Land use history impacts on biodiversity—Implications for management strategies (Western U.S.): Final Report

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Abstract

The prevailing benchmark for restoration in the Southwest United States has been a presumed "pre-settlement" reference condition from ponderosa pine forests near the San Francisco Peaks in northern Arizona. Case studies from four different landscapes in Arizona, Colorado, and New Mexico demonstrate that this benchmark does not adequately describe the range of historic conditions found in other ponderosa pine forests in the region, let alone mixed conifer forests or pinyon-juniper woodlands. Their forest histories are quite dissimilar, particularly with regard to when fire intervals changed, and when (or if) doghair thickets developed. These asynchronies force us to reject this single benchmark, and endorse a broader reference envelope based on site-specific conditions. In each case study, we assessed the relative effects of climate change, soils, fire, grazing, logging, farming, and invasive plant species on forest and woodland change. In each case, the timing, intensity, and duration of land use—combined with the unique physical environment of each study area—created unique effects on the landscape.

Our analysis of past and current climate has led us to conclude that climate variability has been an important shaper of modern Southwest woodlands and forests. Predicted climatic trends indicate that we are possibly entering a prolonged warmer and drier period, which will affect forest and woodland structure, disease frequencies, and wildfire intervals. Managers should attempt to plan for climate change and manage forest and woodland resources for high native biodiversity and landscape heterogeneity to sustain landscape-level processes that may be more resilient in the face of these anticipated changes.

Management implications from our study are listed below:

1. Know the site'shistory and its unique compositional elements; there is no single pre-settlement target for restoration.

2. Construct a reference envelope for each site, incorporating fire history, evidence from biofacts (tree rings, pollen, packrat middens), ethnohistory, and other tools.

3. Do not assume that thinning alone is enough to regenerate understory species richness or NTFPs; drought and arrested ecological processes produce time lags in recovery.

4. Strive to build into restoration programs objectives for ecological integrity, sustainability, and resilience in forest and woodland ecosystems by restoring natural processes and monitoring compositional changes in understory habitats.

Introduction

In recent years, the West has suffered from unprecedented stand-replacing wildfires, and the government has invested more money in preventative forest thinning than ever before. This crisis for Western forests and woodlands has also spurred heated policy debates. Activists, loggers, biologists, and recreationists on the Colorado Plateau differ in their opinions regarding the degree to which thinning can truly serve to restore

wooded habitats, and what reference conditions or restoration goals are needed to guide such plans. While managers may attempt to use "pre-settlement conditions" as a restoration goal (Covington and Moore 1994; Friederici 2003b), it may be difficult or impossible to know with certainty what these conditions actually were. Many times, these "pre-settlement conditions" are a generalized set of structural conditions that may not apply to specific local environments. Restoration plans based on such goals may be able to replicate earlier stand structures, but may nevertheless fall short of addressing landscape-level resilience, ecosystem processes, and the ecological and human implications of thinning.

There is general consensus among researchers and resource managers that ecological restoration of these forests and woodlands to more "natural" conditions is urgently needed (Covington et al. 1997; Allen et al. 2002a; Baker and Shinneman 2004; Dahms and Geils 1997). This consensus has developed from a growing body of literature that documents how more frequent, intense, and large wildfires—as well as the resulting fire suppression and rehabilitation costs—have been increasing over the last decade. These changes in fire dynamics have been related to historic changes in the density and age structure of ponderosa pine forests (Covington and Moore 1994) and of some pinyon-juniper woodlands (Baker and Shinneman 2004). Nevertheless, scientists differ in the degree to which they attribute these structural changes in vegetation to fire exclusion and suppression policies, livestock grazing, climatic fluctuations, bark beetle infestations, or other factors (Baker and Shinneman 2004; Dahms and Geils 1997).

The disagreements with regard to the causes of these problematic changes—as well as the relative efficacy of potential solutions—are no longer restricted to the realm of academic debate. The debate now concerns society as a whole, as indicated by the heated discussions and intense media coverage prior to the passage of Healthy Forests legislation by the U.S. Congress in the fall of 2003. There is little doubt that there will soon be more federal government support for addressing restoration and fire management issues facing Western forests and woodlands than ever before in American history. The central question, then, has become this: How can this unprecedented influx of support for forest management be used not merely to reduce the frequency of property-damaging fires over the short term, but to restore the health, resilience, and diversity of forests and woodlands over the long term?

Unfortunately, there remains considerable scientific uncertainty about how to best achieve these goals in ponderosa pine forests (Kloor 2000; Allen et al. 2002a; Dahms and Geils 1997), not to mention in pinyon-juniper woodlands (Baker and Shinneman 2004; Floyd 2003). Moreover, there has been intense controversy among environmental activists, forestry professionals, and other stakeholders, who do not agree on the relative economic, ecological, and aesthetic costs and benefits of the various practices being championed as ways to restore these forests and woodlands (Nijhuis 1999; Jenkins 2001; Allen et al. 2002b; Friederici 2003a).

Purpose

The purpose of this study was to describe how land use history, climate change, fire history, and other factors have interacted in the past to lead to the structural, processual, and compositional characteristics seen today in four forests/woodlands on the Colorado Plateau. Through this process, we have demonstrated how the use of a single

pre-settlement reference point for restoration is flawed, and we propose the use of a reference envelope including past and current influences on ecosystems as a guide to restoration goals and efforts.

Summary of results

Our study highlights the fact that using a single pre-settlement reference point to guide restoration is flawed in several ways. First, we concede that prehistoric conditions at any single site can never be fully known or understood. Our research indicates that the pre-settlement model is biased to forest overstory structural components and neglects compositional elements of the understory and many important processes. Second, pre-settlement usually refers to before Anglo-American settlement, but our studies highlight the fact that landscapes throughout the West evolved in the presence of humans for thousands of years before Anglo settlement, and that the native inhabitants influenced these landscapes in a multitude of ways. Third, some processes that were important in pre-settlement landscapes are now difficult or impossible to maintain, such as the frequent low-intensity fires that were so important to these Western landscapes, the role of missing predators, and depletion of surface and ground water through human over-use. Finally, such a retrospective view fails to account for several important modern influences on our landscapes, including pollution, exotic species invasions, habitat loss or fragmentation, or climate change.

Instead, we recommend expanding the restoration goal of pre-settlement reference conditions to a site-specific reference envelope, that incorporates information from a number of different data sources. In our case studies, we used information from palynology, dendrochronology, fire scar studies, and packrat midden studies, as well as archaeology, oral and written histories, and repeat photography to develop site histories that help to define the historic range of variability (HRV) in each landscape. We found that all four landscapes—each a part of the Colorado Plateau—were unique in important ways, and therefore required different management strategies. The sites had unique physical characteristics (e.g., substrates, bedrock geology, precipitation and microclimate, and dominant vegetation types), were characterized by complex histories of human occupation and abandonment over the last 12,000 years, and also had different land-use histories, including farming, grazing, and logging. In some cases, the most intensive land use had occurred centuries before Anglo-American settlement.

We reviewed all climatic reconstructions for our study areas, and found examples of flood, drought, or temperature variation that were more extreme in the past than any historic climate event, although the current global warming trend is becoming an extreme event. Fire history varied greatly between our study sites, with periods of fire cessation occurring centuries earlier in some landscapes than in others, but at all sites fires were permanently and dramatically reduced by 1880—well before official fire suppression policies were initiated. Insect infestations across the Colorado Plateau have had dramatic impacts on forests and woodlands in recent years, with 750 million acres of dead or dying trees documented from aerial surveys in Arizona and New Mexico in 2002. This phenomenon may have had an influence on wooded landscapes across the West prehistorically as well.

These unique site histories have led to changes in composition, structure, and ecological processes in all of our study areas. Generally, in ponderosa pine forests and

pinyon and juniper woodland there have been dramatic increases in stand density, a depauperate understory, reduced native biodiversity, and loss of cool-season grasses and non-timber forest products. In the higher elevation mixed conifer forests there is an increase in stand density and shade-tolerant trees. There has been a loss of old-growth ponderosa trees in the Chuska and Jemez Mountains as a result of intensive harvest. Tree and shrub expansion into grasslands has been documented at some of our sites. Ecological processes that have changed over time include some resulting from grazing, which has impacted hydrologic regimes and fire frequency. In densely forested watersheds, overgrazing and/or overlogging reduced fire frequency, and the loss of understory vegetation has resulted in reduced surface water infliltration, which caused lower base and peak flows in streams.

Using the dynamic model of a reference envelope helps us understand the natural range of variation in the past. However, most Western landscapes have crossed a threshold of change, and may not return to conditions within their historic range of variability in a human timescale, if at all. Thus, understanding the history of a site is only one part of what is needed for effective management and planning. We have therefore also reviewed the few high-quality studies of recovery and treatment response that have been conducted in our area to understand how these landscapes respond following wildfire, release from grazing, and restoration treatments.

Three grazing exclosure studies documented increases in native biodiversity, increases in native cool-season grasses, and more well-developed biological soil crusts inside the exclosures at timescales of 3 to 50 years. At Mesa Verde, a 17-foot rise in the water table was documented after grazing was excluded for 11 years. Two studies documented vegetation response to fire with post-fire studies of 5 and 16 years. Pinyon-juniper woodlands were very slow to recover from fire because adult trees, seedlings, and propagules of both dominant species are destroyed by fire, and they must rely on re-introduction of seed. Generally, the fire recovery studies showed changes in species composition and increases in native biodiversity following fire. Invasion by exotic plant species is also a concern in burned habitats. In a study of landscape response to thinning, preliminary results following a thinning and mulching treatment in the Jemez Mountains demonstrate significant changes in grass species composition and cover in the treated areas.

In each study area, we found that the health and richness of understory species was enhanced by the use and harvest of NTFPs. These species tend to increase heterogeneity in a landscape because they prefer certain substrates or growing conditions, and cultural use of them is an important way to encourage stewardship of native biodiversity in these wildlands.

We identified current threats in our study areas from published documents and interviews with land managers (Table 1).

Habitat loss and fragmentation resulting from urban and rural population growth is considered a threat in three of our four study areas, as is the threat of invasive exotic plant species; 10% to 17% of the floras are introduced species at Mesa Verde, in the Jemez Mountains, and in the Canyon de Chelly/Chuska Mountain area.

Table 1. Current threats identified in our study areas.

	Jemez	Mesa Verde	Chuskas	SF Volcanic Shield
Habitat loss/fragmentation	X		X	X
Wildfire	X	X		
Invasive species	X	X	X	
Air pollution		X		
PJ encroachment	X			X
Water issues	X			

In addition to the threats listed in Table 1, we propose that climate change should also be considered a threat, based on predictions that natural climatic trends in combination with regional land use and global warming increase the probability for abrupt, extreme climatic change. Currently, Canada is the only country that has included future climate change as a significant factor in a national fire management plan; we believe that climate change should be included in management and fire policy and planning. Restoring native biodiversity, preserving biological soil crusts, and preserving and enhancing natural heterogeneity in the landscape will help mitigate the threats we have identified, including the potential for catastrophic wildfires resulting from climatic conditions.

Management implications of our study include the following:

1. Know the site's history and its unique compositional elements; there is no single pre-settlement target for restoration.

2. Construct a reference envelope for each site, incorporating fire history, evidence from a broad range of biofacts (tree rings, pollen, packrat middens), ethnohistory, and other tools.

3. Do not assume that thinning alone is enough to regenerate understory species richness, especially for NTFPs; drought and arrested ecological processes produce time lags in recovery.

4. Restoration programs should strive to build ecological integrity, sustainability, and resilience into forest and woodland ecosystems by restoring natural processes and biodiversity.

5. Non-timber as well as timber products need to be taken into account for management plans in the culturally diverse forests and woodlands of the Colorado Plateau.

Approach

We did an extensive review of all pertinent research on paleo-climate, using palynology, tree ring, packrat midden, and archaeological information. We reviewed oral and written histories, historic photographs, and repeat photography for information on land use and its impacts. Our understanding of past fire frequencies is based on fire scar chronologies. We reviewed published reports, and when possible interviewed land managers in each of our study areas to understand more fully the issues specific to each area. We reviewed several modern studies of response to wildfire, release from grazing,

and restoration treatments. Finally, we reviewed current literature on climate change to provide insight into future trends.

We have appended an extensive bibliography of the literature used in our project.

Deliverables

We took advantage of a large conference of land managers and scientists held in Flagstaff in November, 2003, to present preliminary results of our study and begin dialog with others in the field. This was the Seventh Biennial Conference on Research on the Colorado Plateau, sponsored by the National Park Service and the Center for Sustainable Environments. Our paper will also appear in the proceedings of this conference.

Our other deliverables, outlined below, are scheduled after the June 30 end date for our project; we have requested a no-cost extension so that we can complete these aspects of the project.

A book, *Woodlands in crisis: A legacy of lost biodiversity on the Colorado Plateau*, will be published and distributed by the University of Arizona Press this fall. This book is an expanded and detailed exploration of many aspects of land use history, climate, and biodiversity. In addition to much greater detail on the types of information outlined in this report, the book includes sections on the effects of lost predators, woodland change, indigenous fire management and traditional ecological knowledge, invasive plant species, and detailed site descriptions for our study areas.

We will present a poster at the Ecological Society of America conference in Portland, Oregon, in August 2004.

We will use our study as the keynote presentation at the National Network of Forest Practitioners annual meeting in October, 2004, in Ouray, Colorado.

We will be providing three regional workshops with Native American groups, the National Park Service, the National Forest Service, and NGOs beginning in July 2004. These will include PowerPoint presentations and brochure dissemination.

Finally, we will produce a Web site, linked to the CP-LUHNA Web site and the Center for Sustainable Environments Web site, with our project summary and results.

We have agreed to provide lists of participants at our workshops to NCSSF after their completion.

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