Climate, fire, forest—in a cycle for millennia.

Something in the Air: Climate, Fire, and Ponderosa Pine in Southwestern Colorado

Summary

Strong, abrupt climate changes on a time scale of annual to decadal length, can have widespread and long-lasting effects on forest communities. Climate affects forests by creating conditions that kill trees through severe drought, or that promote tree establishment during rainy periods that foster seedlings and saplings. Climate also affects disturbance events that produce the conditions that allow, or limit, fire occurrence. In studying a ponderosa pine forest in southwestern Colorado, scientists found few trees older than a regional "megadrought" that lasted over two decades in the late 1500s. In the 1600s, a long rainy period allowed trees to establish in great numbers over much of the Southwest. Trees established in the early 1700s and mid-1800s grew and survived during "safe periods," two multi decades that were fire-quiet. These periods, of drought and tree death, and ample rain and tree establishment, correspond to shifts in global weather patterns such as El Niño. Similar aged trees in ponderosa pine forests are likely the result of climate-driven tree establishment opportunities rather than episodes caused by severe fire. Fire exclusion since Euroamerican settlement has eliminated the historical fire return interval that occurred approximately every eleven years, excluding the rainy periods. Ponderosa pine forests across the southwestern United States have been relatively fire-free for 100+ years, increasing tree density, changing forest structure and contributing to increasingly severe wildfires in recent years. A clear link between climate, fires, and tree establishment episodes has been identified, showing the importance of regional historical processes on the composition and structure of our current forests.

Key Findings

- Strong but short climate changes, as short as several years or a decade, can have widespread and long-lasting effects on forest communities.

- Climate affects forests by causing trees to die, by producing conditions favorable to tree establishment and growth, or by affecting disturbances such as fire that control tree establishment, growth and mortality.

- In the ponderosa pine forest studied in southwestern Colorado, few trees were older than the region-wide megadrought that lasted through multiple years in the 1580s.

- A lengthy rainy period in the 1600s created an episode in which trees established in the study area, as they did throughout much of the Southwest.

- Wet cycles, followed by dry cycles, contributed to fuel build up and drying. Fire, affected by the climate variations, killed seedlings and saplings during periods of more frequent burning.

- Fire exclusion since Euroamerican settlement began has changed forest composition and increased tree density—factors that have contributed to increasingly severe wildfires in Southwestern ponderosa pine forests.

- In considering the forest studied, the scientists found a clear link between climate, fire, and episodes of tree establishment and growth, revealing the importance of regional processes on the composition and structure of our forests today.

Introduction

When the Soviet Union launched the first artificial satellite off the surface of the earth and into space, many Americans viewed sputnik as a direct threat to the United States' technological supremacy, and were shocked the achievement had been made elsewhere. The Cold War climate forced the creation and rapid expansion of hundreds of thousands of technicians, engineers, scientists, service people, and average citizens into producers and credulous supporters of America's space program, a program of technological recovery that twelve years from its beginning delivered a man to walk on the moon. Throughout human history, such climates have produced major shifts, both in the rapid expansion of our endeavors, and in our quick recovery from catastrophe. What metaphoric climate does for human histories, real climate does for forest histories. Peter M. Brown, Director of Rocky Mountain Tree-Ring Research, and Rosalind Wu, Fire Ecologist with the San Juan National Forest, have looked at the evidence in a familiar southwestern ponderosa pine forest, and made intriguing discoveries about the pace in which catastrophe and recovery can occur across these types of landscapes.

What metaphoric climate does for human histories, real climate does for forest histories.

## The lore of the rings and the stories of the stand

The dramatic changes in some of our western forests is a familiar story: Euroamerican settlers introduced grazing animals which altered landscapes beginning in the 19th century, and later, efforts to exclude fire had a dramatic effect on fuel build up and forest density. Assuming that fire exclusion would have the biggest impact on ecosystems where plants' life histories are adapted to more frequent fire
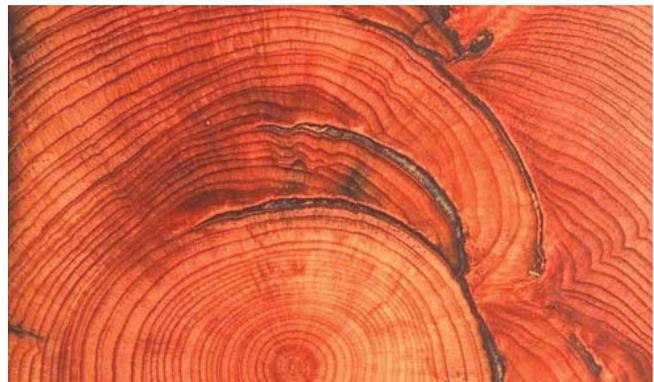
Tree rings reveal stories about a tree's life, and the environment in which it grew. Fire scars from one tree tell that individual burned, but do not indicate the scale of the fire across a landscape. Multiple samples are needed to infer that information. Dendrochronology is the science of dating and analyzing past environmental and climatic conditions under which trees and forests grew, and provides an excellent means of reconstructing past environmental conditions, such as fire.
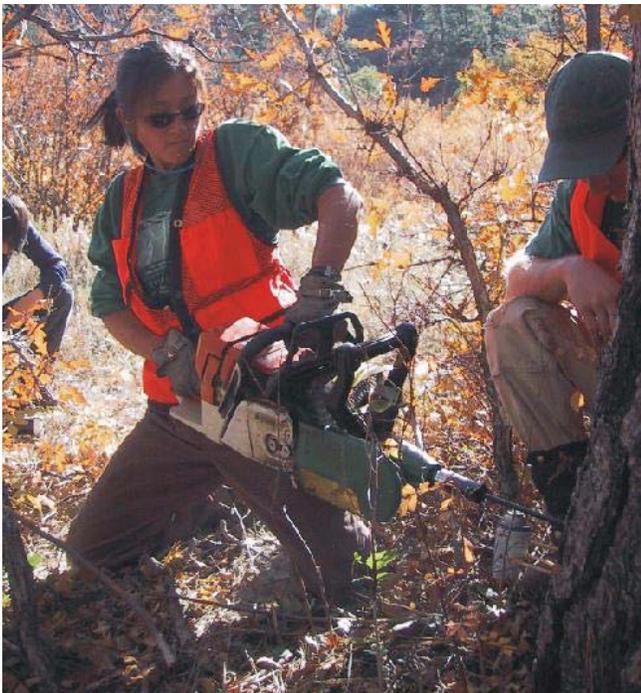
return intervals, such as ponderosa pine forests, we could also assume the impact would not be as great in less fire-prone forest types such as higher elevation mixed conifer or subalpine forests. Brown and Wu, researchers familiar with southwestern forests, examined this assumption in the San Juan National Forest. With their team, they found that while this might be the case at the individual stand level, big changes had occurred across larger landscape-scales in even upper elevation mixed-conifer and subalpine forests. What were the drivers of change, the scientists wondered? In order to answer this question, the scientists had to look at their subjects, from the inside and out.

Having selected three study areas in the middle Piedra River watershed on the San Juan National Forest
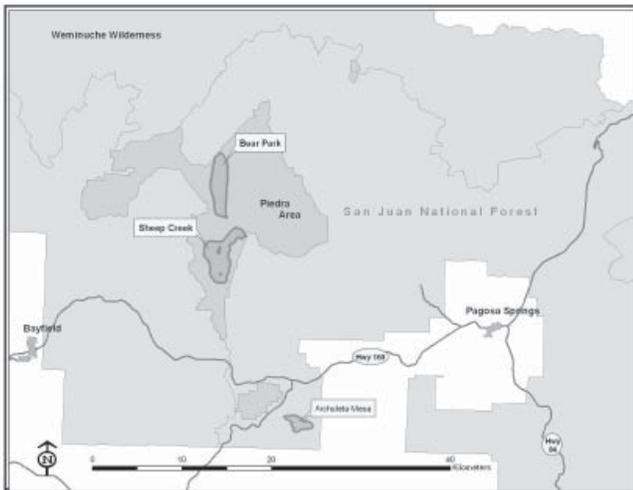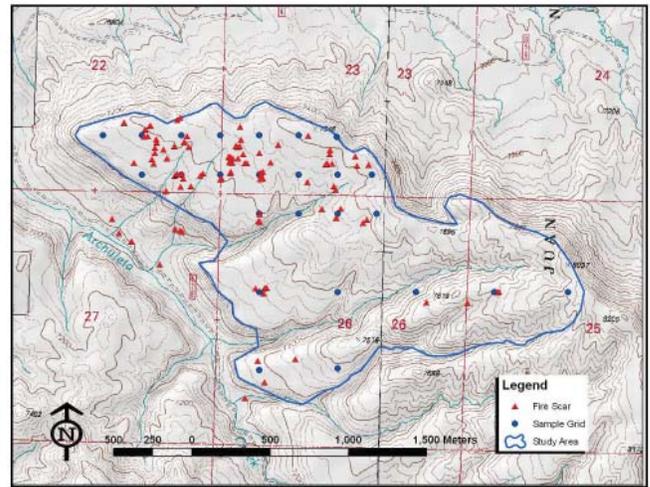
Three landscapes in Southwestern Colorado provided the scientists with clues to develop historical timelines—of wet years, dry years, and fire events.

The scientists collected samples from tree establishment plots (circles on map) and fire-scarred trees (triangles on map) on Archuleta Mesa. Few trees are older than the megadrought of the 1580s.

in southwestern Colorado that were both representative of forest types in the area and were largely unharvested, the team collected samples from over 3,700 trees. The scientists gathered tree-ring evidence that could tell them what the trees had experienced: stand-level fires that might not have killed the tree; the date the tree established, possibly following a stand-opening fire or some other disturbance; or the beginning of the tree's life as part of a wide-scale, climate-driven opportunity.

Scientists collecting tree core samples.

The scientists cross dated the cores and cross sections against master chronologies they had developed for the study areas. This dendrochronological dating of tree rings gave the scientists absolute dates for fire events and tree establishment, or recruitment—dates that they

could compare across landscape scales, and with known land use and climate histories. The scientists evaluated tree establishment timelines and fire years with climate timelines—of wet years, dry years, and larger-scale climate patterns such as El Niño, Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation that affect droughts and therefore fire occurrence in the western United States. In reading the evidence, the scientists saw a story emerge.

A ponderosa pine forest tells its story…

Mature ponderosa pines, with high crowns and thick bark, are well adapted to burning. Recurrent surface fire, the dominant historical disturbance in all ponderosa pine forests, would kill most seedlings and saplings, maintaining a generally open forest structure. On Archuleta Mesa, an isolated, unlogged, old-growth forest displays this classic structure. In examining the ponderosa pine landscape of Archuleta Mesa, one of the study sites, the scientists found very few trees were older than a multi-year megadrought that occurred in the region around the 1580s. This prolonged drought, identified in tree-ring chronologies throughout the western United States and Mexico, was probably the most severe in the Southwest in at least the last thousand years, the scientists discovered. The team identified some seedlings that established a little before or during the megadrought, but the evidence shows they grew slowly until a lengthy rainy period began in the early 1600s. The numerous ponderosa pine trees that established during the early 1600s probably resulted from a combination of factors, the team believes—openings in the forest owing to the dry conditions that killed trees, as well as rainfall that produced the right conditions for seedlings to germinate and saplings to grow in the dry ponderosa pine ecosystem.

But fire was probably not a major factor in this episode of widespread tree establishment, or recruitment. "It is doubtful that severe fires were responsible for stand opening during the megadrought," Brown explains, "since we found no scars on any trees surviving from this period.

Massive tree death can occur from severe drought and beetle outbreaks, a pattern that has happened in the fairly recent, historic past.

It is, however, possible that other disturbance factors, such as bark beetles, contributed to widespread and synchronized mortality during the megadrought." The vast swaths of brown, standing dead trees in the four corners area of the Southwest—stark images of massive forest death from severe drought and beetle outbreaks during 2002–2004—was familiar to any average person reading the paper or watching the news. If the key to the past is the present, as the adage in geology goes, the contemporary event would seem to offer a good indication of the scenario in the centuries-old past. But Brown, Wu and the team could not find evidence of bark beetles, such as blue stain in sapwood, that has survived from the mega drought period. Decomposition, long since accomplished, has eliminated any dead trees that could have offered the story.

In addition to being a long wet period, the early seventeenth century also had few fires. Seedlings and saplings that would normally be killed by surface fires were able to grow to a height that allowed them to survive later fires. After the era of tree establishment in the early 1600s, the scientists identified two long episodes that had few fires, allowing trees to establish—from 1684 to 1724, a period of 40 years, and from 1818 to 1851, a period of 33 years. With the exception of these episodes, the scientists found fires occurred, on average, every eleven years from 1632 to 1871. They identified a climate pattern in which rainy years allowed grasses and forbs to build up, increasing surface fuels, followed by dry years in which the added fuels then burned more easily, and over greater areas. Brown and the team found this pattern in both tree-ring and modern fire-atlas datasets. They believe climate variations were a crucial factor that changed fire occurrence, and produced the wet conditions that allowed trees to establish and grow.

...climate variations were a crucial factor that changed fire occurrence

They also found this pattern occurred in other ponderosa pine forests in the Southwest, which they feel supports the idea that region-wide climate affected fire occurrence, and caused related episodes in which trees were able to establish and thrive. The more important effects on
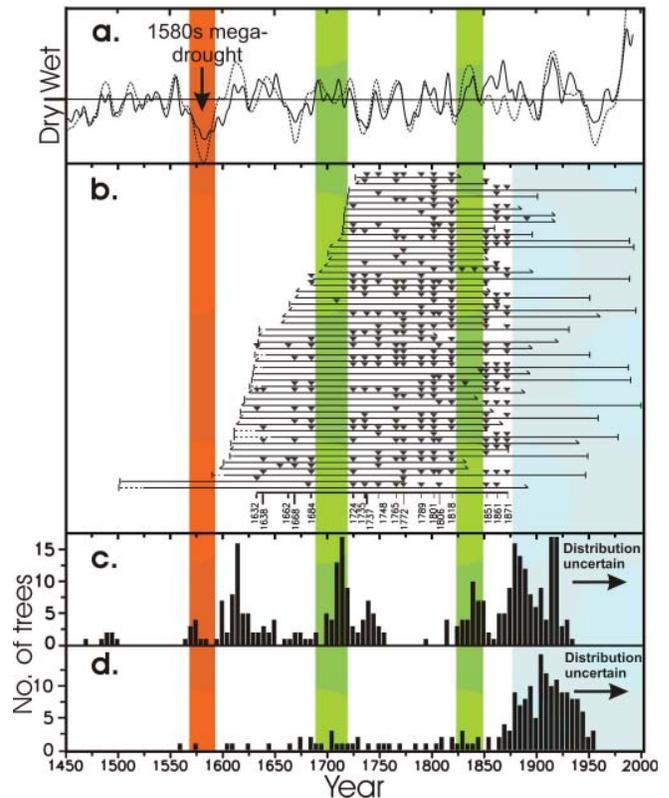
Graph of drought and wet years and establishment and distribution of trees.

broader-scale forest structure, the scientists explain, are what they call "safe periods"—the extended periods where fire did not occur that produced the episodes in which trees established.

…And the story offers a regional history

Scale, Brown offers, is necessary to read an accurate story. "What is clear from our results is that by scaling up from individual plots to the entire landscape, an emergent pattern appears in which cohort structure is uncoupled from any single mortality event and instead appears to be the result of broader scale climate forcing of fire timing that resulted in successful recruitment episodes." Brown and the team urge there are minimum scales of time and area managers must use to see patterns in tree establishment and fire histories that will allow them to infer events. The scientists suggest that managers use scales that cover more than only a few stands and at least one to two hundred years of tree establishment and fire history data. Because Euroamerican settlement has meant land use changes, and accompanying fire exclusion efforts that eliminated surface fires from nearly all ponderosa pine forests across the western United States, Brown explains, "the 135-year-long fire-free period from 1871 to 2005 is more than tree times as long as the longest historical fire-quiescent period of 40 years from 1684 to 1724."

Comprised of fewer fire-tolerant species, and more densely packed, the canopy of ponderosa pine forests has changed. Ladder fuels, plants that allow fire to reach

from surface to canopy, have contributed to more severe fires. Crown fire, the scientists offer, has largely replaced historic surface fire in many ponderosa pine forests. To this negative news, massive forest death due to climate forces has been seen as a rapid event, while tree establishment that follows has been seen as a much slower process. Brown and the team discovered, however, that after the 1580s megadrought, Southwestern ponderosa pine forests recovered fairly rapidly. Climate conditions—bringing ample rain, and few fires—drove this pace. The scientists feel this example has important implications for predicting plant responses after the recent massive die off caused by drought and insect damage over millions of acres of piñon and ponderosa pine forests in the southwestern United States. Brown offers this optimistic

note, "over multicentury time scales, broad-scale dynamics in the Southwest have included abrupt and synchronized mortality that, at least once before in the relatively recent past, was followed by fairly rapid community recovery." He stresses the data reveal the importance of events, contingent upon one another, that give rise to forest structure and composition—climate, disturbances such as fire, and the dramatic, dynamic cycles of dying and flourishing. In looking at their histories, we can see plants offer clues of their responses to climate change, and the effects that accompanying disturbances will have on their survival. While ponderosa pine forests respond to climate forces, rising and falling and rising on timescales that are long in human terms, in the millennial view it is but a season.

Management Implications

- Landscape-scales and timescales need to be considered to assess tree establishment and fire histories. Patterns that result from climate factors only emerge at larger landscape and longer time scales. Managers should consider the size of the scales they use, and the minimum sizes necessary when attempting to analyze patterns.

- In the past, forest recovery from climate-caused, widespread rapid tree death was viewed as a slow process, and millions of acres of trees dead from drought and insect damage have recently captured public emotion. With the example in the relatively recent past of rapid forest recovery in wet years following the 1580s megadrought, managers should consider the interaction of climate, disturbances such as fire, and forest structure when predicting the response of plants over the short, and long-term.

Further Information: Publications and Web Resources

P.M. Brown and R. Wu. 2005. Climate and disturbance forcing of episodic tree recruitment in a southwestern ponderosa pine landscape. *Ecology*. 86:3030-3038. http://www.rmtrr.org/data/Brown&Wu_2005.pdf (November 27, 2007).

P.M. Brown and R. Wu. 2006. Fire and Forest Structure Across Vegetation Gradients in San Juan National Forest, Colorado: A Multi-scaled Historical Analysis Final Report: JFSP Project 01-3-3-13. http://www.rmtrr.org/SJNF/SanJuanFinalReport.pdf (November 27, 2007).

Scientist Profiles

Peter M. Brown is Director of Rocky Mountain Tree-Ring Research, a nonprofit research institute dedicated to using tree-ring studies in understanding climate, fire, forest, and cultural histories of the US, northern Mexico, and Mongolia. He received a PhD degree from Colorado State University, where he is also an affiliate faculty member and teaches courses in forest and fire ecology and dendrochronology.

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Rosalind Wu was the Fire Ecologist and currently serves as Wilderness Specialist for the San Juan National Forest. She received her MS degree in Forest and Fire Ecology from Colorado State University, and plans to apply the knowledge gained from this study to better manage fire in the extensive San Juan National Forest wilderness areas.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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Fire and Forest Structure Across Vegetation Gradients in San Juan National Forest, Colorado – A Multi-Scaled Historical Analysis: A Manager's Perspective

Written By: Lara Durán

Problem

Baseline multi-scale temporal and spatial data about climate, fire and resulting forest structure, species composition, and stand density on the San Juan National Forest was lacking. Long term historical and regional data was needed to tease out the differences between local fire-caused effects and landscape climate-caused effects to forest stands. It was necessary to develop a picture of how land use patterns, climate, tree demographics, and fire interacted and varied from pre-European settlement periods to contemporary periods. This included developing a data set of how fire timing, fire season, fire behavior, tree establishment, drought, and precipitation varied over multiple physical gradients, including forest types, elevation, and landscape physiography.

To derive even more information from tree-ring data, this study hoped to answer some of these questions by including study of tree establishment. Few previous tree-ring studies included tree-establishment data. This unique data contribution was needed to understand historic conditions and trajectories, to support current and future landscape planning and management projects, and to predict future conditions in the San Juan National Forest.

Application for Land Managers: This Study Provides Managers Sorely Needed Data

The results of this project can be directly used at the local level by San Juan National Forest personnel to plan and analyze projects that relate to fire and vegetation history. It provides baseline fire history, climate, and vegetation data sorely needed in an under-studied region

in Colorado that is unique within the state. For instance, this study provides a broader understanding about historical climate trends in the region. It can help local managers describe historic range of variability, develop desired future conditions, and predict future responses of stands to climate change. These data provide a more accurate assessment of historical range of variability of the San Juan National Forest, which is needed for required Fire Regime Condition Class (FRCC) analysis and reporting (Hann et al. 2003).

…this study provides a broader understanding about historical climate trends in the region.

These results can be adopted by national interagency projects that need updated and accurate fire history and vegetation data for the region. For instance, LANDFIRE (LANDFIRE 2007) and FRCC projects require fire history and vegetation data for analyzing reference conditions, measures of departure from historic range of variability, and Internet-based geospatial data. Because these national efforts and their products are Web-based, adjacent land managers and stakeholders can benefit from this study by gaining access to improved interagency products. This is especially beneficial because many Federal land managers lack site-specific, local, historic fire and vegetation data and depend on interagency products (such as LANDFIRE) to fulfill required FRCC reporting.

In a broader context, the results from this study overturn a paradigm that most land managers and researchers have adopted about even-aged ponderosa pine stands. No longer can the assumption be made that even-aged stands always developed from severe fire events. This study now forces managers to consider larger climatic and land use forces that can cause age classes to turn over at magnitudes and scales greater than fire.

For instance, the relationship between precipitation, drought, and fire is intriguing. This study confirms that a cycle of rain and drought is needed to increase fine flashy fuels and improve the chance of fire ignition and spread. In contrast, during severe droughts, fire might not be a big factor in shaping forest structure and composition. This makes sense, because—as this study showed—fine live and flashy fuels would be limited during severe droughts. In this context, climate becomes the driving force in shaping forest structure and composition over and beyond fire. When coupled with land use changes and fire suppression, the impact that climate has on forest structure and composition is obvious.

Considering current climate change trends and predictions, this information is important and timely.

Considering current climate change trends and predictions, this information is important and timely. In addition, the results from this study have wider implications for the southwest region. The study's findings can be used by regional climatologists and ecologists to predict future forest changes and make recommendations to local land managers in the face of climate change.

Though the results from the Sheep Creek and Bear Park mixed conifer and subalpine stands have not been thoroughly disclosed to date, these studies are greatly needed. These forest types are complex and often neglected in research proposals. Contributions from this study about forest structure and fire history will help land managers make more informed decisions about how to best perpetuate the diversity and resiliency of these stands, especially as exurban development of these forest types develops—creating a greater need for managing these stands as wildland-urban interfaces.

Deliverables and Technology Transfer
This project yielded a peer-reviewed publication, a final report, a Web site, and an archived database that land managers and researchers will find useful.

The project Web site makes the perfect launch pad for those interested in this study. From the Rocky Mountain Tree Ring Research Web site, a summary of the project is available, along with digital photographs of the study area and sampling techniques used. The summary and photographs facilitate the transfer of technology from research to the ground. Project maps, with exact locations of sample sites, are available for print or download from this Web site.

References
Hann, W., D. Havlina, A. Shlisky, et al. 2003. Interagency and The Nature Conservancy fire regime condition class web site. USDA Forest Service, US Department of the Interior, The Nature Conservancy, and Systems for Environmental Management. http://www.frcc.gov.

LANDFIRE, 2007. Homepage of the LANDFIRE Project. U.S. Department of Agriculture, Forest Service; U.S. Department of Interior. Online. Available at: http://www.landfire.gov/index.php (February 8, 2007).

Manager Profile
Lara Durán is a Fire Planner for the Sawtooth National Forest in Idaho. Her previous positions included Fuels Specialist, Fire Prevention, and Wildlife Technician for the U.S. Forest Service in Colorado. Lara contributed to the JFSP Risk Roundtable, Manager's Reviews, and participated in the national pilot program Integrated Landscape Design to Maximize Fuel Reduction Effectiveness.

She earned a BA in Ecology from the University of Colorado at Boulder where she earned a National Science Foundation grant for undergraduate research in alpine plant development. She was a Wildlife and Plant Ecology Research Assistant at the University of Colorado, contributing to long-term studies on ponderosa pine, Abert squirrels, dwarf mistletoe, elk, American marten, and yucca plants. Since then, she's completed graduate courses in wildlife and plant ecology, law, and administration. She is interested in disturbance ecology and the effects to wildlife.

This Manager's Viewpoint is based on JFSP Project 01-3-3-13, Fire and Forest Structure Across Vegetation Gradients in San Juan National Forest, Colorado — A Multi-Scaled Historical Analysis; Principal Investigator was Peter Brown.