AN ABSTRACT OF THE THESIS OF

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Title: The Schultz Fire: An Interdisciplinary Perspective on its History, Management, and Ecological Effects.

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This thesis examines the Schultz Fire as a case study to explain the complex history of fire suppression management in America's forests, and to gain further understanding of how management practices have affected the increase in fire severity levels and how forests respond to such a disturbance. The thesis objectives were: (1) to analyze the causes of the fire severity of the Schultz Fire, especially: topography, fuels, or weather; (2); to examine the possible correlation between fire severity and tree density; (3) to investigate whether post-fire species richness was related to fire severity two years after the Schultz Fire; (4) to investigate whether post-fire plant species richness, plant cover, and tree regeneration was related to fire severity two years after the Schultz Fire; and (5) to interlink and convey how these factors relate to the history of fire management and policy and public perception.

The history of fire related policy and management has significantly changed the dynamics of America's national parks and forests. Understanding the larger context of this history, both of national fire management and of the effects of language and perception on policy and public reaction, is part of understanding the Schultz Fire as a whole.

Based on modeling, high winds combined with the presence of high surface fuel load were the main causes of the Schultz Fire's high fire severity levels. As fire severity increased there was a statistically significant increase in species richness. Severity level had little variation on percentage of cover by plants. No statistically significant relationship between tree density and fire severity levels was found.

These findings underline the need for fuel treatments in southwest Ponderosa Pine forests, and effective cooperation between communities, managers, and ecologists. The Schultz Fire serves as an example in understanding the intricacies of how history affects the present and future of fire management. How fire has been managed and portrayed in the past has left an indelible mark on how fire is presently viewed. Without a clear understanding of the history of fire management and the role of fire in the ecology, future policies towards fire will be unable to account for and manage for the diversity of ecosystems and fires effects on those ecosystems across the United States.

The Schultz Fire:

An Interdisciplinary Perspective on its History, Management, and Ecological Effects

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Susanne N. Ranseen, Author

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DFTBA

Don’t forget to be awesome

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DEDICATION

Dedicated to all the wonderful teachers, instructors, advisors, and professors who took time they did not have to open one student’s mind to a world of possibilities. I would not be the person I am without you all.

PREFACE:

In late June of 2010, I received a phone call from my best friend Judy in Flagstaff, Arizona. The forest behind her house was on fire, and their neighborhood was being evacuated for safety. At that time, I was living in Seattle and could do little to help, but I still followed what bits and pieces of news about the Schultz Fire I could find.

After the fire, the media began asking questions about the Schultz Fire and the other fires that had burned near Flagstaff and across Arizona that year. “Why are there so many destructive fires?” “What can be done to stop these fires?”

Immediately after the fire, Flagstaff was hit with the fourth largest rainy season in its history, causing significant flooding in the area around and below the fire. Judy asked me to come and help her. Looking through the windows of her home, I saw a blackened mountain that only a few years before had been lush and green. In the news and in conversations around Flagstaff, I heard that the forest “was not going to return for a hundred years, flooding would be bad for anywhere from 20 through 60 years,” and, again and again, the questions “Why our forest?” “Why the Schultz Fire?”

In 2011 I visited Judy again. Looking out the same window at the same forest of black, I saw green beginning to show. Also visible were efforts to control the flooding up on the mountain, and temporary flood barriers of hay in the urban areas. The housing costs for the area had plummeted due to the flooding, and many people who could move, had. The forest on the mountain above seemed ugly and dead.

Or was it? Even though I did not go up onto the mountain during that visit, life had clearly not ended because of the fire. I remember thinking how beautiful it looked.

A year later, I returned to Flagstaff again, this time to study the area as a scientist and also as a historian, to see what had returned, and maybe answer some of the questions that I had heard a year before. What I found was that the fire had in no way destroyed the area. In the midst of blackened trees, there was life. Elk and mule deer tracks were everywhere, as was the steady tapping of woodpeckers. The mountainside was covered with purples, yellows, and greens of blooming flowers, forbs, and herbaceous species. Out of the ashes of the old forest, a new one was emerging (Figure 1).

Figure 1: View of non-burned and burned area July 2012.[1]

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[1] Photograph taken by Susanne Ranseen June 2012. Unpublished.

CHAPTER 1: INTRODUCTION

In the course of ten days, from June 20 through June 30 in 2010, the Schultz Fire burned across the southeast face of the San Francisco Peaks in the Coconino National Forest. Started by an abandoned campfire in a popular hiking area near Schultz Water Tank, the fire burned almost 13,000 acres in the first four hours.[2] In all, 15,075 acres burned, at a cost of $10 million for fire suppression (Figure 2). As the annual monsoonal rains moved through the area, runoff from the fire area caused a total of $58 million in flood damages.[3] The flooding caused the only fatality associated with the fire, a 12 year old girl caught in a flash flood.[4]

Figure 2: Schultz Fire area July 2010[5]

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[2] Interview Dick Fleishman
[3] Interview Mike Elson
[4] *Arizona Daily Sun*, June and July 2010.
[5] Photographs provided and taken by Dick Fleishman July 2010.

The Schultz Fire is a microcosm of the complex issues in American Southwest forests. While the Schultz Fire was driven by the interaction of weather, topography, and fuels, many other factors played a part in making it. Some of these factors include the history of fire management and the ecology of the Coconino National Forest. The Schultz Fire is also a microcosm of the ecological response to fire.

When fire threatens urban landscapes and timber resources, it is seen as "wild" and an "enemy" to be fought and defeated. In this context, fire takes on an emotional aspect, in the representation of fire as either good or bad. This emotional response clashes with the scientific view of fire as "…neither good nor bad… (but) part of the endless cycle of change" in natural systems.[6]

The emotional and educational context in which policies are passed must also be understood; for example, much of the language of fire found in public media expresses fear with such emotionally charged word such as "catastrophic" and "devastation", or in terms of "victory" and "defeat". Headlines reporting on the Schultz Fire frequently included words such as charred, battling, threaten, lives interrupted and uprooted.[7] Large fires such as the 1910 Fires and the 1988 Yellowstone Fires have the effect of galvanizing public opinion and creating a sense of crisis. Lacking a scientific understanding of fire, the public frequently responds to fear, but does not always see the ecological significance, or hear the scientific voices that might calm such fears. Understanding the larger context of national fire management history and of the effects of perception on policy is part of understanding the Schultz Fire. Knowing how the area burned and is responding to the disturbance in these early years is also essential in completing a whole picture.

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[6] Simon, Seymour. *Wildfire*. Scholastics, New York, 1998.
[7] *Arizona Daily Sun*, June 21-30 2010

The objectives of this thesis were: (1) to analyze the causes of the fire severity of the Schultz Fire, especially: topography, fuels, or weather; (2); to examine the possible correlation between fire severity and tree density; (3) to investigate whether post-fire species richness was related to fire severity two years after the Schultz Fire; (4) to determine whether fire severity effected percentage of cover; and (5) to interlink and convey how these factors relate to the history of fire management and policy and public perception. These objectives where examined within chapter 2 and 3.

Chapter 2 is devoted to exploring the history of fire management in the United States from 1881 to 2012. It reflects on how the United States Forest Service has played a major role in how fire is viewed by the public and how policies have been affected this agency. The chapter examines the effects of policies, major symbols such as Smokey Bear, and events such as the 1910 fires, that have helped to shape the policies and perceptions concerning fire in the United States. The chapter studies this history on a broad scale, and then focuses on how this history specifically relates to the Schultz Fire area.

Chapter 3 focuses on the Schultz Fire area by examining the factors that dictated the fire's behavior and how the area has responded to this disturbance. This chapter starts with a background on fire behavior and how Ponderosa pines and associated species interact with fire. It then turns towards the 104 plots study of the Schultz Fire area. These 104 plots were used to record plant species present, tree density, and data for BEHAVE Plus 5 modeling. The chapter then expands out from the singular focus of the Schultz Fire in comparison it to other studies.

It is important to remember that no one area of this study is more important than the others. An interdisciplinary approach is necessary to understand all the various factors involved in the Schultz Fire, and to understand the effects of all of these factors as a whole. Chapter 4 integrates the science and the history together to form the conclusion to the paper. The Schultz

Fire serves as a tangible link between the complexities of history, science, and management of fire in comparison to the present-day reality of fire in Southwest Ponderosa pine forests.

CHAPTER 2: THE HISTORY OF FIRE MANAGEMENT AND POLICY WITHIN THE NATIONAL FORESTS FROM 1881 TO 2012

The history of fire management within the United States has significantly affected the dynamics of America's ecosystems, especially in the national public lands, forests, and parks. This history is closely tied to the history of the United States Forest Service, an institution that has been instrumental in forming how wildland fire has been viewed in public and private lands. For over a century, the Forest Service has served as the major agency for shaping fire science and policy, and its policies and perceptions have impacted dramatically ecosystems dependent on fire. Despite numerous changes in the scientific understanding of fire and its role in ecosystems, the legacy of this history continues to make itself felt.

During the Progressive Era (1880s-1920s) there was concern over how best to use America's timber resources (Appendix Note1: Progressive Era). The issue boiled down to a simple question: should timber lands be placed in the hands of the government or private interests? There was also a concern that in private hands, no resources would be spared for the future, reducing timber reserves to fall back upon in hard times. Many Progressive era conservationists believed that private organizations would not and could not retain the land's "natural qualities" and would develop it without consideration of public interests. [8] With these concerns in mind, the Division of Forestry was formed in 1881 and was formally recognized by Congress in 1886.[9] The first 25 forest reserves, including the San Francisco Mountain Forest

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[8] Hays, Samuel P. *The American People and the National Forests: The First Century of the US Forest Service*. Pittsburgh: University of Pittsburgh Press, 2009, p 2

[9] Klyza, Christopher McGrory. *Who Controls Public Lands?: Mining, Forestry and Grazing Policies, 1870-1990.* Chapel Hill: University of North Carolina Press, 1996, p67

Reserve, later the Coconino National Forest, were created in 1891 under Section 24 of the General Land Law Revision Act.[10]

However, the first plan for managing these areas did not exist until 1897, when the Sundry Civil Appropriation Act, which allowed for management and the use of resources in the reserves, was passed.[11] Also in 1897, the Organic Act established the right for the Department of Agriculture to regulate the "occupancy and use" of reserves, which existed to "protect the forest from fire and depredations, to secure favorable water flow conditions, and to provide a continuous supply of timber."[12] This act reflects the heart of Progressive Era values: minimum waste and maximum efficiency for the protection of present and future public interests. Such philosophies guided the policies of the Division of Forestry and later the Forest Service until the 1960s and 1970s.

In 1905, the Division of Forestry was transferred to the Department of Agriculture and renamed the United States Forest Service. One of the first and most fundamental aims of the Forest Service was to hold reserves of timber, later to become the various National Forests, for timber production. As the transition to the Department of Agriculture made clear, the trees themselves were to be managed essentially as a crop, rather than as part of a functioning landscape.[13] Gifford Pinchot, the first head of the Forest Service, formulated his initial management strategies and policies around the idea that "the forest should be managed for a constant, sustainable amount of wood."[14]

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[10] Baker, Robert, Robert Maxwell, Victor Treat, and Henry Dethloff. "Timeless Heritage: A History of the Forest Service in the Southwest." USDA Forest Service FS-409 (August 1988), p 25

[11] Klyza, *Who Controls Public Lands*, p69

[12] Hirt, Paul W. *A Conspiracy of Optimism: Management of the National Forests since World War II*. Lincoln: University of Nebraska Press, 1994, p 30-31

[13] Hays, *The American People and the National Forests*, p15-16

[14] Klyza, *Who Controls Public Lands*, p 15

In this context, Progressive-Era conservationists saw fire as a waste of resources in "Nature's Economy."[15] The Progressive reaction against fire was modeled on European forestry practices where centuries of anthropogenic effects created a pastoral landscape in Europe where fire burned only through human actions. Pinchot said that "forest fires encouraged a spirit of lawlessness and a disregard to property rights."[16] Even John Muir, one of the fathers of the preservationist movement, saw fire as a problem that needed to be removed from natural environments.[17] He described the destruction caused by fire as being ten times worse than that caused by wholesale logging.[18] Henry Graves, Pinchot's successor, declared that fire protection was 90% of the Forest Service's job and without fire control, there was no forestry.[19]

The Progressive Era scientists had missed a critical piece of the puzzle: not only was fire an integral part of American landscapes, but humans had been using fire to control and change the landscape of North America for millennia. European fire practices, based on controlled fires in a landscape of heavily populated farmland, did not necessarily translate well to the American wilderness, which was sparsely populated and ecologically different. Native peoples used fire to improve habitat for large game animals and foraging plants, or to clear land for agriculture, a practice commonly referred to as "Paiute burning."[20] Settlers observed and copied the practice; ranchers used fire to clear land for grazing, farmers to clear their fields, and loggers to eliminate

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[15] Pyne, Stephen. *Fire: A Brief History*. London: University of Washington Press, 2001, p 145

[16] Steinberg, Ted. *Down to Earth: Nature's Role in American History*. 2nd ed. Oxford: Oxford University Press, 2009, 142

[17] Pyne, Stephen. *World Fire: The Culture of Fire on Earth*. New York: Henry Holt and Company, 1995,p 184

[18] Pyne, Stephen. *Year of the Fires: The Story of the Great Fires of 1910*. 2nd ed. N.p.: Mountain Press Publishing Company, 2008, p 6

[19] Pyne, Stephen. *Tending Fire: Coping with America's Wildland Fires*. London: Island Press, 2004,p 36

[20] Nash, Roderick. *Wilderness and the American Mind*. 4th ed. London: Yale University Press, 2001, p 24-30

unwanted slash. The result was large scale fires throughout the American west through the 19th century, many of which entered populated areas, killing people and destroying property.[21]

It was easy to ban fire on paper, but it was another thing entirely to fight wildland fires, and prior to the early 20th century, there was no mechanism in place to control fires. Unwanted fires in the wilderness urban interface (WUI), around the houses and fields of civilization, were fought and controlled by local residents as best they could. Fires in the backcountry, away from towns and cities, on the other hand, were usually left to burn. Without a population or economic interest to protect, there was no reason to interfere; the cost simply outweighed the benefit.

This paradigm began to shift in the early 20th century. One of the first works that outlined the Progressive view of fire as an enemy was William James' essay "The Moral Equivalent of War," which called for young American males to fight a war against nature as a surrogate for fighting war against other nations.[22] Young men could prove their masculinity and worth without having to die for it. This moral equivalent of war changed firefighters from "stoop labor" into "heroic" quasi-soldiers fighting for their country.[23] Implicit in the statement was the new view of fire. Now fires were perceived as a force that could be controlled, contained, and extinguished for the protection of fertile landscapes and the economic well-being of the country. Fire was an enemy to be fought and conquered.

The language of fire as an enemy and the policy based on suppression nevertheless found opposition in the early 20th century. Two ideological camps were forming, both inside and outside the Forest Service: those who favored "let burn" and those who supported "suppression". These camps emerged around two forest managers in California, Roy Headley and Coert DuBois.

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[21] Pyne, *Year of the Fires,* p 5-7

[22] Pyne, Stephen. *America's Fires: Management on Wildlands and Forests*. Durham, NC: Forest History Society, 1997, p 17 and 21.

[23] Maclean, John. *Fire and Ashes: On the Front Lines of American Wildfire*. New York: Henry Holt and Company, 2003, p200

Headley proposed a system based on “let burn,” which would allow low intensity fires to spread unless they threatened valuable timberland or populated areas. Headley wrote “forget the concept of fighting a fire. Think of it as a job of constructing and patrolling control lines.”[24] DuBois, who supported suppression, responded by publishing his report “Systematic Fire Protection in the California Forest,” which included early scientific studies on the effects of light burning and the conclusion that they were a mechanism for forest destruction and soil erosion with no redeeming value. [25]

The debate over the use of fire was dramatically changed by the fires of 1910, which burned across large areas of America and killed 79 firefighters. These fires “worked to elevate the policy of fire suppression into a veritable religion at the Forest Service” and were the linchpin event that established fire management policy for much of the 20th century. [26] Existing scientific explanations of why such large fires had burned, how they were started, and how the areas recovered, were ignored or lost in a wave of public fear and anger. From this point on, fire was to be suppressed regardless of its method of ignition or location.[27]

Over the next thirty years, numerous policies and laws were enacted to support the goal of suppression. The Weeks Act of 1911 allowed for cooperative fire protection between states and the federal government.[28] This helped set the groundwork for fire management models at all levels of government to be structured around the suppression model of the Forest Service. By the 1920s, money was set aside for pre-suppression measures. In 1924, the Clarke-McNary Act created a national standard for fire protection, and included plans for firefighting in the

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[24] Cermak, Robert. *Fire in the Forest: A History of Forest Fire Control on the National Forests in California 1898-1956*. Pacific Southwest Region: U.S. Forest Service, 2005, p 83

[25] Pyne, Stephen. "Fire Policy and Fire Research in the U.S. Forest Service." *Journal of Natural History* 25, no. 2 (1981): 64-77, p 69

[26] Steinberg, *Down to Earth*, p 141

[27] Maclean, *Fire and Ash*, p 195

[28] Pyne, *Tending Fire*, p52

backcountry, which had been previously inaccessible.[29] Later, during the New Deal, the Civilian Conservation Corps (CCC) was established to provide young men with jobs in national public works projects. Many of these projects had a firefighting application, such as building government roads, firebreaks, and fire lookouts in the backcountry. CCC workers were frequently tasked with firefighting.

The war on fire created policies such as the 10 A.M. policy and the 10 acre policy, which required all fires to be controlled and/or extinguished by the morning after the day of ignition or before they grew beyond the size of 10 acres. These two policies ruled suppression strategies and tactics from the mid 1920s through the 1970s.[30] Policies such as the 10 a.m. policy and the 10 acre policy encouraged a mentality of suppression by any means and at any cost. The ability to carry out these policies became the measure of the foresters' ability and credibility.

These two policies were premised on the idea that protecting forest lands was an investment in the future by protecting land that would once have been "abandoned" to burn.[31] There was little research into the effects of fire on ecosystems until after World War II, with the exception that of DuBois research. Fire research focused on improving the efficiency and effectiveness of suppression measures by understanding why and how fire burned, not on how species within forests evolved with fire. In 1948, the Forest Service created the Division of Forest Fire Research, establishing the Forest Service as the main source for research concerning fire and forestry.[32]

Some historians argue that money, not the language or science directly related to suppression or even research concerning fire, created policies where suppression tactics were, and

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[29] Pyne, Stephen. "Fire Policy and Fire Research in the U.S. Forest Service.", P 70-71

[30] Linton, Jeremy, ed. *Wildfires: Issues and Consequences*. New York: Nova Science Publishers, Inc., 2004, p46 and 84

[31] Pyne, Stephen, Patrica Andrews, and Richard Laven. *Introduction to Wildland Fire.* 2nd Ed. New York: John Wiley & Sons, Inc., 1996, p255-257

[32] Pyne, *Introduction to Wildland Fire,* p 420

still are, favored over “let burn” and other ecological policies. According to this argument, fire suppression has been given “nearly unlimited” funding, while activities to reduce fire hazards or understand fire are “woefully underfunded.”[33] The Weeks Act of 1911 established the beginning of what is commonly referred to as the “Blank Check” mentality in the Forest Service with regards to forest fires.[34] The Weeks Act enabled the Forest Service to expand through federal and state cooperative programs in fire control. Even with the removal of the 10 A.M. policy in 1977, and the repeal of the 1908 Forest Fire Emergency Act in 1978, weak enforcement of policy changes and an increase in an ostensibly limited budget for suppression has allowed such a mentality to continue even today.[35]

It was not just the policies that fed and funded the war on fire, but public education and involvement, which were dramatically shaped by symbols such as Smokey Bear and Bambi, which focused on fire as a destroying force and an enemy. According to Roderick Nash, symbols such as Smokey and Bambi have done “more to shape American attitudes toward fire in the wilderness ecosystems than all the scientific papers ever published on the subject.”[36] The most powerful symbol of all was Smokey Bear, who has become almost “synonymous with fire protection.”[37]

Smokey Bear was conceived in 1944 by the wartime advertisement council and hit the national stage in 1945.[38] Numerous campaigns using language depicting fire as a threat to the nation and the war effort were started during the war, but none were quite as effective as Smokey.

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[33] Wuerthner, George, ed. *Wild Fire: A Century of Failed Forest Policy*. Sausalito, CA: Island Press, 2006, p 200

[34] Jensen, Sara and Guy McPherson. *Living With Fire: Fire Ecology and Policy for the 21st Century*. Berkeley: University of California Press, 2008, p 72

[35] Wuerthner, *Wild Fire: A Century of Failed Forest Policy*, p 217-219

[36] Wuerthner, *Wild Fire: A Century of Failed Forest Policy*, p 26

[37] Baker, Robert, Robert Maxwell, Victor Treat, and Henry Dethloff. "Timeless Heritage”, p162

[38] Morrison, Ellen, Earnhardt. *Guardian of the Forest: A History of the Smokey Bear Program*. New York: Vantage Press, 1976, p1

After the war, Smokey continued to be the main advertising campaign for the Forest Service, and quickly took on a life of his own. As wildland firefighter/author Peter Leschak wrote of a public school visit, "I was Smokey, and until I wriggled into that deluxe outfit I didn't fully realize the startling power of that bear. If the costume weren't so hot and uncomfortable, I'd be tempted to live in it, constantly enjoying the benefits of universal admiration."[39]

The power of Smokey was in the simplicity of his message: "Only You Can Prevent Forest Fires." However, the subtleties of difference between "careless fire" (i.e. natural wildfire versus human set wildfire) and other kinds of fire were lost on the public; the simplicity of the message resisted explanation. For over 60 years, this message remained essentially the same: any fire in a forest setting was something to prevent.[40] While the exact wording of this message changed over time, reflecting changes in scientific understanding of fire, the core concept of the message influenced fire policy from 1945 to the present day. In recent years, some managers have called for more radical action; some feel that a new symbol must be created, and that "to save the forest, we must kill Smokey" and the old ways of understanding fire along with him.[41] Such a reaction, though extreme, underlines the importance of public understanding of the changing science of wildland fire.

Mainstream scientific perceptions of fire began to change in the 1960s and 1970s as fire science changed as part of the environmental movement.[42] In 1960, Congress passed the Multi-Use Act, which determined that timber production could no longer be the sole purpose of

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[39] Leschak, Peter. *Hellroaring: The Life and Times of a Fire Bum*. St. Cloud, MN: North Star Press of St. Cloud, Inc., 1994, p 217-218

[40] Carle, David. *Burning Questions: America's Fight with Nature's Fire*. Westport, CT: Praeger, 2002, p 4

[41] Wuerthner, *Wild Fire: A Century of Failed Forest Policy*, p 271

[42] Pyne, *Tending Fire*, p 72-72 and 77

National Forests. [43] While the forests had long been used for other purposes such as recreation, water sources, and grazing, the Multi-Use Act codified the view that the National Forests as a system had to be available for all uses. The Wilderness Act of 1964 also built another multi-use facet into the National Forests, as areas were set aside to protect them for species conservation.[44] The Wilderness Act stipulated for the preservation of "natural conditions" within wilderness areas, one of which was wildfire.[45]

Another early change in the traditional view of national forests as solely timber reserves was the National Environmental Policy Act of 1969, signed into law January 1, 1970, which required the Forest Service to undertake comprehensive and interdisciplinary analysis of the environmental consequences of their policies and procedures.[46] Review of projects and procedures would be performed by outside sources, which would ensure that the agency would not impact the science toward any one directive or policy such as suppuration versus treatment.

As scientists became more aware that fire was part of the natural system, the concept that fire suppression and exclusion had been an unproductive reaction to fire became stronger. To many scientists, the remedy for fire exclusion was simple: restore fire to the ecosystem.[47] The 10 A.M. policy of fire suppression, which was once termed "a continental experiment", was gradually phased out.[48] In 1968, a new experiment involving the restoration of fire in natural ecosystems was started by the National Park Service. It was called Prescribed Natural Fire and was premised on letting naturally set fires in certain areas burn until they went out naturally.

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[43] Hays, *American People and the National Forests*, p 105 and Hirt, *A Conspiracy of Optimism*, p 34

[44] Hays, Samuel P. *A History of Environmental Politics Since 1945*. Pittsburgh: University of Pittsburgh Press, 2000, p 26.

[45] Carle, *Burning Questions*, p 177

[46] Hays, *American People and the National Forests*, p 18

[47] Pyne, *Tending Fire*, p 104

[48] Pyne, *Tending Fire*, p 72

Firefighters were to manage the fire, and to extinguish it only if it threatened wilderness-urban interfaces or moved out of its planned area.[49]

One of the most important phrases that came into use during this time was the concept of "forest health." In the 1970s, the media created the term of forest health to easily explain the new focus of ecology on disturbance and restoration within the forest environment. However, it meant different things to different people. In the media, it was frequently used in reference to aesthetic values and uses, and was often given a negative connotation to forest fires. On the other hand forest managers used the term "forest health" to identify desired forest conditions, often in relation to timber production, and the recovery of these conditions after damage from fire. Finally forest ecologists thought of "forest health" as a measure of forest conditions and restoration. [50]

Orie Loucks became the first ecologist to include fire in models of forest growth cycles. In 1970, his publication "Evolution of Diversity, Efficiency, and Community Stability", proposed that by suppressing fire humans had caused the "greatest upset of the ecosystem of all times."[51] His theories reflect the changing social views of the 1970s; specifically the preservation of natural environments solely for their ecological importance was gaining support within the public and scientific spheres. This conflicted with the traditional role of the national forests as economic timber reserves that still persisted even in the face of changing political, public, and scientific opinion.[52] Forest ecology was becoming a multidisciplinary field which led to better understanding of how ecosystems were affected by disturbances such as fire and timber production and how they could be restored to natural conditions. The goal of "desirable forest-

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[49] Carle, *Burning Questions,* p 181

[50] Hays, *American people and the National Forest*, p 120-122

[51] Orie Loucks, "Evolution of Diversity, Efficiency, and Community Stability" *American Zoologist* 10, 1970, p 17-25

[52] Hays, *American people and the National Forest*, p106-111

wide ecological condition" was termed "forest health". One aspect of ensuring "forest health" was the use of "controlled burning" to reduce hazardous fuel conditions and limit the number of extreme fires.[53]

This philosophy was supported by the Tall Timber Conference in 1972. Founded in 1962, the Tall Timber Conference was a venue to question the ecological benefit of fire and the impact of suppression management. Robert Marsh, a research scientist from the Tall Timber Lab, accurately described this new trend of thought when he said at the conference, "We are actually protecting trees to death; we are building towards a disaster situation."[54] Research showing the benefits of fire on soil composition and ecological diversity was presented. Henceforth, contemporary ecology included fire as a function of natural systems. Fire was no longer viewed as ecological murder, but a necessary function for ecological survival.[55]

Policies began to reflect the new scientific understanding of fire. The National Forest Management Act of 1976 set a new management directive for the National Forest Service. [56] Under the new act, the National Forests were to be managed for their diversity of plants and animals, not just for their economically valuable species. In 1978, Prescribed Natural Fire became part of the national "total fire" management policy across all federal lands.[57]

The Prescribed Natural Fire policy was put to the test during the 1988 fires in Yellowstone National Park. The fires started that summer through natural causes such as lightning strikes were left to burn, whereas fires ignited by unnatural causes such as human negligence were suppressed. However, as the fires grew larger and the weather worsened, park officials decided to suppress all the wildfires. This decision made little difference to the fires;

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[53] Hays, *American people and the National Forest*, p122
[54] Carle, *Burning Questions*, p 112- 175
[55] Pyne, *America's Fire*, p 22-23
[56] Klyza, *Who Controls Public Lands*, p73
[57] Carle, *Burning Questions*, p 181

high winds and numerous lightning strikes throughout August and early September led to eight major fires burning over 1,405,000 acres in the Greater Yellowstone Area alone.[58] The fires were not extinguished by the resources or men; rather, they were finally extinguished by the winter snows.[59]

The media coverage of the 1988 fires was emotionally charged and backed by little to no scientific support for a large number of the stories. Support for the Prescribed Natural Fire approach quickly turned to outrage as an icon of American identity "burned to the ground"[60] The public perception of the fires was that "the world's first national park had been destroyed" and had "been ruined forever."[61] While the public felt the Prescribed Natural Fire plan was "misguided and contentious," a large sector of the scientific community held that it had been "prescribed fire with no prescription."[62] Prescribed Natural Fire was, to these scientists, far too simplistic a solution for a complex problem. The fire regimes within many ecosystems had been changed by the history of suppression and changing land uses; simply putting fire back into the forest with no plan or objective was no longer a viable option. The fires of 1988 promoted a national review of fire policy by federal land agencies and stimulated fire research.[63]

In 1994, the Congress appointed the National Commission on Wildfire Disasters, a multidisciplinary commission, reported that within the National Forests there were dangerous fuel

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[58] Guth, A. Richard and Stan B. Cohen. *Red Skies of '88: The 1988 Fire Season in the Northern Rockies, the Northern Great Plains, and the Greater Yellowstone Area*. Missoula, MT: Pictoral Histories Publishing Company, 1989*, p* 120

[59] Guth , *Red Skies of '88,* p 120

[60] Jensen, Sara and Guy McPherson. *Living With Fire*, p12-13

[61] Hansen, Liane and Laura Krantz. August 29, 2008. "Remembering the 1988 Yellowstone Fires." National Public Radio. http://www.npr.org/templates/story/story.php?storyId=94126845. Accessed Dec 21, 2012

[62] Jensen, . *Living With Fire,* p12-13 and Pyne, *American Fires*, p 38

[63] Pyne, Stephen. *Fire: A Brief History*. London: University of Washington Press, 2001, p 42 -44

accumulations that had the possibility to increase the size and severity of fires. [64] In 1995, the Federal Fire Policy/Wildland Fire Management Policy and Program was created with the aim of providing clear and concise direction for managing fires throughout all relevant federal agencies by establishing clear guide lines.[65] These principles focused on areas such as firefighter safety, the role of fire in ecology, and making fire protection economically viable when necessary. Fires were to be prevented rather than suppressed and suppression measures were to be based on a value risk assessment. The program was intended to create a national unified fire plan across all the federal agencies. However, by 2000 it was discovered that ecological conditions within the study areas were far more degraded than previously perceived.[66]

The 1995 Fire Plan was replaced in 2001 by the Federal Fire Policy, which was intended to achieve many of the same goals as the previous plan.[67] However, it was hardly established before it was overshadowed by the 2002 Healthy Forest Initiative. The policy was passed in an atmosphere of political pressure caused by the large Southern Californian fires earlier that year, the Healthy Forests Initiative focused on the reduction of fuel loads and the restoration of forest health. [68]

The 2002 Healthy Forest Initiative, along with the 2009 Collaborative Restoration Act, created large-scale restoration projects such as the Four Forest Restoration Initiative (4FRI) that aims to treat 2.8 million acres within four National Forests in Arizona over a 10 year period. The 4FRI project goal is designed to restore structure and pattern composition of dry and mixed conifer systems with an added economic objective for areas around the 4FRI project in the form of timber production. Implementation of treatment for the first 300,000 acres will begin in

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[64] Linton, *Wildfires,* p85
[65] Linton, *Wildfires*, p 122
[66] Carle, *Burning Questions,* p248
[67] Linton, *Wildfires*, p 124
[68] 4 Forest Restoration Initiative. Accessed February 6, 2013. http://www.4fri.org/.

2013.[69] A small portion of those 2.8 Million acres will encompass part of the Schultz Fire area located within the Coconino National Forest.

The Coconino National Forest has the unique benefit of being located in Northern Arizona, one of the most studied areas concerning fire and its effects within the United States. Arizona is largely composed of public lands and many of the first Forest Reserves were created within it; it has an ever-expanding wilderness urban interface, and its ecosystems have been "profoundly disturbed by…fire exclusion (from grazing to fire suppression.)"[70] The Fort Valley Experimental Forest and the Gus Pearson Natural Area long-term research projects have helped to prove the fire adaptation of species and the benefits from fuel treatments such as thinning and prescribed fire. The Schultz Fire area is also largely composed of Ponderosa pine, which is one of the most studied tree species in America, due to its importance to a wide variety of forest ecosystems.

The history of forest management in the Coconino National Forest has reflected much of the same historical issues as the rest of the country. The Coconino National Forest was established in 1898, not long after Flagstaff was founded. It was originally called the San Francisco Mountain National Forest Reserve, and encompassed the San Francisco Mountains and its four major peaks. In 1908, the Reserve was expanded and re-designated as the Coconino National Forest which is divided into two parts, north and south, by the city of Flagstaff.[71] The Schultz Fire was located within the northern part of the Coconino Forest along the San Francisco Peaks. Until the 1980s the forest provided a large amount of Ponderosa pine timber, mainly for railroad construction.[72] To protect these timber resources, and the nearby wildland-urban interface, fires have been suppressed for much of the Forest's history. The majority of fires

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[69] Interview Dick Fleishman and Mary Lata
[70] Pyne, *America's Fires,* p 46
[71] USDA Forest Service. Accessed February 6, 2013. http://www.fs.usda.gov/coconino.
[72] Interviews Beale Monday and Joseph Luttman

within the Coconino National Forest from 1970 to 1999 were contained to or under 10 acres.[73] Small amounts of timber are still removed through seasonal fire wood permits distributed throughout different designated areas along the Coconino Forest. The area is now mainly used for recreational purposes.

The last major fire to burn in the Schultz Fire area was the Radio Fire in 1977 at 4,684 acres. There has been no fuel or fire treatment within the area in recent history; most of the small fires within the area have been attributed to escaped campfires or other human related causes. For Example the Mesa 89 fire that burned earlier in 2010 was caused by human activity and controlled at 555 acres (Figure 3).[74]

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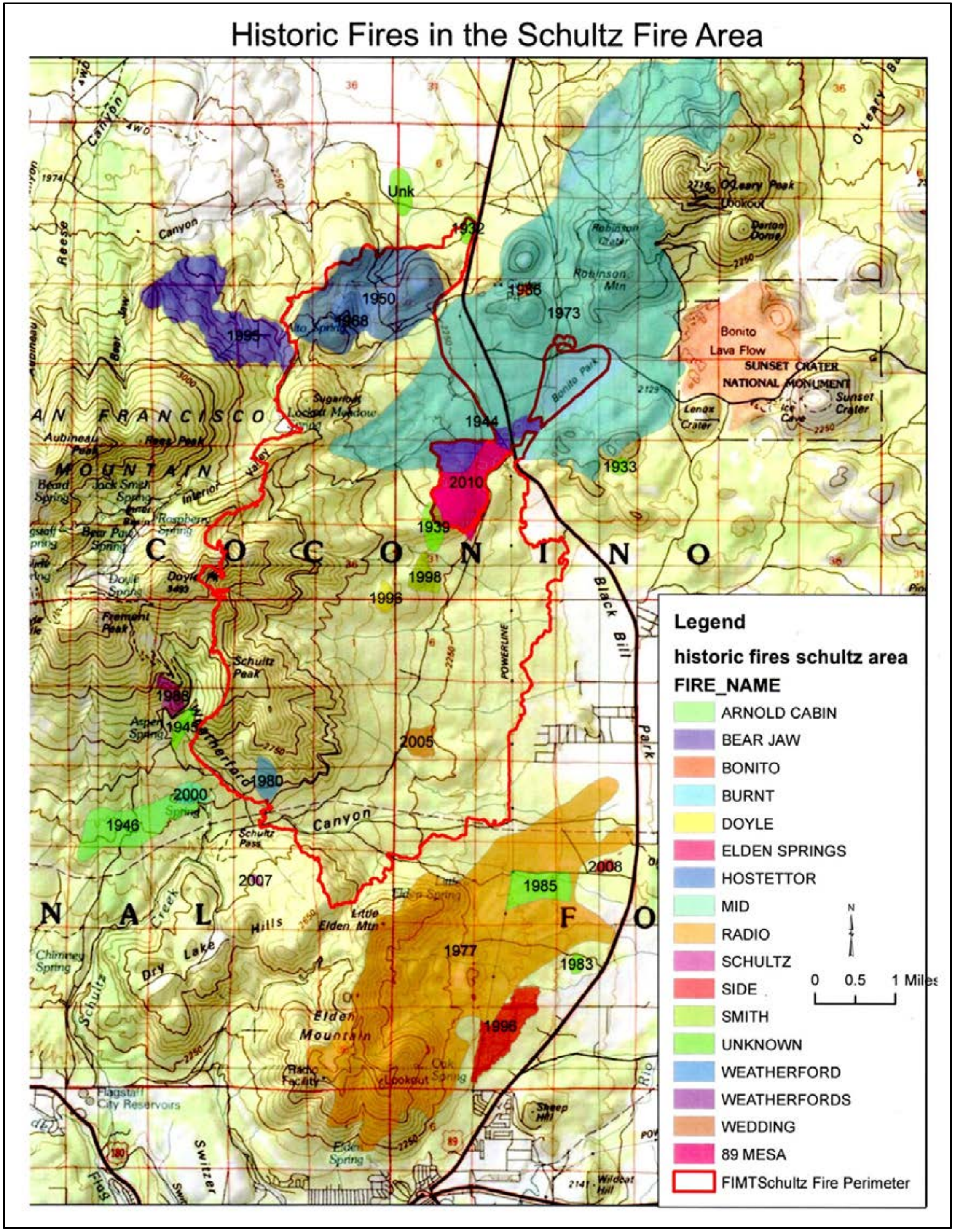
[73] Fule, Peter, Charles McHugh, Thomas Heinlein, and W W. Covington. "Potential Fire Behavior is Reduced Following Forest Restoration Treatments." USDA Forest Service Proceedings RMRS-P-22 (2011), p33

[74] Interviews Dick Fleishman and Mike Elson

Figure 3: Schultz Fire area burn history.[75]



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[75] Interview Dick Fleishman Map created by Fleishman for the purposes of this thesis.

A planned fire and fuel treatment for the area, the Jack Smith/ Schultz Fuels Reduction and Forest Health Project (Jack Smith/ Schultz), was to be performed in 2008. This treatment would have encompassed approximately two-thirds of what became the Schultz Fire area (Figure 4).[76] The project was canceled due to litigation by environmental groups concerned about the thinning portion of the treatment and the decline of timber prices.[77] The project would have treated a total of 11,827 acres. Mechanical thinning would have encompassed 7,078 acres, hand treatment and thinning 1,110 acres. Prescribed burning would have covered 9,662 acres: 8,818 acres would have received thinning and burning treatments, while 844 acres would have been treated with prescription burning only.[78] The aim of the treatments were to reduce fuel loads within the area, reduce tree density especially in the case of small diameter trees, enhance uneven age forest structure, and reintroduce natural/historic fire composition of low/moderate intensity fires. The second aim of the project was to reduce risk to surrounding wilderness urban interfaces such as Doney Park and Timberline, urban areas that were evacuated during the Schultz Fire and later impacted by flooding. Finally, the plan was intended to restore health to the forest structure, increase species diversity, reduce the risk of crown fire, and remove non-native species from within the area. The projected cost of performing the (Jack Smith/Schultz project) treatment was $2.1 million.[79]

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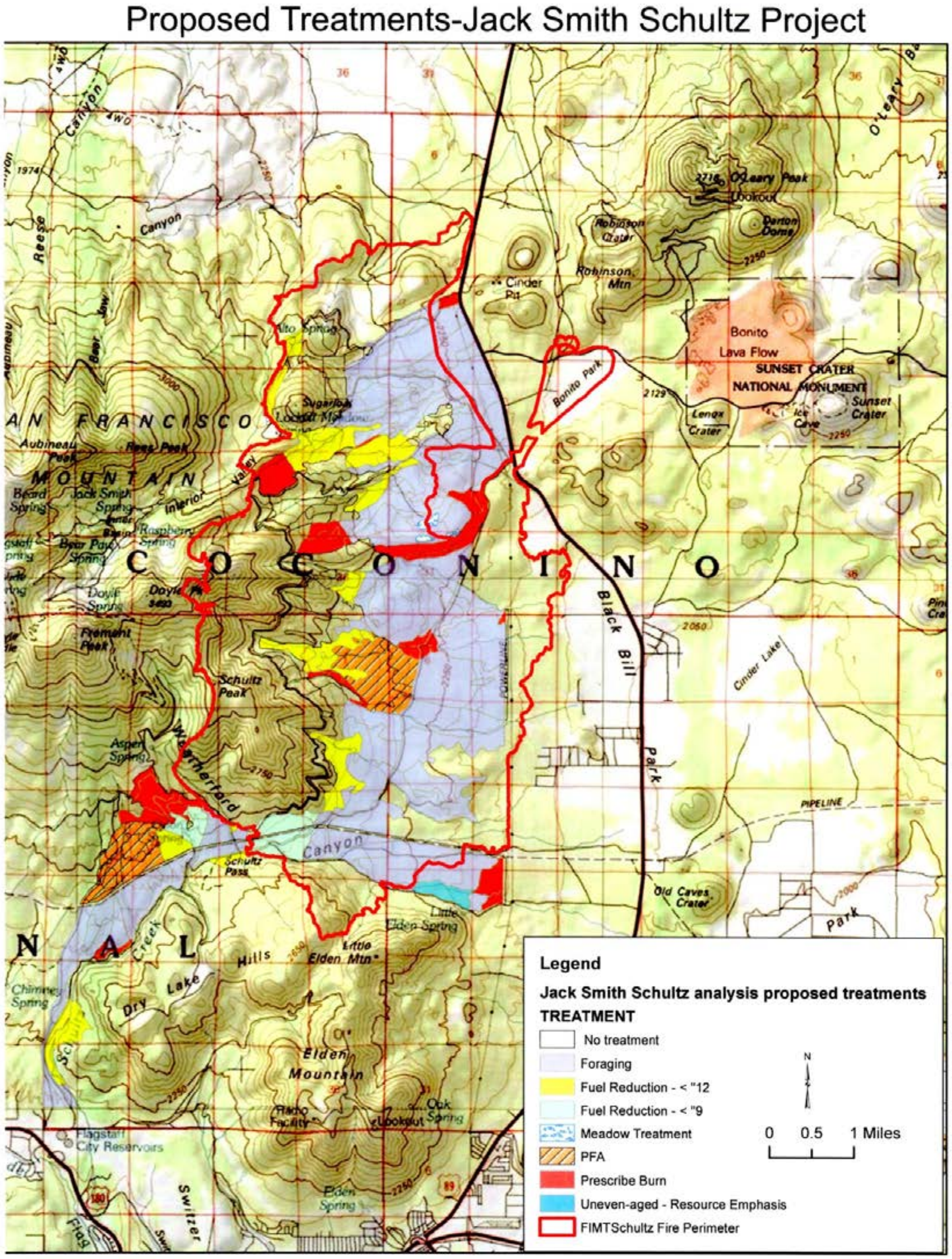
[76] Interview Mike Elson

[77] Interview Mike Elson, Joe Luttman, And Beale Monday

[78] "Environmental Assessment Jack Smith/Schultz Fuel Reduction and Forest Health Project." USDA Forest Service (2008). And "Decision Notice and Finding of No Significant Impact Jack Smith/Schultz Fuels Reduction and Forest Health Project." USDA Forest Service (August 2008).

[79] Schultz Fire/Flood and Burned Area Emergency Response Briefing Paper

Figure 4: Comparison of Schultz Fire perimeter with Jack Smith/Schultz project.[80]



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[80] Interview Dick Fleishman Map created by Fleishman for the purposes of this thesis.

The Schultz Fire was reported at 11 A.M. on the morning of June 20, 2010. Firefighters were initially dispatched from the Summit Fire District and various federal agencies. Many federal fire crews were already in the area due to several other large fires in Northern Arizona at that time. By 1 pm, aerial attack had begun using helicopters, water tankers, and retardant drops. Due to high winds, these aircraft had difficulty making their drops.[81] Indirect dozer lines were constructed near populated areas to protect houses. Due to high winds and crowning, the fire was mainly fought indirectly. After the first three days, fire activity slowed, and the fire was declared contained seven days later.[82]

Much of the media response during the fire was emotionally charged, and focused on the "bravery" of firefighters rather than on the ecological importance of fire in Ponderosa pine forests. After the fire this emotional language remained. For example, language taken from a USFS/NPS Interpretive hike of the Schultz Fire area offered to the public the same year as the fire emphasizes the story of the fire rather than an understanding of its effect on the surrounding area. This interpretive hike was designed to educate local residents about the Schultz Fire area but the emotional language of the pamphlet given to hike participants overshadows of importance of fire within the ecological system:

> Sunday, June 20, 2010: hot and dry in Flagstaff with winds gusting to 40 mph. At 11 am, a campfire left smoldering just east of Schultz Pass spreads into surrounding ground debris. Within minutes the ground fire tears into dense ponderosa stands and explodes into the most disastrous wildfire in Flagstaff's history.
>
> By mid-afternoon it was consuming a square mile an hour on the east side of the San Francisco Peaks…Ground crews guided heli-tankers and slurry bomber drops, trying to contain the fire's spread. The fire raged for ten days…miraculously, firefighters kept the fire from reaching any homes, and no one died in the blaze.[83]

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[81] Interview Don Howard

[82] "InciWeb-Incident Information System: Schultz Fire." Accessed February 6, 2013. http://inciweb.org/incident/1996/.

[83] "Schultz Fire: The Source and Waterline Road." NPS/USFS Interpretive Partnership (2010).

Following the fire the return of native bunchgrasses such as Arizona fescue and Squirreltail were witnessed in the fire area even before monsoonal rains began at the end of June. Due to the effects of hydrophilic soil and the loss of crown and surface vegetative cover in the high severity areas, mixed with the slope steepness of the San Francisco Peaks, Burn Area Emergency Response (BAER) efforts were focused on the mitigation and prevention of flooding. A total of 11 watersheds were measured within the burned area by the Burned Area Emergency Response project. Of these 11 watersheds, 5 experienced high severity burns over 50% of their area, while 2 watersheds experienced high severity burns over 70% of their area. [84] The Schultz Fire area also contained some of the major water resources for the city of Flagstaff, such as the Schultz Pipeline road. Steps were taken in 2010 to stabilize this road before and after flooding, and major repairs were being performed to the pipeline and road in 2012 during the time of this study. Higher flooding levels are expected for up to 10 years after the fire, with the major flooding expected to peak within the first 3 to 5 years.[85]

To stabilize the slopes in preparation for Flagstaff's annual monsoons, aerial application of straw over 3,000 acres of the burn was performed by July 22, 2010. A seed mixture of native and nonnative species was also aerially dropped over 700 acres of the burn during the same period. The aerial mulching and seeding was primarily performed to provide ground cover on the high severity areas that had slopes of 40% or more. The effectiveness of the treatment was rated for a 10-year storm event. Unfortunately the area experienced a 17-year rain event (1 inch in 15 minutes) on July 20, 2010 followed by an 85+ year flood event later that day. [86] This flooding sadly claimed the only human casualty of the fire and flooding events, a 12-year-old girl who was

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[84] "Burned Area Emergency Response Report." U.S. Forest Service, Coconino National Forest, Flagstaff, Arizona. (July, 8, 2010)

[85] Interview Rory Steinke

[86] "Schultz Fire/Flood and Burned Area Emergency Response Briefing Paper." Coconino National Forest, Flagstaff Ranger District (April 30, 2012).

reportedly caught in the floodwaters while trying to view them.[87] A secondary aerial drop of straw was performed after the first set of monsoonal floods covering about 700 acres. A secondary aerial seeding was also performed over 1,146 acres with a mixture of native and non-native seeds.[88] Both were performed by October of 2010.

The cost of suppressing a fire often outweighs the cost of treating an area to reduce fire risks. The total suppression cost for the Schultz Fire was nearly $10 million, with almost 900 people working to contain the fire. The BAER treatments cost approximately $4.1 million. The cost to Coconino County in manpower, both from the local Fire Department and from controlling flooding effects and repairing damages, is reported at $58 million. The projected cost of performing the (Jack Smith/Schultz project) treatment that would have thinned two thirds of the Schultz Fire area was $2.1 million.[89] By comparison a total of $72.1 million was spent on the Schultz Fire itself and its after effects.

Due to the Schultz Fire and the flooding that followed for several years, Flagstaff passed Bond Question 405 to raise up to $10 million in general obligation bonds to fund the Forest Health and Water Supply Protection Project. This bond money will be used to treat the Rio de Flag Watershed and Lake Mary Watershed to prevent further flooding and fires.[90] The city of Flagstaff will employ bond funds in connection with local environmental, non-profit, and government agencies. (Appendix Note 2: Ballot Question 405)

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[87] *Arizona Daily Sun*, June and July, 2010

[88] "Burned-Area Report (Reference FSH 2509.13." USDA Forest Service (September 8, 2011).

[89] Schultz Fire/Flood and Burned Area Emergency Response Briefing Paper

[90] "Information Pamphlet for the City of Flagstaff, Arizona Special Debt Authorization Election November 6, 2012." The City Council of the City of Flagstaff, AZ (November 6, 2012). Accessed February 6, 2013. http://www.flagstaff.az.gov/DocumentCenter/View/40521.

The future of fire in America is caught up in the legacies of the past, balanced between fire suppression and scientific studies of fire's place within systems, while trying to return fire to a manageable factor in the overall structure of various ecosystems. Future management will require greater cooperation in the public, management, and scientific spheres of society to be efficient. Finally, The Schultz Fire serves as a good example of how a better understanding of the intricacies of how history of fire management affects the present and future of policy regarding fire.

CHAPTER 3: FIRE BEHAVIOR AND EARLY SUCCESSION WITHIN THE SCHULTZ FIRE AREA

ABSTRACT:

By examining the Schultz Fire as a case study, I hoped to gain further understanding of how management practices have affected fire severity levels and how the forest structure was affected by such a disturbance. The main objectives of this study were: (1) to analyze the causes of the fire severity of the Schultz Fire, especially: topography, fuels, or weather; (2); to examine the possible correlation between fire severity and tree density; (3) to determine whether fire severity effected percentage of cover; and (4) to investigate whether post-fire plant species richness, plant cover, and tree regeneration was related to fire severity two years after the Schultz Fire.

The main factors that influenced the rapid spread and high severity of the Schultz Fire, based on modeling, were high winds combined with the presence of high surface fuel load. No statistically significant relationship between tree density and fire severity levels was found. As fire severity increased, there was a statistically significant increase in species richness. Severity level had little effect on the percentage of pant cover by. There is a possibility for a change in woody species composition in the future due to the lack of seedlings, especially Ponderosa pine, measured in the burned area. The Schultz Fire demonstrates that the combination of high fuel loads and high winds can create high severity crown fires that have an impact on ecosystems and communities.

INTRODUCTION:

Throughout the last century, wildfires have been seen as a major threat to forest health and have been excluded within the American southwest landscape through a variety of management policies.[91] In more recent years, however, studies have shown that fire may have been the most important disturbance process in shaping the American southwest Ponderosa pine forests. [92] These ecosystems have historically been influenced by frequent low-severity surface fires, but the exclusion of fire has changed fire regimes in these forests to infrequent high-severity crown fires. These infrequent high-severity fires regimes have helped to change forest structure in a variety of ways, including increased numbers of smaller diameter trees, heavier fuel loads, and increased canopy cover.[93]

The way fire behaves within an ecosystem is dictated by three general factors: weather, topography, and fuels. The interactions of these three factors during a fire determine the characteristics of a fire and its behavior, intensity, and severity. Topography is a fixed property composed of slope, aspect, elevation, and the configuration of the landscape. Weather includes factors such as temperature, relative humidity, precipitation and wind speeds before or during the fire. Fuels are affected by the mixture, load (i.e. amount), and arrangement of fuel types over their varying sizes and moisture contents.[94] Within these given factors wind, fuel levels, and slope have the greatest effect on fire behavior affecting flame length and the rate of spread of a

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[91] Beschta, Robert L., Jonathon J. Rhodes, J. Boone Kauffman, Robert E. Gresswell, G. Wayne Minshall, James R. Karr, David A. Perry, F. Richard Hauer, and Christopher A. Frissell. “Post fire Management on Forested Public Lands of the Western United States.” *Conservation Biology*. 18:4 (2004): 957-67, p 958

[92] Beschta et al., “Postfire Management”, p958

[93] Passovoy, M. David and Peter Z. Fule. “Snag and Woody Debris Dynamics Following Severe Wildfires in Northern Arizona Ponderosa Pine Forests.” *Forest Ecology and Management* 223 (2006): 237-46, p237

[94] Pyne, *Introduction to Wildland Fire,* p 48-52

fire. Wind and fuel influence the increase/decrease of intensity and severity of a fire over a landscape, and its ability to move from surface fuels into crown fuels.

A basic premise of fire ecology is that a majority of terrestrial systems have experienced recurrent fire over several millennia and species within these systems have evolved adaptations which respond favorably to these recurrent events.[95] Species such as Ponderosa pine have adapted to frequent low intensity surface fire.[96] Many of the plant species associated with Ponderosa pine forest are fire resistant, dependent, or resilient. For example, fire is the primary means within these systems for restoring and maintaining herbaceous cover.[97]

A change from one fire regime to another may lead to the loss of fire dependent and adapted species within a system.[98] Anthropogenic changes, such as fire suppression, have impacted the fuel load and structure in southwestern Ponderosa pine forest. These changes in fuels and fire regimes have also impacted the regeneration of fire dependent species and the composition of species in forests. Frequent low-intensity surface fires removed smaller trees of all species and reduced surface fuels, helping to maintain sparse, open stands in xerophytic (dry) Ponderosa pine forest. Increased fuel loading due to the changes in fire regimes within these systems have been linked to the increase in high severity fires.[99]

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[95] Pyne, *Introduction to Wildland Fire,* p180

[96] Noss, Reed, Jerry Franklin, William Baker, Tania Schoennagel, and Peter Moyle. "Managing Fire-prone Forests in the Western United States." *Frontiers in Ecology and the Environment* 4, no. 9 (2006): 481-87, p152

[97] Moir, William, H B. Geils, M A. Benoit, and D Scurlock. "Ecology of Southwestern Ponderosa Pine Forests Gen. Tech. Rep. RM-GTR-292." U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station (1997): 3-27, p152

[98] Thonicke, Kirsten, Sergey Venevsky, Stephen Sitch, and Wolfgang Cramer. “The Role of Fire Disturbance for Global Vegetation Dynamics: Coupling Fire into a Dynamic Global Vegetation Model.” *Global Ecology and Biogeography* 10, No. 6 (Nov,2001.) 661-77, p661-662

[99] Cocke, Allison E., Peter Z. Fule, and Joseph E. Crouse. “Forest Change on a Steep Mountain Gradient after Extended Fire Exclusion: San Francisco Peaks, Arizona, USA.” *Journal of Applied Ecology* (2005): 814-23.

The main objectives of this study were: (1) to analyze the causes of the fire severity of the Schultz Fire, especially: topography, fuels, or weather; (2); to examine the possible correlation between fire severity and tree density; (3) to determine whether fire severity effected percentage of cover; and (4) to investigate whether post-fire plant species richness, plant cover, and tree regeneration was related to fire severity two years after the Schultz Fire. By examining the Schultz Fire as a case study, I hoped to gain further understanding of how management practices have affected fire severity levels and how forests respond to such a disturbance.

STUDY AREA:

The Schultz Fire area was located 4 miles outside of Flagstaff, Arizona along Highway 89, on the east side of the San Francisco Peaks in the northern section of the Coconino National Forest. The dominant vegetation type of the area was Ponderosa pine/ Arizona fescue (Appendix Note 3: Ponderosa pine). The fire area, as identified by the US Forest Service, was composed of 5,876 acres of high severity fire, about 40% of the total area burned; 4,128 acres, or 27%, mixed severity fire; 3,825 acres, or 25 %, low severity fire; and 1,222 acres, 8% of the total fire area, unburned. In total, the Schultz Fire area covered 15,075 acres of the Coconino National Forest.[100]

The historic fire regime for the area was one of frequent low/moderate intensity surface fires every 3-15 years. Historic accounts of the area describe a park-like environment dominated by open woods and thick herbaceous cover.[101] Historic stand reconstruction identified a tree density of between 20 and 60 trees per acre, compared to 200 to 600 trees per acre in

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[100] "Schultz Fire Treatment Effectiveness Monitoring Report, September 8, 2011." USDA Forest Service (September 2011), Burned-Area Report (Reference FSH 2509.13 , and "Burned Area Emergency Response Report."

[101] Friederici, Peter, ed. *Ecological Restoration of Southwest Ponderosa Pine Forests.* Washington: Island, 2003, p31

contemporary stands.[102] The area had not experienced commercial lumber production since the 1970s.[103] The impacts of the timber industry and the removal of fire from the system had created largely even-aged stand conditions. The fire hazard for the Schultz Fire area was in the 90th percentile with winds over 32 km/h (20 mph) from April to July. Winds in the Flagstaff area during the month of June normally range between 29 to 64 km/h (18 and 40 mph). Due to the canopy being almost closed 84%, there were serious concerns about the ability to suppress a crown fire from July to October within the Schultz Fire area.[104] The area is bordered by a wilderness-urban interface, including major water and natural gas lines, road systems, and numerous private homes, making suppression necessary

The dominant soil type is Mollic Eutroboralfs, loamy-skeletal, mixed, deep cobbly, sandy loam as modeled by the Forest Terrestrial Ecosystem Survey in 1995. This soil type accounts for 49% of all soil types associated with Ponderosa pine forest. [105] The area ranges in elevation from 2,134 to 2,438 meters (7,000 to 8,000 feet), with a predominantly east-facing aspect. Slopes are at 2% along Highway 89 and increase to 40% into the San Francisco Peaks. The area includes 11 separate watersheds.

At the time of the Schultz Fire, Flagstaff was experiencing normal temperatures for June, but precipitation was below normal levels, leading to pre-drought conditions in the Coconino National Forest. The last precipitation in the area before the fire was 1.27 cm (0.5 in) of snow on May 2, 2010.

The fire was reported at 11 A.M. on the morning of June 20, 2010. Indirect dozer lines were constructed near populated areas to protect houses. Due to high winds and crowning, the

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[102] Friederici, *Ecological Restoration of Southwest Ponderosa Pine Forests*, p 34

[103] Interview Joseph Luttman and Beale Monday.

[104] "Environmental Assessment Jack Smith/Schultz Fuel Reduction and Forest Health Project." P 15

[105] “Burned Area Emergency Response Report”

fire was mainly fought indirectly. During the first three days, the fire was driven by winds that averaged 64 km/h (40 mph) with gusts up to 113 km/h (70 mph).[106] The majority of the fire burned within the first day due to high winds creating a large portion of the high severity burn area (Figure 5).

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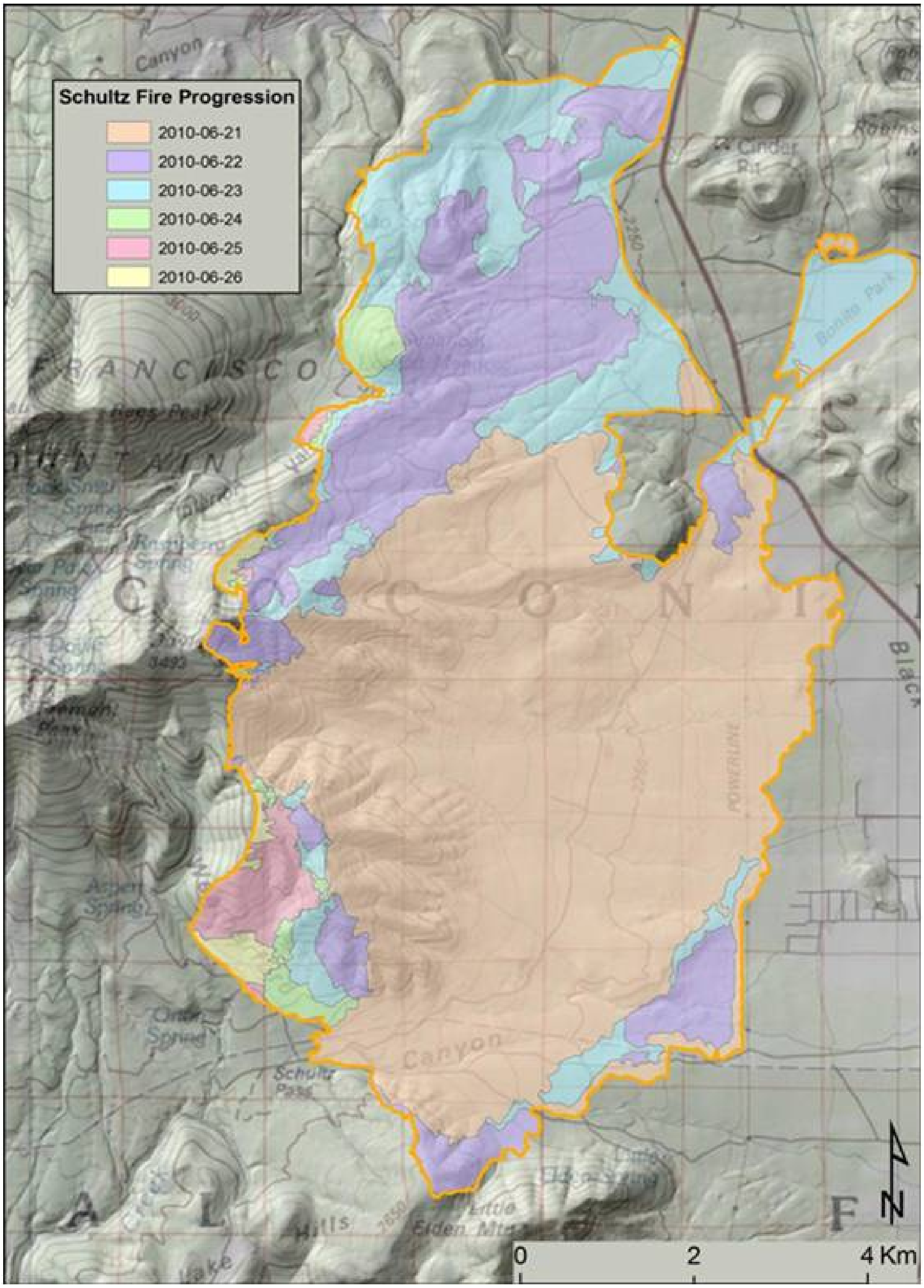
[106] Interview Mike Elson and Don Howard

Figure 5: Schultz Fire progression June 21-26, 2010.[107]



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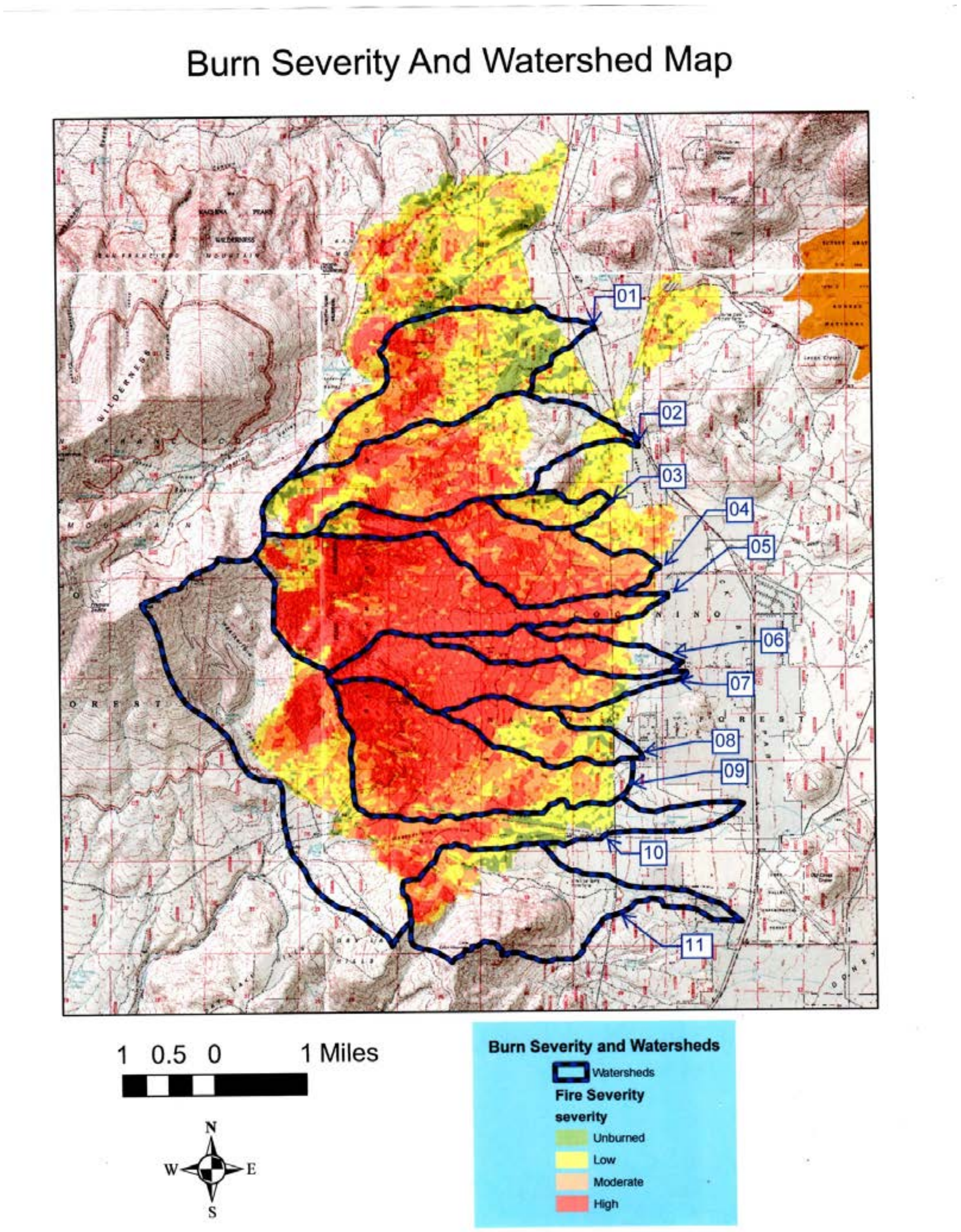
[107] Youberg, Ann, Karen Koestner, and Dan Neary. "Wildfire, Rain and Floods: A case study of the June 2010 Schultz Wildfire, Flagstaff, Arizona." *Arizona Geology* (2010). Accessed February 6, 2013. http://www.azgs.az.gov/arizona_geology/winter10/article_feature.html.

METHODS:

EXPERIMENTAL DESIGN:

The majority of the Schultz Fire area is transected by FS road 420, which contours the mountainside, with the west side of the road forming the up-slope area, and the east side of the road forming the down slope area. Using this road as a landmark, three 10 meter by 10 meter plots for each severity level were measured on both the up slope and down slope areas when available. Severity levels were divided into control (no evidence of burn), low (some evidence of burn and little to no death), mixed (evidence of burn into the lower crown of the trees and some death), and high (evidence of burn into crown or complete crown burn, plot mostly made up of dead trees). A total of 26 plots per severity level were measured, for a total of 104 plots. These 104 plots were used to record plant species present, tree density, and data for BEHAVE modeling. Plots were laid out in a paired offset pattern, linked by a single corner, where conditions allowed. Some plots were studied singularly where the offset joined plot could not be measured safely. All plots were measured in Burned Area Emergency Response (BAER) mapped areas (Figure 6).

Figure 6: BAER severity and watershed map for Schultz Fire.[108]



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[108] "Burned Area Emergency Response Report"

A second road, the Schultz Pipeline Road, contours the mountains further up the slope. Slopes in this area frequently reach over 30%, and much of the area is high severity burn with significant erosion. During the time of study, this area was closed to the public for road work. Due to safety concerns related to the steep, unstable slopes and continued road work, I gathered no data in this area.

TOPOGRAPHY:

Elevation, slope, and aspect were measured for each plot to estimate conditions for fire modeling. Placement of each plot was tracked by measuring the latitude and longitude at the top right corner facing downhill using a hand held GPS (model Garmin Etrex10). Elevation was calculated through readings made with the GPS. Slope was measured in percent using a clinometer. Aspect was determined with an orienteering compass and noted in cardinal direction.

TREES:

Trees within plots were determined to be either dead or living by the coloration and visible crown mass. Those with little to no green crown mass were determined to be dead trees, while those with green crown mass were considered living. The diameter at breast height (DBH) of six trees within each plot was measured to the nearest half centimeter to determine relative stand age and size. The total number of trees in the plot was counted to help to determine stand density and its relation to fire severity levels. Ponderosa Pine trees were described as either small or large diameter dependent on DBH with trees under 6 cm in diameter classified as small diameter, and those over 6 cm in diameter were classified as large diameter.

The average DBH based of large diameter Ponderosa pine present within each severity level was calculated to determine the relative size structure of large trees within these classes. Small diameter trees for Ponderosa pine were excluded from the DBH calculations. DBH for other recorded woody species was not calculated owing to the small number recorded in the area and to give an accurate representation of average DBH across the landscape.

FUELS:

Fuels were measured to help determine fuel models to be used within BEHAVE. In the 26 control plots, litter and duff depth along with woody debris classes of 1, 10, 100, and 1000 hour time-lag solid and rotten fuels were measured to give an estimated average of fuel loading conditions in the area. Woody Debris was examined with a Go/No Go gauge to determine time-lag class along the whole of a 10 meter (32.81 feet) transect line using a Modified Brown line transect technique. Litter and duff depth were measured to the nearest half centimeter by placing a ruler into the ground vertically at set sample point along the line at 1, 3, 5, 8, and 10 meters. Fuel loading calculations were performed using standard fuel load calculations from Brown 1974.[109] Measurements were converted from metric to English for modeling purposes.

MODELING:

BEHAVE Plus 5 is a fire modeling system used to calculate fire behavior, spread, and intensity/severity. The BEHAVE modeling was used to help to determine rate of spread (ROS) in chains per hour (ch/h), flame length (FL), and the effects of weather, slope, and fuels as factors in this fire. Fire behavior fuel models were entered into the system along with moisture content of fuels based off of relative humidity for the days of the fire, slope (%), and wind speed (mph) to determine calculations. BEHAVE was used to determine chains per hour (ch/h), or 20.12 meters per hour (66 feet per hour), to gauge the relative rate of fire spread (ROS) on its own accord and flame length (fl), which will help verify likely fire behavior within the system such as crown fire, intensity, and severity.

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[109] Brown, James. *Handbook for Inventorying Downed Woody Material*. Ogden: USDA Forest Service Gen, Tech, Rep, INT-16, 1974.

Original fuel model 8 and 9 along with standard fuel models timber liter (TL) 1, 3, 6, and 8 were run through BEHAVE. Fuel model 8 and TL6 represented an interior ponderosa pine with recent (in the last 2 years) prescription fire, whereas model 9 and TL8 represented an interior Ponderosa pine forest with a long period of fire exclusion (Appendix Note 4: Fuel Models). These four models were chosen from the Fuel Characteristic Classification System (FCCS) as a standard fuel bed used in subtropical steppe desert under Bailey's Eco-region Divisions map. Standard models TL 1and TL3 were chosen for their comparability to measured fuels within the Control plots. Model TL 1 and 8 represented a low fuel load, models TL 3 and TL 6 represented a moderate fuel load, and model 9 and TL8 represented a high fuel load.

Parameters were set to be tested in low moisture content and high moisture content based on relative humidity data from NOAA. The temperatures for the 20-30th of June averaged a high of 26 to 29 degrees Celsius (78 to 85 degrees Fahrenheit) and a low of 2 to 11 degrees Celsius (36 to 52 degrees Fahrenheit) with a relative humidity low of 5% and a high of 15%. The effects of temperature over the course of the day and the day's relative humidity were used as the basis for calculating fuel moisture content in BEHAVE. Fuel moisture content (MC) in 1 hr fuels was tested at a low of 2% and a high of 5%, whereas 10 and 100 hr fuels were tested at a low of 5% and a high of 15%.[110] Wind speeds were tested in BEHAVE at speeds of 0, 16, 32, 48, and 64 km/h (0, 10, 20, 30, and 40 mph). Wind speeds were based on reported highs for Flagstaff measured at the Western Region Headquarters weather station in Bellemont, AZ, roughly 32 kilometers (20 miles) from the fire, and observed wind speeds at the fire. Due to the fact that BEHAVE does not process wind speeds over 64 km/h (40 mph), the reported wind speeds up to 113 km/h (70 mph) could not be tested. Slope was tested at 0, 10, 20, 30, and 40%. These slopes are based on ranges available within the tested plots and the surrounding area; though I was

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[110] NOAA, n.d. Web. 11 Feb. 2013. <http://www.wrh.noaa.gov/fgz/>.

unable to measure plots on steeper slopes due to safety concerns, the fire burned in slopes up to 40%.

EARLY SUCCESION:

The presence and amount of cover of each plant species was estimated within each plot across all severity levels to determine early plant species richness. Plots were divided into four triangles meeting in the center of the plot, and the plant species presence and cover were recorded within each triangle from the boundary line in to the center. The relative cover for each species was calculated by percentage of ground cover per observed species within each triangle. A code system was used for ease of recording these percentages: 0=no cover; 1=1-5%; 2=6-25%; 3=26-50%; 4=51-75%; 5=76-100% (Appendix: plot paperwork). Midpoints for each cover code were: 1=3%, 2= 15.5%, 3= 38%, 4= 63%, and 5=88%. To estimate the percentage of cover per severity level and species, the recorded code for each measured line was converted to the midpoint percentage and then averaged across all four lines. The average for each plot was then calculated to form an estimate of the total average percentage of cover. The observed species were divided by their physiognomic type into three classes: forbs, grasses, and woody species such as trees and shrubs. The number of species per plot was recorded to determine if species richness increased as severity increased. Relative species cover for each plant was recorded to determine the variance of cover within each severity level. Coefficient of community was calculated to examine degree of similarity in the species present between the severity levels. Seedlings for woody species were recorded to determine woody species recovery within the burned areas.

STATISTICS:

ANOVA statistical analyses were performed in Statgraphics Centurion version 16.1.03 to test the relationship of tree density measurement and severity level, as well as species richness and severity level. Homogeneity of variances was checked against the Levene's and Bartlett's tests .

RESULTS:

TREES:

A total of 8 woody species were recorded across all the plots. Ponderosa pine was the dominant species present across all severity levels and was recorded in all 104 plots (Table 1). Only 3 species were recorded within all severity levels: Gambel oak, One-seed juniper, and Ponderosa pine.

Table 1: Total woody species distribution by plot and severity

Common name	*Scientific name*	# of plot present in	Severity	Large diameter	Small diameter	Total
Alligator juniper	*Juniperus deppeana Steud.*	1	M	1	0	1
Gambel oak	*Quercus gambelii Nutt.*	5	C,L,M,H	15	1	16
Limber pine	*Pinus flexilis James*	1	C	1	0	1
One-seed juniper	*Juniperus monosperma (Engelm.) Sarg.*	5	C,L,M,H	7	0	7
Ponderosa pine	*Pinus ponderosa Lawson & C. Lawson*	104	C,L,M,H	833	276	1,109
Quaking aspen	*Populus tremuloides Michx.*	1	C	6	0	6
Utah juniper	*Juniperus osteosperma (Torr.) Little*	2	M,H	8	0	8
White fir	*Abies concolor (Gord. & Glend.) Lindl. ex Hildebr.*	9	C,M,H	18	8	26

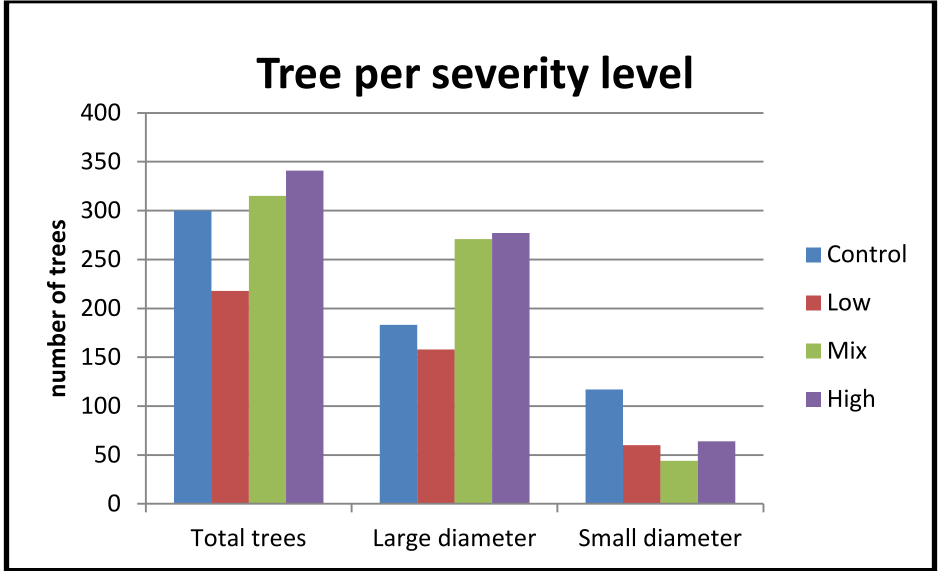
The average DBH for large diameter Ponderosa pine for all the severity levels was 29 cm (11 in). The average DBH within the severity levels ranged from approximately 25 cm to 32 cm (10 in to 13 in). DBH ranged within the severity levels from 6 cm to 107.5 cm (2.36 in to 42.42 in) in large diameter trees. Mixed and high severity plots had the greatest variability between their total average DBH and their minimum/ maximum average DBH (Table 2).

Table 2: Ponderosa pine DBH (cm) per severity level

Severity	Ave total DBH	Ave min DBH	Ave max DBH	Min DBH	Max DBH
Control	31.89	22.15	42.75	6	90.5
Low	30.03	19.83	41.98	6	79
Mixed	27.87	16.92	41.9	6	100
High	25.22	15.00	38.17	6	107.5
Total	28.75	18.48	41.2	6	107.5

Even though there was a slight increase within the total tree density in connection with increased severity level, there was no significant statistical relationship between tree density and severity level (Figure 7). (ANOVA test: P= 0.53).

Figure 7: Tree density as a function of severity level.



FUELS:

The average total fuel level of 23.40 tons per acre (t/ac) was comparable to fuel models 9 and TL8. Fuels loading in the 1, 10, and 100hr fuels at 1.81 t/ac were similar to fuel model TL 1, 3, 6, and 8. There were higher levels of large woody fuels (100 and 1000hr) at 18.76 t/ac than the smaller fine fuels (1 and 10 hr) at 0.48 t/ac. The 1000hr rotten fuels at 13.18 t/ac accounted for almost half of the average total of 23.40 t/ac within the fuel calculations (Table 3). The average total litter and duff depth was near 4 cm making the fuel loading comparable to fuel models 8, 9,and TL1. The combination of the maximum average liter and duff was near 7.5 cm in depth and was similar to fuel models TL3, 6, and 8 (Table 4).

Table 3: Fuel loading average and standard deviation tons per acre (t/ac)

fuel class	Ave t/ac	S.D. t/ac
1hr	0.01	0.003
10hr	0.47	0.19
100hr	1.33	0.85
1000 hr solid	4.25	9.12
1000hr rotten	13.18	7.59
Litter	1.83	0.68
Duff	2.28	1.15
Total	23.40	16.79

Table 4: Average litter and duff depth (cm)

Fuel class	Ave depth	Min ave depth	Max ave depth
Litter	2.17	0	4.57
Duff	1.5	0	3.05
Total	3.67		

FIRE MODELING:

In models of lower fuel loads, such as model 8 and TL1, there was a low rate of spread (ROS) and short flame length (FL). As the fuel loading increased, so did the ROS and FL. There was also an increased ROS and FL as wind speed increased. Slope had little to no effect on ROS and FL except in model TL8, where there was a slight increase in the ROS and FL when slope increased from 0% to 40%. (Table5).

Table 5: All fuel models minimum and maximums divided by fuel load type and moisture content (MC). (note: ch/h= 20.12 meters)

Low fuel load											
Low MC		Model 8		High MC		Low MC		TL1		High MC	
Slope (%)	Wind (km/h)	ROS (ch/h)	FL (m)	ROS (ch/h)	FL (m)	Slope (%)	wind (km/h)	ROS (ch/h)	FL (m)	ROS (ch/h)	FL (m)
0	0	0.4	0.18	0.3	0.12	0	0	0.2	0.09	0.1	0.06
0	16			5.3	0.52	0	16	1.7	0.27	0.9	0.18
0	32	10.3	0.79								
Medium fuel load											
Low MC		TL3		High MC		Low MC		TL6		High MC	
Slope (%)	wind (km/h)	ROS (ch/h)	FL (m)	ROS (ch/h)	FL (ft)	Slope (%)	wind (km/h)	ROS (ch/h)	FL (m)	ROS (ch/h)	FL (m)
0	0	0.3	0.15	0.2	0.12	0	0	0.9	0.40	0.6	0.31
0	16			2.9	0.40	0	48	121	3.69	60	2.41
0	32	6	0.64								
High fuel load											
Low MC		TL8		High MC		Low MC		Model 9		High MC	
Slope (%)	wind (km/h)	ROS (ch/h)	FL (m)	ROS (ch/h)	FL (m)	Slope (%)	wind (km/h)	ROS (ch/h)	FL (m)	ROS (ch/h)	FL (m)
0	0	1.1	0.52	0.8	0.43	0	0	1.3	0.43	0.9	0.34
0	64	155.8	5.06	93.8	3.66	0	64	301.6	5.18	145.3	3.35
40	64	158.2	5.09								

EARLY SUCCESION:

It was found that species richness increased as burn severity level increased (ANOVA test: $P < 0.001$). A total of 66 species were observed across the 104 plots measured. Of the total 66 species observed, 53 were forbs, 5 were grasses, and 8 were woody within the physiognomic groups. A total of 6 invasive species were observed within the forbs and grass physiognomic groups. Of the total species observed across the varying severity levels, 35 were in the control, 40 in low severity, 41 in mixed severity, and 54 in high severity levels (Table 6). A list of the overall species can be found in Appendix B: Appendix Table 1.

Table 6: Number of species present in severity levels cataloged by physiognomic group

Severity	Forbs	Grasses	Woody	Invasive	Total
Control	25	3	6	3	34
Low	32	5	3	5	40
Mixed	30	5	6	4	41
High	44	5	5	6	54
Total	53	5	8	6	66

Coefficient of community represents the percent of species in common between any pair of the 4 severity levels. Low and Mixed severity plots had the highest similarity when compared with other multi-level severity groupings, having 94.46% community similarity for total species. Low and Mixed severities also shared the highest similarity of forbs accounting for 93.75% species in common. In contrast Control and High severities had the lowest similarity of total community composition at 57.18% and lowest forbs similarity at 56.82%. All severity classes excluding the Control had the same grass species present. The Control shared 60% of its species with each of the other severity classes (Table 7).

Table 7: Coefficient of community matrix.

Forbs				
Severity	Control	Low	Mixed	High
Control	100	78.13	83.33	56.82
Low		100	93.75	72.73
Mixed			100	68.18
High				100
Grass				
Severity	Control	Low	Mixed	High
Control	100	60	60	60
Low		100	100	100
Mixed			100	100
High				100
Total				
Severity	Control	Low	Mixed	High
Control	100	75.68	80	57.18
Low		100	94.46	75.51
Mixed			100	71.43
High				100

There was little fluctuation between the severity groups in terms of their average total ground cover of plants. Low severity had the highest average percentage of ground cover at 6.28% whereas the other severity level and the total averaged from 5.41% to 5.89% (Table 8). Arizona fescue composed 22.29 % of the 5 to 6% total cover within the severity levels in comparison to Common mullen, which was the most pervasive invasive species within the burn area, which only had an average cover of 4.90% (Table 9).

Table 8: Average percentage of cover by severity level		
Severity	Average % cover	Standard deviation
Control	5.86	12.45
Low	6.28	15.47
Mixed	5.41	12.55
High	5.95	12.15
Total	5.89	13.12

Table 9: Dominant species present in 40+ plots.				
Forbs				
Common name	*Scientific names*	# plots present in	Severity	% of cover Average
Purple Locoweed	*Oxytropis lambertii Pursh var. biglovii A. Gray*	64	C, L, M, H	2.93
Common Mullen	*Verbascum thapsus L.*	63	C, L, M, H	4.90
Dalmatian toadflax	*Linaria dalmatica (L.) Miller*	41	C, L, M, H	4.19
Macoun's cudweed	*Pseudognaphalium macounii (Greene) Kartesz*	41	C, L, M, H	2.03
Wild Chrysanthemum	*Amauriopsis dissecta (A. Gray) Rydberg*	41	C, L, M, H	2.83
Grass				
Common name	*Scientific names*	# plots present in	Severity	% of cover Average
Arizona Fescue	*Festuca arizonica Vasey*	74	C, L, M, H	22.29
Squirreltail	*Elymus elymoides (Raf.) Swezey*	42	C, L, M, H	2.38

A total of 6 invasive species were recorded within the plots (Table 6 and 10). In the survey of the burned area, none of the nonnative species used in the Burned Area Emergency Response (BAER) seeding were observed. All six of the invasive species were present within the high severity areas. The 3 invasive species observed within the controls indicate these species were possibly present along the extent of the area before the fire. From this limited study area, it was inconclusive whether the other 3 invasive species not located within the controls were present before the fire. The most prevalent invasive species was Common Mullen which densely covered most of the high severity plots (Figure 8 and 9). This high percentage of cover is supported by visual observations made in the field (Figure 8).

Table 10: Invasive species by plot and severity level

common name	*scientific names*	# plot present in	Severity
Cheatgrass	*Bromus tectorum L.*	20	L, M, H
Common mullen	*Verbascum thapsus L.*	63	C, L, M, H
Dalmatian toadflax	*Linaria dalmatica (L.) Miller*	41	C, L, M, H
Prickly lettuce	*Lactuca serriola L.*	27	L, M, H
Russian thistle	*Salsola tragus L.*	14	C, L, M, H
Yellow salify	*Tragopogon dubius Scopoli*	2	H

Figure 8: High severity area looking into mixed severity with Common mullen (nonnative) and Arizona fescue (native) ground cover.[111]

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[111] Photograph taken by Susanne Ranseen June 2012. Unpublished.

Figure 9: High severity area with Common mullen ground cover[112]

Very few saplings were recorded within the burned areas. Gambel oak had the largest presence with 6 seedlings between Low and Mixed severity levels, and One seed Juniper had 1 seedling in a mixed severity plot (Table 11). Gambel oak seedlings were not found within the same plot as the One seed juniper seedling. Gambel oak, Quaking aspen, and White fir had seedlings within the control plots. There were no Ponderosa pine, Limber pine, Utah juniper, or Alligator juniper seedlings recorded within any of the severity levels.

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[112] Photograph taken by Susanne Ranseen June 2012. Unpublished.

Table 11: Seedlings per severity level			
Common name	*Scientific name*	# Seedling present	Severity
Gambel oak	*Quercus gambelii Nutt.*	6	L,M
One-seed juniper	*Juniperus monosperma (Engelm.) Sarg.*	1	M

DISCUSSION:

RELATIONSHIP BETWEEN TREE DENSITY AND SEVERITY LEVEL:

While there was no statistically significant relationship found between tree density and fire severity levels in this study, the statistical analysis could not account for fire behavior effects from such factors as ladder fuels, fire spotting, crown mass, topography, and stochastic differences in winds on fire severity levels.

High tree density, especially in forests with a large percentage of closed crown mass, allows for the spread of crown fire even in the cases where wind speeds are not above average levels. Fire is transferred from crown to crown more effectively when crowns are in close proximity of each other. Ladder fuels such as small diameter trees can transfer fire from the surface fuels into the crown mass. Wind enables the spread of fire from crown to crown and from ember transfer (spotting). Another factor to this spread is that there is a distance at which neither the proximity of crown mass or the radiation of heat can spread the fire throughout the crown.

Studies on the effects of thinning treatments on reducing fire severity levels show that when stand density and crown mass are reduced to historic levels there is a reduction of high severity stand replacing fires and high intensity crown fires. These studies showed that changes in crown base height and crown mass also reduced likelihood of crown fire spread caused by winds.[113] The long period of fire suppression within the Coconino National Forest has caused a

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[113] Fule, et al. "Potential Fire Behavior," p33.

measurable increase in stand density, ladder, and surface fuels that likely led to high severity fires.[114]

There was a large variability of tree size within the study area across the various severity levels. Even though the average DBH for the total burn area was between 25 cm and 31 cm, tree DBH ranged from under 6cm in small diameter trees to 107 cm in large diameter trees. Of the total Ponderosa Pine counted, 25% of the total, 1,109 trees, were identified as small diameter.

The large proportion of smaller diameter trees in the study area may be due in part to the removal of fire from within this system. Historic low severity fires in Ponderosa pine killed smaller trees while rarely killing larger trees.[115] Within this study, there was an observed and a measured death of both small and large diameter trees, especially within high severity plots. Most telling is the 107.5 cm tree measured within a high severity plot which was observed to have no crown mass and was recorded as dead. In close proximity to it was a number of small diameter trees that were also recorded as dead, with much of their lateral structure burned away. The close proximity of these smaller trees may have allowed for fire transfer from surface fuels to crown fuels allowing for increased tree mortality within the larger diameter trees.

FACTORS INFLUNCING THE SCHULTZ FIRE BEHAVIOR:

Based on the modeling the main factors that influenced the rapid spread and high severity of the Schultz Fire were the high winds (reaching the 90th percentile conditions for Flagstaff) combined with the presence of high surface fuel loads. The BEHAVE modeling showed that topography had little to no effect on ROS and FL across the fuel models examined. Within the

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[114] Heinlein, Thomas A., Margaret M. Moore, Peter Z. Fule, and W. Wallace Covington. “Fire History and Stand Structure of Two Ponderosa Pine-Mixed Conifer Sites: San Francisco Peaks, Arizona, USA.” *International Journal of Wildland Fire* 14 (2005), p817-821.

[115] Noss, Reed, Jerry Franklin, William Baker, Tania Schoennagel, and Peter Moyle. "Managing Fire-prone Forests in the Western United States." *Frontiers in Ecology and the Environment* 4, no. 9 (2006): 481-87, p483

low fuel density models, the ROS and FL reached their maximum~~s~~ modeled behavior before reaching prevailing weather conditions measured for the area near the Schultz Fire during its first three days. These lower fuel models could not produce the observed severity conditions of the Schultz Fire regardless of wind speed. As fuel loading and wind speed increased, there was an increase in ROS and FL. The largest increase in ROS and FL was seen in the high fuel models combined with increased wind speeds, which reflect the conditions observed during the fire. As wind speed increased in combination with the higher fuel loads, overall FL increased from being a surface fire manageable with hand tools to a fire with a high likelihood of crowning that would be fought with heavy machinery such as aircraft and bulldozers.[116] This reflects the reality of the Schultz Fire, where large scale crown fire was observed throughout the first three days.

High surface fuels and high wind speeds can spread fire from the surface to the crown even with low tree density through ladder fuels, embers, and high flame lengths. If surface fuels have low to medium amounts there is a limited ability for fire to transfer from the surface to crown fires even with high wind speeds. These variables might have played a part in creating the increased severity of the Schultz Fire.

A limitation of this study is that there were no fuel measurements taken within the area before the fire, so I cannot estimate the fuel availability within higher severity areas outside of model reconstruction. In high and mixed severity areas there were observed signs of ground fire around the bases of larger diameter trees indicating fuel load were built up enough to stimulate this type of fire behavior. These indications of ground fire show that temperatures were high enough to kill trees independently of crown fire. High levels of fuel, especially those high

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[116] Andrews, P L., and R C. Rothermel. "Charts for interpreting wildland fire behavior characteristics." USDA Forest Service General Technical Report INT-131. (1982), p21

enough for ground fire, are independent of tree density levels and crown distance that affect severity levels.

RELATIONSHIP BETWEEN SPECIES RICHNESS AND SEVERITY LEVEL:

In this study, there is a statistically significant relationship between species richness and severity level: As severity rises, so does species richness. This increase in richness may be attributed to changes in litter and duff depths, nutrient availability, and changes in crown structure.[117] The effects on litter and duff depths may account for the high coefficient of community percentage between the Low and Mixed severity plots. If litter and duff layers are too deep, they limit the ability of plants and seed banks to become established.[118]

Decreased crown cover may account for the increase in species as severity increases. Previous studies have shown that there is a strong link between over story structure in Ponderosa pine forest and understory dynamics.[119] The opening of the canopy due to the large amount of tree death in the high severity areas may be linked to the increase in recorded species within those plots. The opening of the canopy would have increased the available sunlight.

The long term effects of the Schultz Fire on plant species richness and composition within the burn area are unknown at this time. The limited amount of seedlings within the burned plots suggests a possible change in woody species presence. Ponderosa pine has a limited seed bank life of only 2 years with most of its banks being stored within maturing cones on the tree.

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[117] Laughlin, Daniel C. and Peter Z. Fule. “Wildland Fire Effects on Understory Plant Communities in Two Fire-Prone Forests.” *Canadian Journal of Forestry Research*. 38 (2008): 133-42, p133-141 and Stoddard, Michael T., Christopher M. McGlone, Peter Z. Fule, Daniel C. Laughlin, and Mark L. Daniels. “Native Plants Dominate Understory Vegetation Following Ponderosa Pine Forest Restoration Treatments.” *Western North American Naturalist* 71, No. 2 (2011), 206-14, p212

[118] Laughlin and Fule. “Wildland Fire Effects”, p133 and 137

[119] Bakker, Jonathon D. and Margaret M. Moore. “Controls on Vegetation Structure in Southwestern Ponderosa Pine Forests, 1941 and 2004.” *Ecology* 88, no. 9 (2007): 2305-19, p 2305.

Cones reach maturity and disperse their seeds primarily in August and September.[120] Due to the large amount of canopy loss within the mixed and high severity areas, there is a limited likelihood that Ponderosa pine seed bank remains within those areas due to cone loss. The flowering period for Ponderosa pine falls within the months of April through June.[121] The fire spanned most of late June, so there is a high likelihood of bloom disruption. If Ponderosa pine was to return in the Mixed and High severity areas, there would be seedlings present by this point. The future forest composition of this area may be a lack of trees within the mixed and high severity areas or a change to a forest dominated by juniper species or Gambel oak. Restoration measures were taken in December, 2011 within the high severity areas along FS Road 420 with the planting of 400 Ponderosa pine saplings.[122] It was unclear at the time of the study whether these planted saplings will make a measureable long term impact on woody species composition of these areas.

RELATION OF FINDINGS TO OTHER HIGH SEVERITY FIRES IN SOUTHWESTERN PONDEROSA PINE FORESTS:

The Schultz Fire was comparable the findings on other high intensity fires within the southwest driven by fuel loading and high winds. The Rodeo-Chediski Fire in June 2002 is another such example. Both of these high severity fires had significant stand death due to large crown fires. Prior to the 1960s, 50 acres was considered large for a high severity crown fire in Ponderosa pine. By the 1990s, large scale crown fires had expanded to “tens of thousands” of acres.[123] This increase in high severity fires has been linked with the increase of fuel loading

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[120] Schopmeyer, C S., ed. *Seeds of Woody Plants in the United States: Agriculture Handbook No. 450*. Washington, D.C.: Forest Service, U.S. Department of Agriculture, 1974; http://floranorthamerica.org/ and http://plants.usda.gov/.

[121] Schopmeyer, C S., ed. *Seeds of Woody Plants in the United States: Agriculture Handbook No. 450*. Washington, D.C.: Forest Service, U.S. Department of Agriculture, 1974; http://floranorthamerica.org/ and http://plants.usda.gov/.

[122] "2011 Stakeholders Report." *Coconino National Forest*, 2012

[123] Friederici, *Ecological Restoration of Southwest Ponderosa Pine Forests*, p xv-xvi

within these Ponderosa pine systems.[124] Observations made during and after the Rodeo-Chediski fire showed that areas that had either previously burned or had been treated for reduced fuel levels had a lower severity levels then those without any type of fuel treatment. Larger fuel treated areas within the Rodeo-Chediski Fire moderated the effects of wind on the fire's intensity level and rate of spread.[125]

CONCLUSION:

The Schultz Fire serves as a case study of the type of fires that have burned and will continue to burn outside of historically influenced levels.[126] The implications of the Schultz Fire as a case study bring into perspective the effects of long term fire suppression management and increased fuel loading on increased fire severity within Ponderosa pine systems. The Schultz Fire demonstrates that the combination of high fuel loads and high winds can create high severity crown fires that can have an impact on ecosystems and communities. The severity level also impacted the species richness seen within the early succession of the fire area. It will take more time than was available for this study to see the lasting effects of this fire on the landscape. There is a possibility for a change in woody species composition in the future due to the lack of seedlings, especially Ponderosa pine, measured in the burned area.

The severity and scale of change from historical regimes could increase dramatically in these ecosystems in the face of climate change. The effects of climate change could alter levels of precipitation, wind, species phenology and composition, and the likelihood of fire. These

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[124] Jensen and McPherson. *Living With Fire*, p 62-63

[125] Finney, Mark A., Charles W McHugh, and Issac C. Grenfell. "Stand- and Landscape-Level Effects of Prescribed Burning on Two Arizona Wildfires." *Canadian Journal of Forest Research* 35 (2005): 1714-22, p 1719-20 and Jensen, p 62-63

[126] Interview Peter Fule.

findings underline the need for fuel treatments in southwest Ponderosa Pine forests, and effective cooperation between communities, managers, and ecologists.

CHAPTER 4: OVERALL CONCLUSIONS

It is important to remember that neither the Schultz Fire nor this study can be used to explain all fires within the southwest or even in northern Arizona. They serve as tangible links between the history of fire management and the present-day reality of fire in Southwest Ponderosa pine forests. They also reflect the effects of historic fire suppression on dry-forest ecosystems.

Throughout most of the Southwest, Ponderosa pine forests were historically open “park-like” areas with a dense herbaceous understory.[127] This forest structure was and is maintained by frequent low-intensity surface fires. Many of forests in this area now have a dense canopy structure and a sparse understory. Previous studies have shown that the latter forest structures are often the result of fire suppression, and that these forest structures facilitate large-scale, high-severity crown fires. In this context, the Schultz Fire is part of a pattern of higher severity fires in dry forest ecosystems.[128] It serves as an example of how fires might continue to burn in Ponderosa pine forests if management treatments are not oriented to returning to a semblance of historic forest structure and fire regimes.

The critical issues surrounding fire have grown larger than what can be managed by any one agency, community, or discipline. Cooperation is necessary within all agencies that have contact with wildfire and within communities where wildfire occurs, to create more inclusive policies that effect America’s vast and diverse ecosystems. There is a need for a public education on the necessity and efficiency of fuel treatment and on the importance of fire in various ecosystems. Furthermore, better connections between the public, managers, ecologists, and

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[127] Friederici, *Ecological Restoration of Southwest Ponderosa Pine Forests*, p 31
[128] Interview Peter Fule

policy makers, since the challenges involved are beyond any one discipline. Fire polices must extend beyond reinventing old symbols, such as Smokey Bear or changing the language used to manage, suppress, or talk about fire. As users and managers of forested systems we must understand the historic structure and disturbance regimes to make informed managerial decisions in the face of expanding wilderness urban interfaces, complex economic issues, environmental changes, and global climate change.

It is necessary to have an interdisciplinary perspective to understanding fire, if resource management is to be based on rational decisions rather than desires and emotions. Simply focusing on the science and excluding the history and public perceptions of fire will create an understanding of fire that is, at best, incomplete. Managers, scientists, and the public all need to understand how management and science has changed over time to make informed decisions for the future. Policy decisions that are made without a clear understanding of this background will likely continue to adversely affect the ecosystems involved. It is not just a reconnection of the science to the landscape; it is also a reconnection of the landscape to the people. Fire is an indelible part of America’s forests and national identity. Until we accept fire in this context, we cannot manage for ecological complexity.

EPILOGUE:

Fire is inescapably personal, and it is impossible to completely distance oneself from this emotional context. After I had completed my study of the Schultz Fire area, I wanted to share what I had learned and observed with my friend Judy, whose house had been threatened by the fire. I took her out to the forest, a forest she thought destroyed and ugly, to show her why I wanted to work in such a “ruined place.” I showed her the different severity areas, the plants in bloom, and the animals that had returned. I explained how the fire had burned and how the area was and is adapting to fire. After several hours of hiking, answering questions, and interacting with the landscape, Judy told me how she now understood why I wanted to study the area and how beautiful it was. Through interaction and education she had a new understanding of fire. She not only saw the beauty in the burnt areas but also understood their importance in maintaining forested systems (Figure 10).

Figure 10: Low-severity burn area.[129]

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[129] Photograph taken by Susanne Ranseen June 2012. Unpublished.

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INTERVIEWS:

Formal interviews were conducted with various Coconino National Forest employees to support the study with first hand observations of fire conditions and actions taken during and after the fire. Complimentary interviews were made at Northern Arizona University, Summit Fire District, and the Rocky Mountain Research Station to further lend support to the structure of this study. Supplementary information such as unpublished photographs, maps (created for me by Dick Fleishman), and both published and unpublished reports were gained through these interviews. All interviews were conducted in person between the months of July and August, 2012.

Rory Steinke: Watershed program Manager, CPSS. United States Department of Agriculture: Forest Service: Coconino National Forest.

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Joseph (Joe) Luttman: Supervisory Forester. United States Department of Agriculture: Forest Service: Coconino National Forest.

Jennifer Hensiek: Deputy District Ranger. United States Department of Agriculture: Forest Service: Flagstaff Ranger District, Coconino National Forest.

Jim Fowler: Ecologist. United States Department of Agriculture: Forest Service: Rocky Mountain Research Station.

Peter Fule: Professor. Northern Arizona University

Don Howard: Fire Chief. Summit Fire District

APPENDICES:

APPENDIX A: NOTES

NOTE 1: PROGRESSIVE ERA

The Progressive Era was a period of American history lasting from the 1880s into the 1920s. Under political leaders like Theodore Roosevelt, Herbert Hoover, and Woodrow Wilson, the Progressive Era was a time of political and social reform, an increase in the role of the government, and the rise of the middle class. Among the various reforms and movements associated with this period of time were the rise of conservationism and preservationism, and the creation of the National Parks and other federal land use agencies. Preservationists, such as John Muir, wanted to preserve areas of the country for their natural beauty rather than their economic value. Conservationists, such as Gifford Pinchot, wanted to preserve natural areas for their future economic value more than for their esoteric worth. Both groups were allies on a variety of specific subjects, such as the creation of natural reserves and national parks, but often clashed over issues of land use.

NOTE 2: BALLOT QUESTION 405

“A Flagstaff municipal bond issue would provide financial resources and voter support towards restoring forests within high threat areas, providing greater protection for the Flagstaff community from the health, public safety, and economic impacts of fires and floods. The bond project will provide value added to two areas: the Rio de Flag Watershed and Lake Mary Watershed.” Treatments combining thinning slash disposal and prescribed fire will start in the spring/summer of 2013 and continue for an estimated 5-8 years. Treatments will be conducted by the Forest service and “other private and non-private partners” while “the City will have a key role in the planning, the implementation, and the monitoring.”[130]

NOTE 3: PONDEROSA PINE

Ponderosa Pine has a wide and variable distribution, growing from southern Canada to northern Mexico, from the Pacific Coast to Nebraska and Oklahoma. It can grow in a variety of climate conditions, from the dry forests of Arizona to mixed wet conifer forests of the Rockies. It grows across a range of elevations from sea level to 3,048 meters (10,000 feet), and tolerates a wide variety of soil moistures and nutritional conditions. Ponderosa pines within the southwest grow within two main soil types: xerophytic (dry) and mesophytic (wet) forests. Soil type along with climate help determine the seral stages and plant species associated with Ponderosa pine.[131] Ponderosa Pine is divided into two subspecies, Pacific Ponderosa Pine and Interior Ponderosa Pine, which includes Arizona Ponderosa Pine.[132] Ponderosa Pine is associated with other tree and shrub species such as aspen, Gambel oak, White Fir, Utah Juniper, and One-Seed Juniper.[133]

The species is highly adapted to fire, having both high resistance and high resilience to fire. Ponderosa pine is adapted to frequent low intensity fires, with return intervals ranging from 2-36 years with an average fire interval of 2-8 years throughout most of Northern Arizona.[134] The fire regime of frequent low intensity burns that consume understory and surface fuel accumulation has been recognized as the dominant regime type for over 50 years.[135] Juvenile

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[130] Information Pamphlet For The City of Flagstaff, Arizona Special Debt Authorization Election November 6, 2012

[131] Moir, et all, *Ecology of Southwestern Ponderosa Pine Forest*, p152

[132] Wyk, G V. *Pines of Silvicultural Importance*. New York: CABI, 2002., p 343-356

[133] Eyre, F H, ed. *Forest Cover Types of the United States and Canada*. Washington DC: Society of American Foresters, 1980,p 114-115

[134] Friederici, . *Ecological Restoration of Southwest Ponderosa Pine Forests*, p 8-10

[135] Friederici, . *Ecological Restoration of Southwest Ponderosa Pine Forests,* p 168

Ponderosa Pine becomes fire resistant at approximately 10 cm in diameter and 3 meters in height.[136]

There is some debate as to the appropriate way to date fire history in Ponderosa Pine. The typical and most widely used method of determining the fire regime history of an area is through fire scar data. However, there are three main inherent flaws in the fire scar dating: scars do not consistently record fire presence on any one tree, recent fire events may over scar over previous fire events thereby destroying the data, and errors can introduced in how data is processed.[137]

The debate centers around whether the fire scar data either over-represents the fire return interval, creating a shorter time between fires and a more frequent fire regime, or underestimates how many fires occurred due to the lack of fire scar data, creating a larger gap between intervals. The sampling of fire scarred trees is often focused on trees with multiple scars. This targeting of trees is criticized for breaking statistical assumptions of true randomness within sampling data.[138]

Records of fires in the area are also used to better perceive fire regimes. Composited fire intervals are used to negate the statistical issues with using fire scar data. However, using historical data also has its limitations due to the lack of records in some areas and no written record prior to European settlement. Historical dating does allow a more accurate assumption when available on those areas where fire scar data is recorded. This data, though imperfect, allows fire management decisions to be made more accurately to fire regime history, and gives scientists a general starting point of how to view the changes in an area and what management might be needed to restore an area or manage it in the future.

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[136] Friederici, *Ecological Restoration of Southwest Ponderosa Pine Forests,* p 618

[137] Van Horne, Megan L. and Peter Z. Fule. "Comparing Methods of Reconstructing Fire History Using Fire Scars in a Southwestern United States Ponderosa Pine Forest." *Canadian Journal of Forestry Research*. 36, (2006): 855-67, p 855

[138] Van Horne, Comparing Methods of Reconstructing Fire History, p 856

NOTE 4: FUEL MODELS

Fuel models are classified into two groups. The original 13 models were established by Rothermel and Albini in the 1970s.[139] These models were expanded upon by the 40 standard models, which were established in the early 2000s.[140] Fuel models are divided into 5 groups: non-burn, grass, brush, timber, and slash.

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[139] Anderson, Hal. "Aids to Determining Fuel Models for Estimating Fire Behavior." USDA Forest Service Gen. Tech. Rep. INT-122 (April 1982), p1

[140] Scott, Joe, and Robert Burgan. "Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model." USDA Forest Service Gen. Tech Rep. RMRS-Gtr-153 (2005), p 1-3

APPENDIX B: APPENDIX TABLES

Appendix Table 1: Total species list ordered by plot presence highest to lowest by physiognomic group

Forbs

Invasive/ Native	common name	*scientific names*	# plots present in	Severity
N	Purple locoweed	*Oxytropis lambertii Pursh var. biglovii A. Gray*	**64**	C, L, M, H
I	Common mullen	*Verbascum thapsus L.*	**63**	C, L, M, H
I	Dalmatian toadflax	*Linaria dalmatica (L.) Miller*	**41**	C, L, M, H
N	Macoun's cudweed	*Pseudognaphalium macounii (Greene) Kartesz*	**41**	C, L, M, H
N	Wild Chrysanthemum	*Amauriopsis dissecta (A. Gray) Rydberg*	**41**	C, L, M, H
N	Silverstem lupine	*Lupinus argenteus Pursh*	**39**	C, L, M, H
N	Fetid goosefoot	*Dysphania graveolens (Willd.) Mosyakin & Clemants*	**35**	C, L, M, H
N	Greyfelt thorn	*Tetradymia canescens de Candolle*	**31**	C, L, M, H
I	Prickly lettuce	*Lactuca serriola L.*	**27**	L, M, H
N	Bristly cryptantha	*Cryptantha setosissima (A. Gray) Payson*	**25**	C, L, M, H
N	Freemont's goosefoot	*Chenopodium fremontii S. Watson*	**24**	L, M, H
N	Broom groundsel	*Senecio spartiodes Torrey & A. Gray var. spartiodes*	**22**	C, L, M, H
N	Spreading fleabane	*Erigeron divergens Torrey & Gray*	**22**	L, M, H
N	Narrow leaf stone seed	*Lithospermum incisum Lehm.*	**19**	C, L, M, H
N	Wheeler thistle	*Cirsium wheeleri (A. Gray) Petrak*	**18**	C,L, M, H
N	Sparse flower goldenrod	*Solidago velutina de Candolle subsp. sparsiflora (A. Gray) Semple*	**16**	C, L, M, H
N	Red-root buckwheat	*Eriogonum racemosum Nuttall*	**15**	C, L, M, H
I	Russian thistle	*Salsola tragus L.*	**14**	C, L, M, H
N	Fendler ceanothus	*Ceanothus fendleri A. Gray*	**13**	C, L
N	Kaibab pussytoes	*Antennaria rosulata Rydb.*	**12**	C,L, M,

				H
N	Narrowleaf wirelettuce	*Stephanomeria tenuifolia (Raf.) H.M. Hall*	**12**	L, M, H
N	Lobeleaf groundsel	*Packera multilobata (Torrey & A. Gray) W.A. Weber & A. Love*	**10**	C, L, H
N	Rubber rabbit brush	*Ericameria nauseosa (Pall. ex Pursh) G. L. Nesom and G.I. Baird*	**10**	C, L, M
N	Pale-Bastard toadflax	*Comandra umbellata (L.) Nutt. ssp. pallida (A. DC.) Piehl*	**9**	L, H
N	Harlequinbush	*Gaura hexandra Ortega*	**7**	C, L, H
N	Many-Flower puccoon	*Lithospermum multiflorum Torr. ex A. Gray*	**7**	C, L, M, H
N	Western yarrow (common)	*Achillea millefolium L.*	**6**	L, M, H
N	Macdougal Verbena	*Verbena macdougalii Heller*	**5**	H
N	Wild geranium	*Geranium caespitosum E. James*	**5**	C, H
N	Canadian horseweed	*Conyza canadensis (Linnaeus) Cronquist*	**4**	H
N	False mesquite	*Calliandra humilis Bentham var. humilis*	**4**	C, M, H
N	Slimleaf plainsmustard	*Schoenocrambe linearifolia (A. Gray) Rollins*	**4**	L, M, H
N	Wand-Bloom penstemon	*Penstemon virgatus A. Gray*	**4**	L, M, H
N	Western bracken fern	*Pteridium aquilinum (L.) Kuhn*	**4**	L,M
N	Branched noseburn	*Tragia ramosa Torr.*	**3**	H
N	Hairy golden aster	*Heterotheca villosa*	**3**	L
N	James' cryptantha	*Cryptantha cinerea (Greene) Cronquist*	**3**	H
N	Wholeleaf indian paintbrush	*Castilleja integra Gray*	**3**	L, M
N	Adonis blazingstar	*Mentzelia multiflora (Nutt.) A. Gray var. integra M.E. Jones*	**2**	H
N	Common dandelion	*Taraxacum officinale G.H. Weber & F.H. Wiggers*	**2**	H
N	Coyote tobacco	*Nicotina attenuata Torr. ex S. Wats.*	**2**	H
N	Hoary tansyaster	*Dieteria canescens (Pursh) Nutt.*	**2**	L,H
N	Slender gallardia	*Gaillardia pinnatifida Torr.*	**2**	H
N	Skyrocket	*Ipomopsis aggregata (Pursh) V. Grant*	**2**	H
N	Spiny goldenweed	*Xanthisma spinulosum (Pursh) D.R. Morgan & R.L. Hartman*	**2**	H
I	Yellow salify	*Tragopogon dubius Scopoli*	**2**	H
N	Colorado rubberweed	*Hymenoxys richardsonii (Hook.) Cockerell var. floribunda (A. Gray) Parker*	**1**	H

N	Fendler's sandwort	*Arenaria lanuginosa (Michaux) Rohrbach*	**1**	C
N	Golden crownbeard	*Verbesina enceliodes (Cavinilles) Bentham & Hooker*	**1**	H
N	Groundcover milkvetch	*Astragalus humistratus A. Gray*	**1**	L
N	Princely daisy	*Erigeron formosissimus Greene*	**1**	M
I	Red raspberry	*Rubus idaeus L.*	**1**	H
N	Scrambled eggs	*Corydalis aurea Willd.*	**1**	H
GRASS				
Invasive/ Native	common name	*scientific names*	# plots present in	Severity
N	Arizona fescue	*Festuca arizonica Vasey*	**74**	C, L, M, H
N	Squirreltail	*Elymus elymoides (Raf.) Swezey*	**42**	C, L, M, H
N	Mountain muhly	*Muhlenbergia montana (Nutt.) Hitchc.*	**22**	C, L, M, H
I	Cheatgrass	*Bromus tectorum L.*	**20**	L, M, H
N	Blue grama	*Bouteloua gracilis (Kunth) Lag.*	**5**	L, M, H
Woody				
Invasive/ Native	common name	*scientific names*	# plots present in	Severity
N	Ponderosa pine	*Pinus ponderosa Lawson & C. Lawson*	**104**	C,L,M,H
N	White fir	*Abies concolor (Gord. & Glend.) Lindl. ex Hildebr.*	**9**	C,M,H
N	Gambel oak	*Quercus gambelii Nutt.*	**5**	C,L,M,H
N	One-Seed juniper	*Juniperus monosperma (Engelm.) Sarg.*	**5**	C,L,M,H
N	Utah juniper	*Juniperus osteosperma (Torr.) Little*	**2**	M,H
N	Alligator juniper	*Juniperus deppeana Steud.*	**1**	M
N	Limber pine	*Pinus flexilis James*	**1**	C
N	Quaking aspen	*Populus tremuloides Michx.*	**1**	C

Appendix Table 2: Plot information and species distribution

Plot #	Severity	Elevation	Slope	Aspect	Forbs	Woody	Grass	Richness
1	High	7254	10	Se	6	1	0	7
2	Low	7249	20	Sw	9	1	0	10
3	Mixed	7240	10	Sw	10	1	0	11
4	Low	7201	10	Sw	9	3	0	12
5	High	7301	10	E	11	2	0	13
6	Mixed	7319	14	Se	6	1	0	7
7	Mixed	7313	12	Ne	8	2	0	10
8	Mixed	7340	10	E	10	2	0	12
9	Mixed	7370	6	Ne	9	1	0	10
10	Control	7467	18	Ne	9	1	0	10
11	High	7441	26	Ne	7	1	0	8
12	Mixed	7595	10	Ne	6	1	3	10
13	Low	7622	10	Ne	6	1	2	9
14	High	7384	16	Se	18	2	0	20
15	High	7317	12	Se	16	1	0	17
16	High	7294	16	Ne	20	1	2	23
17	High	7300	18	Ne	17	1	0	18
18	High	7335	12	E	17	1	0	18
19	High	7314	18	Ne	17	1	2	20
20	High	7270	10	Se	12	1	2	15
21	High	7262	20	E	14	1	3	18
22	High	7600	20	Se	12	1	3	16
23	High	7592	16	Se	11	1	2	14
24	Mixed	7632	10	E	5	1	0	6
25	Mixed	7690	10	E	6	1	0	7
26	Low	7655	14	E	6	1	2	9
27	Low	7662	20	Se	8	1	2	11
28	Mixed	7580	10	S	6	2	3	11
29	Mixed	7554	6	S	7	1	3	11
30	High	7464	30	Se	15	2	2	19
31	High	7461	22	S	16	3	4	23
32	High	7416	10	N	10	1	3	14
33	High	7397	20	N	8	1	2	11
34	Mixed	7371	14	E	8	1	2	11
35	High	7346	12	Ne	11	1	0	12

36	Mixed	7494	12	N	10	1	0	11
37	Mixed	7334	16	Se	9	1	0	10
38	Low	7386	16	S	10	1	3	14
39	Low	7364	16	E	11	1	2	14
40	Low	7421	16	E	13	1	0	14
41	Low	7426	14	E	14	1	0	15
42	Low	7442	14	Se	6	1	0	7
43	Low	7438	18	Se	12	1	0	13
44	Low	7292	16	E	7	1	0	8
45	Mixed	7265	14	E	3	1	3	7
46	Low	7231	4	Nw	6	1	0	7
47	Mixed	7239	2	S	9	1	0	10
48	Mixed	7218	2	N	6	1	0	7
49	Low	7248	6	Ne	10	1	0	11
50	Mixed	7299	10	E	9	1	0	10
51	Mixed	7301	10	E	10	1	0	11
52	Low	7337	4	Se	7	1	0	8
53	Low	7338	10	Se	3	1	0	4
54	Low	7346	20	E	6	1	0	7
55	Low	7375	20	E	5	1	0	6
56	High	7603	6	Ne	9	1	2	12
57	High	7595	10	Ne	12	1	2	15
58	High	7647	8	E	12	1	3	16
59	High	7627	8	Se	13	1	3	17
60	Mixed	7667	16	Ne	5	1	2	8
61	Mixed	7600	16	Ne	5	1	2	8
62	Low	7672	16	E	8	1	2	11
63	Mixed	7618	16	E	7	1	3	11
64	High	7477	14	Ne	9	1	2	12
65	High	7497	14	Ne	10	1	0	11
66	Mixed	7416	10	N	5	1	3	9
67	Mixed	7552	12	N	9	1	2	12
68	Mixed	7482	12	N	7	3	3	13
69	Mixed	7500	12	E	11	2	0	13
70	Low	7468	2	Ne	9	1	2	12
71	Low	7452	2	Ne	9	1	3	13
72	Low	7444	18	Ne	10	1	2	13

73	Low	7447	4	Se	5	1	0	6
74	Low	7423	4	Se	6	1	0	7
75	Low	7400	8	E	3	1	3	7
76	Low	7400	8	E	5	1	2	8
77	Control	7449	4	Se	2	1	0	3
78	Control	7457	10	Ne	1	2	0	3
79	Control	7418	4	Ne	4	1	2	7
80	Control	7473	14	N	2	2	0	4
81	Control	7373	14	N	4	2	0	6
82	Control	7463	10	Ne	4	2	0	6
83	Control	7462	18	Ne	3	5	2	10
84	Control	7363	6	E	6	1	0	7
85	Control	7372	6	E	5	1	0	6
86	Control	7345	8	Se	2	1	2	5
87	Control	7345	8	Ne	10	1	0	11
88	Control	7320	4	E	6	1	0	7
89	Control	7337	20	N	5	1	2	8
90	Control	7330	8	Se	9	1	0	10
91	Control	7337	8	Se	6	1	0	7
92	Control	7340	10	Sw	12	2	0	14
93	Control	7360	6	Ne	6	1	0	7
94	Control	7399	4	Se	6	1	0	7
95	Control	7359	4	Se	9	1	0	10
96	Mixed	7980	12	S	9	2	2	13
97	High	7988	14	Ne	16	2	0	18
98	High	7996	14	Ne	12	1	2	15
99	Control	7375	16	Ne	1	2	2	5
100	Control	7389	6	Ne	4	1	2	7
101	Control	7373	4	Ne	6	1	0	7
102	Control	7353	10	Ne	7	1	2	10
103	Control	7390	14	Ne	1	1	0	2
104	Control	7418	14	Ne	1	1	2	4

Appendix Table 3: Distribution of plots over class of elevation, slope, and aspect

Elevation (rounded)	Plot #	severity	slope	aspect
7900	96	M	12	s
7900	97, 98	H	14	ne
total in each class	**3**	**2**	**2**	**2**
Elevation (rounded)	Plot #	severity	slope	aspect
7600	24	M	10	e
7600	25	M	14	e
7600	26	L	14	e
7600	58	H	8	e
7600	62	L	16	e
7600	63	M	16	e
7600	59	H	8	s
7600	13	L	10	ne
7600	56	H	6	ne
7600	60, 61	M	16	ne
7600	22	H	20	se
7600	27	L	20	se
total in each class	**13**	**3**	**6**	**4**
Elevation (rounded)	Plot #	severity	slope	aspect
7500	36	M	12	n
7500	57	H	10	n
7500	67	M	12	n
7500	28	M	10	s
7500	29	M	6	s
7500	8	M	10	e
7500	69	M	12	e
7500	12	M	10	ne
7500	23	H	16	se
total in each class	**9**	**2**	**4**	**5**
Elevation (rounded)	Plot #	severity	slope	aspect
7400	40	L	16	e
7400	41	L	14	e
7400	75, 76	L	8	e

7400	31	H	22	s
7400	30	H	30	se
7400	42	L	14	se
7400	43	L	18	se
7400	73, 74	L	4	se
7400	77	C	4	se
7400	32	H	10	n
7400	64, 65	H	14	n
7400	66	M	10	n
7400	68	M	12	n
7400	80	C	14	N
7400	10	C	18	ne
7400	11	H	26	ne
7400	70, 71	L	2	ne
7400	72	L	18	ne
7400	78, 82	C	10	ne
7400	79	C	4	NE
7400	83	C	18	NE
7400	104	C	14	NE
total in each class	**27**	**4**	**10**	**5**
Elevation (rounded)	Plot #	severity	slope	aspect
7300	5	H	10	e
7300	18	H	12	e
7300	34	M	14	e
7300	39	L	16	e
7300	51	M	10	e
7300	54, 55	L	20	e
7300	84, 85	C	6	E
7300	88	C	4	E
7300	38	L	16	s
7300	6	M	14	se
7300	14	H	16	se
7300	15	H	12	se
7300	37	M	16	se
7300	52	L	4	se
7300	53	L	10	se

7300	86, 90, 91	C	8	SE
7300	94, 95	C	4	SE
7300	92	C	10	SW
7300	33	H	20	n
7300	81	C	14	N
7300	89	C	20	N
7300	7	M	12	ne
7300	9	M	6	ne
7300	17, 19	H	18	ne
7300	35	H	12	ne
7300	87	C	8	NE
7300	93	C	6	NE
7300	99	C	16	NE
7300	100	C	6	NE
7300	101	C	4	Ne
7300	102	C	10	NE
7300	103	C	14	NE
total in each class	**28**	**4**	**9**	**6**
Elevation (rounded)	Plot #	severity	slope	aspect
7200	21	H	20	e
7200	44	L	16	e
7200	45	M	14	e
7200	50	M	10	e
7200	47	M	2	s
7200	1	H	10	se
7200	20	H	10	se
7200	2	L	20	sw
7200	3	M	10	sw
7200	4	L	10	sw
7200	48	M	2	n
7200	49	L	6	n
7200	16	H	16	ne
7200	46	L	4	nw
total in each class	**14**	**3**	**7**	**7**

Appendix Table 4: Severity distribution over elevations

Elevation	High	Mixed	Low	Control	Total
7,900	2	1	0	0	3
7,600	4	5	4	0	13
7,500	2	7	0	0	9
7,400	6	2	11	8	27
7,300	8	6	6	18	38
7,200	4	5	5	0	14

Appendix Table 5: Historic Fires of the Schultz Fire Area

Fire	**Date**	**Acres**
ARNOLD CABIN	1946	381
BEAR JAW	1995	790
BONITO	1986	14
BURNT	1973	7,316
DOYLE	1996	43
ELDEN SPRINGS	2008	22
HOSTETTOR		1,303
	1950	1,078
	1968	225
MID	2000	59
RADIO	1977	4,684
SCHULTZ	2007	10
SIDE	1996	321
SMITH	1998	82
UNKNOWN		543
	1932	36
	1933	27
	1939	82
	1944	59
	1945	49
	1983	23
	1985	183
	Unknown	84
WEATHERFORD	1980	79
WEATHERFORDS	1988	67

WEDDING	2005	81
MESA 89	2010	555
Grand Total	**1932-2010**	**18,194**

APPENDIX C: POLICY TIME LINE

- 1891- The General Revision Act section 24
- 1897- The Sundry Civil Appropriation Act
- 1905- Forest Service
- 1908- Forest Fire Emergency Act
- 1910- The Big Blow Up
- 1911- Week’s Act
- 1924- Clarke-Mc Nary Act
- 1920’- 10 A.M. Policy
- 1930’- 10 Acre Policy
- 1945- Smokey Bear created
- 1952- Smokey the Bear Act
- 1964- Wilderness Act
- 1968- Prescribed National Fire
- 1970- Clean Air Act
- 1970- National Environmental Policy Act
- 1972-Tall Timber Conference
- 1973- Endangered Species Act
- 1976- National Forest Management Act
- 1976- Federal Land Policy and Management Act
- 1978- Fire became part of the national “total fire” management policy across all federal lands

- 1988- Yellowstone Fire
- 1995- National Fire Plan
- 2001- Federal Fire Policy
- 2002- Healthy Forest Initiative

Division of Forestry (renamed Forest Service in 1905) under the General Land Office (transferred to Department of Agriculture in 1905) was formed in 1881 and was formally recognized by Congress in 1886.

APPENDIX D: PLOT PAPERWORK

PLOT #____ SEV____ LAT__________ LONG_______ SLOPE___ ASPECT___ELEV ______

Density cover code: 0=none, 1=1-5%, 2=5-25%, 3=25-50%, 4=50=75%, 5=75-100%

Species	**L1**	**L2**	**L3**	**L4**	**species**	**L1**	**L2**	**L3**	**L4**

Fuels:

1 hr	**10 hr**	**100 hr**	**1000 hr**	**Meter**	**duff**	**litter**
				1		
				3		
				5		
				8		
				10		

Trees:

Species	**DBH (cm)**	**L/D**	**Total L/D**	**Total SD/LD**	**Notes/ seedlings**
			LSD:	**SD:**	
			DSD:	**LD:**	
			LLD:	**T:**	
			DLD:	**Total trees**	
			LT:		
			DT:		