials, and assess value/use.

We will form working groups for these issues and pursue additional aspen topics that arise. WAA will seek external funding to support this coordinated research, management, and communication effort. We welcome your input and participation!

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Figure 5. Prospectus for the Western Aspen Alliance (WAA).

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Appendix

List of attendees at the Aspen Summit Meeting, Salt Lake City, Utah, December 18 and 19, 2006.

Name	Organization
Bill Jacobi	Colorado State University
Brian Kurzel	Colorado State Parks
Carl Edminster	USFS - Rocky Mountain Research Station
Cindy Swanson	USFS - Region 1
Dale Bartos	USFS - Rocky Mountain Research Station
Darren McAvoy	Utah State University
Dave Cleaves	USFS - Rocky Mountain Research Station
David Burton	Aspen Delineation Project
Henry Lachowski	USFS - Remote Sensing Applications Center
Ingrid Aguayo	Colorado State Forest Service
Jack Troyer	USFS - Region 4
James Hoffman	USFS - Region 4
James Worrall	USFS - Region 2
Janine Powell	USFS - Rocky Mountain Research Station
Jim Long	Utah State University
John Guyon	USFS - Region 4
John Shaw	USFS - Rocky Mountain Research Station
Julia Richardson	USFS - Region 4 (Humboldt-Toiyabe NF)
Karen Mock	Utah State University
Ken Hehr	USFS - Region 2 (San Juan NF)
Laura Moffitt	USFS - Region 4
MaryLou Fairweather	USFS - Region 3
Melissa Jenkins	USFS - Region 4 (Caribou-Targhee NF)
Michael Wilson	USFS - Rocky Mountain Research Station
Mike Duncan	USFS - Region 4 (Dixie NF)
Mike Kuhns	Utah State University
Phillip Kemp	USFS - Region 2 (San Juan NF) (Retired)
Robert Campbell	USFS - Region 4 (Fishlake NF)
Ron Ryel	Utah State University
Skip Smith	Colorado State University
Steve Ambrose	USFS - Rocky Mountain Research Station
Steve Solem	USFS - Rocky Mountain Research Station
Tim Garvey	USFS - Region 2 (Grand Mesa, Uncompahgre & Gunnison NF)
Tom Martin	USFS - Region 4
Valerie Hipkins	USFS - Pacific Southwest Research Station
Vicki Berrett	USFS - Rocky Mountain Research Station
Wayne Shepperd	USFS - Rocky Mtn. Res. Station (Retired)



The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of the National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals. Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

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