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TITLE OF PROPOSED PROJECT **CNH: Long-term vulnerability and resilience of coupled human-natural ecosystems to fire regime and climate changes at an ancient Wildland Urban Interface**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 1,498,027	36 months	01/01/12	

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PROJECT SUMMARY

Human communities have been a part of fire prone environments for millennia, but current understanding of human-fire-climate relationships, particularly those associated with high-density human settlements in natural surroundings, is underdeveloped. Scholarship frequently presumes a linear relationship between human population density and "human impact" on existing fire regimes, but in the few case studies to date, the nature of that impact appears to be non-linear; at small demographic scales, fire activity is enhanced by human ignitions, whereas at larger population densities, fire frequency is suppressed. Recent research also suggests that anthropogenic burning in surface-fire adapted forests may enhance their resilience to long-term (centennial to millennial-scale) climate change. It is currently unknown if the mosaic of enhanced ignition but fuel fragmentation at the Wildland-Urban Interface would also enhance resilience or make these environments more vulnerable to climate change at the larger spatial scales and at longer timescales. Understanding this dynamic will be important for developing effective and sustainable fire and fuel management policy in these contexts.

This project develops paleoecological and model-based evaluations to test alternative hypotheses of how human activities in ancient contexts analogous to modern communities at the Wildland-Urban Interface (> 25 people/km^2) affect the resilience of forests and fire regimes to climate change over the last millennium. Archaeological analysis will define the relative population size and chronology of occupation at four village localities in northern New Mexico where human impacts on fuels and ignitions are likely. Paleoecological research will include fire-scar and tree-demographic analysis in ponderosa pine stands with sedimentary charcoal analysis, radiocarbon dating, palynology, and soil geochemistry from alluvial deposits at the four village localities and two unoccupied "control" localities. Together, the dendroecology and paleoecology will be used to build multi-century, forest stand to landscape scale fire and forest histories across human occupation gradients, ranging from heavily occupied to relatively unoccupied areas. Ethnoecological research with cultural advisory committees of American Indian tribes whose ancestors lived in these ponderosa pine forests for centuries will contextualize the interpretations of fire and forest histories in terms of traditional knowledge. Model simulations of forests and fire dynamics will be used to quantitatively explore the sensitivity of occupied ponderosa pine forests to varying intensities of human land use in the context of climate change at the landscape scale. Simulations will be tested against paleoecological data and will be varied in the importance of the ancient human land-use "footprint" to identify tipping points in fire regime change associated with a mosaic of human-impacted fuels and ignitions.

This is the first large-scale research program that combines dynamic ecological modeling, archaeology, oral tradition, dendroecology, and sedimentary paleoecology to investigate the long-term dynamics of human activities, fire regimes, and climate change at an ancient Wildland-Urban Interface. The proposal assembles a research team of scientists, educators, and American Indian collaborators with expertise and cultural knowledge uniquely relevant to the project. The research outcomes, outreach activities, and disseminated information will alter the discourse surrounding the climate-human-fire nexus by expanding the value of socionatural historical studies to inform contemporary adaptation strategies. The results of this study will contribute critical information on the landscape scale dynamics of forests adapted to frequent, low-severity surface fire regimes that will be relevant to contemporary policy discussions and sustainable management of similar forests at the Wildland-Urban Interface in the American West and across northern Eurasia.

Outreach associated with this project will involve the participation of more than 20 secondary school teachers in developing and implementing lesson-plans that integrate fire and climate change concerns in science and history classrooms in local schools that primarily serve underrepresented communities. This project includes participation by more than 40 members of four American Indian tribes in scientific research on the landscapes that their ancestors occupied and that remain sacred and important today. The project results will be widely disseminated through secondary school educational activities, special publications, displays at tribal museums, and public lectures.

As global climates change, uncontrolled wildland fires have become regular features of national and international news. From the shrublands of southeastern Australia to conifer forests of Canada and the western United States, warming trends and prolonged droughts have led to increasing numbers of large, severe fires (Gillett et al., 2004; Westerling et al., 2006; Littell et al., 2009). After more than a century of suppressing surface fires, many pine-dominated forest ecosystems are now vulnerable to unusually severe canopy fires, especially during droughts (e.g., Allen et al., 2002).

Human communities have been a part of fire-prone environments for millennia and the dramatic scenes of fires burning the landscapes around currently occupied but ancient settlements as diverse as Athens, Greece and Taos Pueblo, New Mexico (see Figure 1) highlight these connections but also underscore the degree to which we have an underdeveloped understanding of human-fire-climate relationships. Despite common knowledge that people have used fire for a variety of purposes over millennia and that drought and fire are strongly coupled, general theory that might explain or predict human-fire-climate dynamics have been slow in developing (Bowman et al., 2009; Pyne 2007).

Figure 1. The diversity of human-fire interactions are illustrated by recent fires burning in landscapes near the Parthenon in Athens, Greece (left) and near Taos Pueblo, New Mexico (right). Surely people have witnessed wildfires in these places during past centuries and millennia, but are the fire severities and impacts occurring now extraordinary? And if so, what role did past and recent human land uses and climate have to do with such changes?

Persistent academic and cultural barriers between the humanities, social, physical and biological sciences have been impediments to advances in knowledge and theory of human-fire dynamics (Pyne 2007). Although the written historical record of human-fire relations is qualitatively very rich, only rarely has it been used in a quantitative manner to develop testable hypotheses that can be evaluated with independently derived data. Paleofire records have greatly expanded in time depth and spatial coverage in recent years, but these studies have tended to focus primarily on climatic and other physical and ecological drivers of the reconstructed patterns. Scholars focusing on these issues in the western U.S. have tended to conclude or assume that the degree of human impacts on past fire regimes was strongly connected to population density, and that human effects were limited in spatial extent and to specific time periods (e.g., Allen, 2002; Whitlock *et al.*, 2010). Research on human-fire dynamics in historical (Guyette *et al.*, 2002) and modern periods (Syphard *et al.*, 2007), however, indicate that human controls over fire regimes can be non-linearly related to population density. We think that coupled human-natural fire regimes are best approached as complex systems capable of generating emergent dynamics with outcomes dependent upon a variety of linear and non-linear relationships between human population density, fuel structure, land-use, and climate. The complexity of the interactions necessitates interdisciplinary research that explicitly compares information from paleoecology, archaeology anthropology, and history to test alternative hypotheses about these emergent dynamics.

RELEVANCE AND GENERALIZABILITY

Fire is fundamental in local, regional, and global scale ecosystem patterns and processes. Fire is a keystone process in many ecosystems and is embedded in complex relationships with climate change, ecosystem dynamics, and human activities (Bowman et al., 2009). Socionatural systems over the last few millennia have developed in the context of particular *fire regimes*—characteristic frequencies, seasonal timing, sizes, and severities of fire. Fire regimes are *dynamic* (Johnson, 1992; Agee, 1993), but tend to maintain particular meta-stable states or adaptive cycles over time (Holling and Gunderson, 2002). An important property of ecosystems (and their characteristic fire regime) is ecological *resilience*—the ability of the system to maintain or recover ecosystem functions and structures in the face of perturbations, novel conditions, or extreme events (Holling, 1996; Millar et al., 2007). Alterations to characteristics of fire regimes across spatial scales may reduce resilience and ultimately result in state shifts to degraded conditions (Scheffer and Carpenter, 2003).

Changes in climate and human activities over the past 150 years have altered the properties of many fire regimes globally and in diverse ways (Marlon *et al.*, 2008; Girardin *et al.*, 2009; Krawchuk *et al.*, 2009). The dynamic interactions of fire, climate, and human activities across scales, however, are incompletely understood (Bowman et al., 2009), because they are often based on instrumental data that only take into account decades of change and thus are biased toward contemporary conditions. Many scholars (including us) recognize that the many "no-analog" conditions of modern environments means that past ecosystem structures and processes are imperfect, and in many cases inappropriate, as explicit targets for ecological restoration (e.g., Millar *et al.*, 2007). This limitation of history, however, does not undermine its core values and uses. First, historical reconstructions and assessments are still essential to answer basic questions, such as: Have ecosystem structures and processes actually changed substantially? Where? When? What magnitude? What were the likely causes of these changes? And most importantly for our purposes here, are there fundamental dynamical relations inherent in the system, which may not have changed despite changes in system variables, which we can learn about and use in our models to anticipate the future? Second, the predictive uncertainties of future climate change scenarios are so large that the historical/archaeological/paleoecological record remains the most reliable source of information on the dynamics of socionatural systems in the context of variable climates (Keane *et al.*, 2009). Third, because of the long-timescales necessary for understanding the dynamics and interactions of forests, climate variations, and sedentary societies (centuries to millennia), the paleo record is a necessary reference for identifying the likely transition points at which these socionatural systems may not be sustainable. Conversely, case studies (such as we propose) may provide useful insights on how past human societies lived sustainably for multiple centuries within fire-prone and climatically variable environments. This knowledge is needed to identify potential strategies for managing today's fire-prone ecosystems with increasing human populations, including novel resilient ecosystems that maintain key structures, functions, and services (Jackson and Hobbs, 2009).

Although our proposed research is fundamentally a case study, our project has the potential to generate knowledge that is applicable to very widespread, pine-dominant systems around the northern hemisphere. Pine-dominated forests that were historically characterized by low-severity or mixed severity surface fire regimes are widespread throughout Western North America (associated with the distribution of *Pinus pondersosa*) and across Northern Eurasia (associated with the distribution of *Pinus sylvestris*). These two pine species are among the most widely distributed conifer species in these respective continents. The fire regimes were variable across the ranges of these species, but in general, their dominant characteristics included frequent, low to moderate-severity surface fires (<less than 20 year intervals in most *P. ponderosa*, and somewhat longer intervals in *P. sylvestris* stands). These frequent fires tended to maintain relatively low tree densities and fuel accumulations, resulting in a relatively rare occurrence of extensive, high-severity crown fires. (Note that, PI Swetnam is currently also engaged in a 3 year NASA/US Forest Service fire history and climate investigation in *P. sylvestris* forests of central Siberia, where human-fire interactions are also a central issue of study and importance.)

There is ongoing debate and uncertainty about the frequency, extent, and causal factors of past high severity crown fires in *P. ponderosa* dominant forests in North America (Pierce *et al.*, 2004; Roos, 2008; Frechette and Meyer, 2009). There is a broad consensus, however, that the frequent, widespread surface fire regimes that existed in most of the drier, interior-continental *P. ponderosa* forests have been disrupted for a century or more by human land uses and fire suppression, and that this has led to anomalous fuel accumulations and extraordinary fire behavior during recent droughts, especially in the

Southwestern U.S. (Allen et al. 2002, Covington and Moore 1994). Hence, with the exception of tropical rain forests, these surface-fire maintained pine forests may be among the fire regimes furthest from their historical range of variability after more than a century of passive and active fire suppression.

It is critically important that we improve our understanding of the *long-term* fire-climate-society nexus by employing integrated interdisciplinary approaches precisely because: 1) there is increased human settlement of fire-prone areas often referred to as the Wildland Urban Interface (or Intermix, WUI); 2) we are entering an era of climate change and extreme fire regime responses driven in part by anthropogenic greenhouse gas emissions; and 3) further advancement of fire science and its application requires effective integration of physical, ecological, and social sciences (Daniel *et al.*, 2007; Pyne, 2007; Bowman *et al.*, 2009). These issues are particularly salient to the USDA Forest Service, whose management responsibilities include extensive WUI areas within fire-prone forests. Landscape-scale forest restoration programs to be led by the Forest Service have recently been authorized and appropriated by Congress, and understanding of climate/ecosystem/human history and dynamics are valuable, if not essential, for justifying and developing the plans. Efforts to undertake forest "restoration" treatments where forest structures have most changed in the past century (e.g., ponderosa pine) have expanded in recent years, and to support these efforts Congress recently passed the "Collaborative Forest Landscape Restoration Act" (CFLRA). This Act authorizes $40 million per year for large-scale treatments of forest landscapes (> 50,000 acre projects) on Forest Service lands (approximately $1-3 million/year per project). The Santa Fe National Forest and other federal, tribal and state collaborators were recently awarded funding for one of these initiatives within the Jemez Mountains, including our proposed study area (http://www.fs.fed.us/r3/sfe/jemez_mtn_rest/index.html).

Planning for this landscape-scale forest restoration effort is underway. A key research need to help inform this endeavor is an improved understanding of the role of climate, human activity, and fire in changes to forest structure and composition. Moreover, landscape-scale prescribed burning will likely consume much of the remnant tree-ring record of past centuries of fire and forest history (i.e., in logs, stumps and snags), which has been accumulating (ironically) for the past century because of the lack of extensive fires. Hence, there is some urgency in "salvaging" this irreplaceable environmental and cultural history while it is still obtainable, i.e., before the treatments take place within the next few years.

A fundamental goal of our proposed project is to understand the dynamic interactions of climate, human activities, and fire regimes over a variety of temporal, spatial, and demographic scales in an ancient Wildland Urban Interface. Specifically, we propose to evaluate these alternative hypotheses: 1) human activities had no effect on fire regime variability, and fire dynamics were driven exclusively by climate-fuel relationships (i.e., a null model); 2) human actions enhanced the resilience of these forests to low-frequency, high severity fire events (Roos, 2008); or 3) that as human populations reached WUI-levels, there were non-linear responses of coupled human-natural fire regimes that resulted in increased vulnerability to climate changes (Guyette *et al.*, 2002; Syphard *et al.*, 2007). In essence we are asking the questions: Do low human populations enhance resilience whereas the impacts of larger human populations on fuel structure reduce resilience and elevate vulnerability to fire regime shifts? We will employ a combination of archaeology, ethnoecology, dendroecology, sedimentary paleoecology, and dynamic simulation of fire regimes and ecosystem processes to test these hypotheses.

Our proposed study area in northern New Mexico is uniquely suited for this research. In this region we have the opportunity to obtain and analyze an extraordinarily rich set of paleoecological, geological, archeological and historic period documentary records. According to historical estimates, more than 7,000 people lived in as many as nine villages over roughly a 10km by 25km area (28 people/km^2) between circa 1300-1550 CE in the Jemez Plateau area. Most of these dwellings were located within or immediately adjacent to surface fire-adapted ponderosa pine forests (Kulisheck, 2005; Liebmann, 2006). At this population density, the ancient occupation of the Jemez Plateau is analogous to contemporary WUI contexts that have a minimum population density of 24.7 people/ km^2, if one assumes 4 residents per housing unit (Radeloff *et al.*, 2005; Schoennagel *et al.*, 2009). The management of fires and fuels in these contexts is a central policy issue today and improved understanding of the dynamics of fire, fuels, and forest behavior in WUI contexts will be important for these policy discussions (Schoennagel *et al.*, 2009).

THEORETICAL FOUNDATIONS AND RESEARCH CONTEXT

It has become increasingly apparent over the last three decades that fire behavior and fire regimes in Southwestern ponderosa pine forests have been substantially altered relative to pre-Euroamerican (i.e., pre-1870 CE) dynamics (Fulé et al., 1997; Allen et al., 2002). A well-replicated network of approximately 120 tree-ring based fire-history reconstructions across the Southwest indicate that prior to ca. 1900 ponderosa pine forests sustained frequent (i.e., about every 3-15 years), low-severity surface fires (Swetnam and Baisan, 1996, 2003; Swetnam and Brown, 2010). These fires maintained open-canopy structures of mixed age stands with herbaceous, park-like understory plant communities. Frequent surface fires ceased in nearly all locations following construction of railroads, establishment of Indian reservations, heavy livestock grazing, and increasingly effective fire suppression efforts by government agencies (Swetnam and Baisan, 2003). The importance of herbaceous fuels in these frequent surface fire regimes is indicated by several examples of early fire regime disruption (e.g., mid 1700s to mid 1800s) at some locations that experienced early Hispanic or Navajo livestock grazing (e.g., Savage and Swetnam, 1990; Swetnam and Baisan 2003).

Prolonged warm and wet conditions in the early 20th century (Salzer and Kipfmueller, 2005; Woodhouse *et al.*, 2005) in the absence of frequent surface fires produced widespread germination and recruitment of young ponderosa pine (Savage et al., 1996) that resulted in hyper-dense stand structures (i.e., "dog-hair" thickets) with vertical fuel continuity (Biondi, 1999). Mid and late 20th century land uses (e.g., livestock grazing, road building, logging) and the absence of surface fires perpetuated and may have exacerbated forest alterations. Prolonged or severe droughts over the last 60 years have produced increasingly large and severe fires in these altered forests (Allen et al., 2002). Late 20th and early 21st century fire regimes of mixed or high-severity fires in Southwestern ponderosa pine may promote succession to meta-stable hyper-dense forests, grasslands, or shrub-fields, and not necessarily a return to open-canopied stands that existed for centuries prior to these recent burns (Allen et al., 2002; Savage and Mast, 2005).

Altered stand densities and fuel structures, rather than climate variability alone, appear to be key properties leading to unusual fire severity and extent in these forests. Severe drought conditions occurred during previous centuries (e.g., during the 17th, 18th, and 19th centuries, Salzer and Kipfmueller, 2005:475) but apparently did not result in altered fire severity or the large patch size crown fires observed during recent drought events. For example, the 2002 Rodeo-Chediski Fire in central Arizona burned more than 187,000 ha, of which about 50 percent was deemed "moderate to high severity", with many large (>100 ha) high severity patches where all overstory trees were killed (Finney et al., 2005). No pre-21st century crown fire patches of this extent have been identified in Southwestern ponderosa pine forests, despite extensive documentary, photographic and tree-ring investigation (Cooper, 1960; Allen *et al.*, 2002; but see Iniguez *et al.*, 2009, for an example of a smaller extent, pre-1900 crown fire in a *P. ponderosa* dominant forest). New evidence is emerging now, however, from sedimentary charcoal-based studies encompassing longer time scales and potentially more severe droughts (e.g., the Medieval Climate Anomaly of circa CE 900-1300) that large crown fires may have occurred in some Southwestern ponderosa pine forests (New, 2007; Roos, 2008; Frechette and Meyer, 2009), but the spatial extent (crown fire patch size) of these events is unknown at this time.

Both climate and land uses are implicated in the 20th and early 21st century Southwestern changes described above, but our understanding of the interactions of human activities, climate change, and forest dynamics at multiple scales is limited, especially prior to the 20th century. With a few notable exceptions (Fish, 1996; Kaib, 1998; Allen, 2002), scholarly research on human-fire dynamics in the Southwest has been limited.

Although a divergence of views exists about the importance of humans in controlling past fire regimes (cf., Pyne, 1982; Allen, 2002; Vale, 2002 [and chapters therein]; Kay, 2007) there has been relatively little direct, quantitative evidence brought to bear to test these perspectives in cases where high-resolution time series of all the relevant variables are available (e.g., fire, climate, and human chronology). As a consequence, many scientists, land managers and others hold diametrically opposed and over generalized views that *either* humans were of dominant importance in controlling past fire regimes virtually everywhere for thousands of years, *or* humans were of limited or no importance in changing fire patterns at any time in the past.

Increased fire frequency due to human presence is often the key topic in the human-fire debate, however, this is only one way in which humans (or climate) can affect fire regimes through the two primary parameters that determine fire behavior and fire regimes—ignitions and fuels. For example, human activities affect fuel amount and continuity (spatio-temporal distributions) through trampling, livestock grazing, fuelwood and architectural wood harvesting, and establishment of the built environment (villages, fields, and trails/roads). Indeed, some of these effects on fuel quantity, type, and spatial arrangement, and consequent effects on fire ignition and spread, may offset the effects of increased ignitions via purposeful burning. Many of these likely fire regime consequences are dependent upon population density and residential mobility and could manifest themselves on the landscape in heterogeneous ways. For example, large populations of agriculturalists in the Southwest may have reduced fire-frequency in the vicinity of their villages due to fuel reduction and discontinuity via the processes listed above. Given that some of the village sites were located in forests above 1,800 meters (6,000 feet) elevation, fuelwood demands for heating habitations during cold seasons would have been substantial (e.g., Samuels and Betancourt, 1982; Kohler and Mathews, 1988). Likewise, the many large, multi-story townhouse villages on the Jemez Plateau required the harvesting of many thousands of roofing timbers of varying sizes and lengths. Although wildfires during the natural fire season (and agricultural growing season) near agricultural fields may have been disastrous (Fish, 1996), frequent early season burning (or post-harvest burning) for fuel reduction or as a natural fertilizer (Sullivan, 1982) could have pre-empted or superseded lightning and climate-driven fire regimes.

For mobile, low-density human populations, fire regime impacts may have been quite different or more variable. For example, Apaches who were seasonally mobile gatherer-gardeners and occasionally reliant on a raiding economy (Griffin et al., 1971; Basso, 1998), used fire both at local and landscape scales for a variety of purposes, including for agriculture, hunting, wild plant manipulation, and warfare (Buskirk, 1986; Kaib, 1998). Although human influences on past fire regimes may be difficult to clearly identify in some Southwestern environments that are "saturated" with lightning ignitions (Allen, 2002) the use of multiple lines of evidence and comparative spatial/temporal analysis of independent chronologies of humans, climate, and fire have been used to disentangle natural and cultural fire patterns (Barrett and Arno, 1982; Seklecki et al., 1996; Kaye and Swetnam, 1999; Roos, 2008).

In sum, human activities and climate can both affect ignitions and fuels in different ways, potentially increasing or decreasing fire frequency and altering fire severity. Consequently, the nexus of humans, fire, and climate potentially generates system dynamics that have not been predicted by dichotomous and over generalized views of the effects of either humans or climate on fire. Patchy landscape fire histories, as might be expected in long-occupied, coupled human-natural ecosystems with mosaics of both elevated and suppressed fire frequencies might respond to climate changes in ways that are unpredictable based on current knowledge. Again, a central need in advancing our understanding of these systems are tests of hypotheses with quantitative data which will contribute to the development of general theory about human-fire-climate dynamics.

Fire climatology of ponderosa pine forests

An emergent property of network compilations of fire-scar chronologies from throughout this region (and the broader western U.S.) are highly synchronous fire dates in many scattered locations (Swetnam and Betancourt, 1998; Kitzberger et al., 2007). Likewise, there is a high degree of synchrony of low fire occurrence years. This synchrony of fire activity occurs at stand to mountain range spatial scales, suggesting actual fire spread among sampled locations in some cases. Fire event synchrony among widely separated mountains at regional scales suggests climate synchronization of separately ignited and burned areas. Over the past several centuries (i.e., ca. 1600 CE to present) widespread fire years tended to be very dry and typically occurred after multiple wet years (Swetnam and Betancourt, 1998; Swetnam and Baisan, 2003). This effect of inter-annual climate variability on fire regimes is probably operating through production and moisture condition of surface fuels. In semi-arid ponderosa pine forests, wet years produce abundant and continuous fine fuels that are cured for burning in subsequent dry years. This wet/dry pattern is also evident in late 20th and early 21st century landscapes, especially in dry ponderosa pine and lower elevation grassland-dominated ecosystems (Westerling et al., 2003; Crimmins and Comrie, 2004; Littell et al., 2009). Moreover, interannual to decadal climate variability in the Southwest is partly controlled by ocean-atmosphere oscillations (e.g., the El Niño-Southern Oscillation and the Pacific Decadal Oscillation), and indices of these oscillations are well correlated with modern and paleo-fire chronologies (Swetnam and Betancourt, 1990; Westerling and Swetnam, 2003; Brown and Wu, 2005; Kitzberger et al., 2007).

The effects of decadal and centennial scale climate variability on ponderosa pine forests are not as well known. Multi-year droughts have been implicated in geomorphic studies of larger and more severe fires during the Medieval Climate Anomaly (MCA; ca. 900-1300 CE) (New, 2007; Frechette and Meyer, 2009). Cook et al. (2004) suggest that persistent drought during the MCA was related to increased wildfire and reduced lake levels in the Sierra Nevada and Northern Rockies. In long-term climate reconstructions, some decades of the MCA appear to have been relatively wet (Petersen, 1994; Grissino-Mayer and Swetnam, 2000), and some decades exceptionally dry (Meko et al., 2007). Regional and sub-regional effects may have been quite variable (Hughes and Diaz, 1994) in both temperature and moisture (e.g., Salzer and Kipfmueller, 2005) making Southwestern fire-climate linkages during the MCA uncertain at present.

Long-term climate-based reconstructions of centennial scale variability in regional fire activity suggest that fire frequencies between 1350-1650 CE may have elevated fuel accumulations and enhanced canopy recruitment, thus creating forests vulnerable to altered fire regimes, particularly during prolonged drought (Savage and Mast, 2005; Roos and Swetnam, 2010). In other words, this may have been a multi-century period during which the presence or absence of human communities and their effects on fuels and ignitions may have been particularly significant in enhancing or eroding ecosystem resilience.

Fire regimes and ecological resilience of natural and human-natural ecosystems

Ecological resilience refers to the ability of a system to tolerate a perturbation without disrupting ecosystem functions or collapsing into an alternative state. Emerging evidence that ecosystems have multiple, alternative states that are characterized by their own adaptive cycles or regimes of disturbance, structure, diversity, and services (Beisner et al., 2003) presupposes that ecological resilience is one of the most fundamental properties of socionatural systems (Folke et al., 2004). Ecological resilience has two key dimensions: 1) the range of ecosystem parameters that sustain a particular meta-stable state and regime (i.e. “latitude”), and 2) the ease or difficulty transforming the entire system (i.e., "resistance," Walker *et al.*, 2004). These can be represented in two-dimensional fashion in a ball and cup diagram (see Figure 2). *Ecological resilience* is a continuous variable, the inverse of which is *vulnerability* (Walker et al., 2006). More *resilient* ecosystems are less *vulnerable* to catastrophic regime shifts with changes in land-use or climatically driven parameters, and vice versa. Ecosystem approaches to alternative stable states suggest that change within these systems is a non-linear process in which a range of conditions (i.e., latitude) may support a particular meta-stable state until a critical parameter threshold is crossed and the entire system transforms rapidly into an alternative state or regime.

This body of theory is useful for investigating the dynamic interplay between human behaviors, climate change, and ecosystems. Particularly in fire-adapted landscapes, where key ecosystem parameters are maintained by a characteristic fire regime (i.e., a particular frequency, seasonality, and severity/intensity of fires that shape the evolutionary environment of that ecosystem), human activity and climate dynamics have feedbacks on key variables, including ignitions, fuel quantity and structure, and the length of possible fire seasons. Over the past century, active and passive fire suppression have increased the vulnerability of some ecosystems (i.e., reduced the resilience) by reducing ignitions and fire spread. This in turn had positive feedbacks on fuel accumulation, eventually pushing many of these ecosystems into alternative regimes of high severity fires and with possible state transitions to grasslands or shrublands (Allen et al., 2002; Savage and Mast, 2005).

There are two feedback loops that affect the resilience and vulnerability of ponderosa pine forests to state shifts. Frequent (<20 year fire free interval) low-severity surface fires thin young conifers and maintain an open canopy structure that promotes herbaceous plant growth (Zwolinski, 1990) and inhibits the development of high fuel loads and fuel structures that provide ladders between surface fuels and canopy fuels. This is a stabilizing (i.e., negative) feedback loop in which frequent surface fires maintain a resilient, open-canopied forest promoting frequent surface fires. By contrast, infrequent surface or mixed-severity fires (i.e., > 30 year intervals) may drive a destabilizing (i.e., positive) feedback loop in which live and dead fuels can accumulate, resulting in forests that are more vulnerable to disturbances and collapse into an alternative meta-stable state (Savage and Mast, 2005). (Note that the fire intervals and associated states listed above are only hypothetical. The actual interval distributions and other fire regime parameters associated with variable forest states, and the tipping points between them, are largely unknown and a subject of our proposed research.)

Human activities and climate variability can influence both of these feedback loops by affecting ignitions and fuel properties that affect fire spread. Human activities, in particular, can affect the spatial scale at which these feedback loops can operate. For example at low population densities, the addition of human ignitions may be the most significant contributor of human activities (Guyette *et al.*, 2002). In surface fire regimes, human ignitions may help sustain the stabilizing feedbacks even as other processes reduce fuel continuity, thus enhancing ecosystem resilience. As human populations increase, the cultural landscape may fragment fuels, thus reducing the average size of burned areas and landscape scale fire frequency (Syphard *et al.*, 2007; Archibald *et al.*, 2009), which might result in altered fuel and stand structures and an erosion of resilience. This could be counteracted if humans deliberately burned most parts of the landscape, including areas that would not have otherwise burned because of loss of fuel continuity (and fire spread) due to other types of human activity (like fuelwood harvesting, trailing, agricultural activities, etc.).

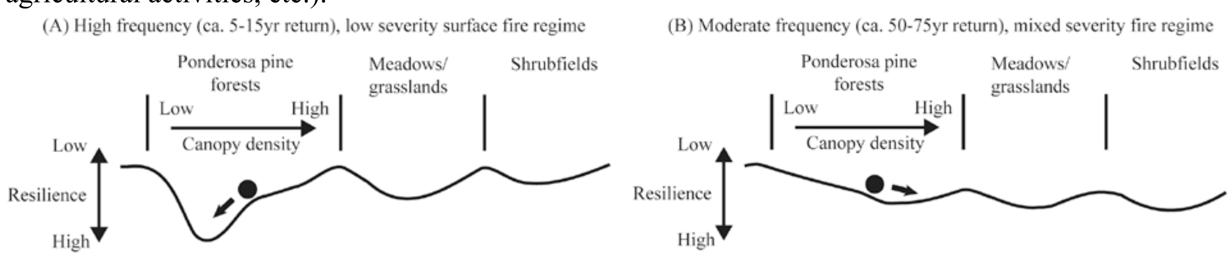

Figure 2. Ball and cup models of resilience and alternative meta-stable states for *P. ponderosa* forests under (A) low stand density and frequent, low-severity fires, or under (B) high stand density with vertical fuel continuity, and infrequent, mixed-severity or high severity fires. These figures illustrate how the stability of a forest environment can change with variable frequencies and severities of fire. Like a ball and a cup, the ridges, or edges are unstable; the ball will either fall in or out of the cup but will not stay on the edge. Deeper cups indicate environments that are "resistant" to changes. Wider cups have larger "latitude." It would take a big jolt to knock the ball out of a deep, wide cup but a smaller jolt would knock a ball out of a shallow cup. In forests that experience frequent, low-severity fires, even large fires are small "jolts" and the forest remains stable and healthy. In forests with long intervals between fires, even a minor drought may be enough to promote high severity fires, kill trees in large patches, and jolt the environment into shrublands or grasslands; alternatively, forests may partially recover as dense stands in the absence of frequent surface fires, and thereby remain vulnerable to future high severity fires.

In a recent dissertation, Roos (2008) examined sedimentary fire histories across a gradient of unoccupied, short-occupied, and long-occupied ponderosa pine forests in Eastern Arizona over the last 1,000 years. The short-occupied watersheds were depopulated (ca. 1325 CE) prior to the reduction in climate-driven fire frequency between 1350-1650 CE (Roos and Swetnam, 2010), whereas the long-occupied watersheds overlapped with the first half-century and the last century of this period. Sedimentary proxies, including charcoal, pollen, phosphorus, and radiocarbon data, indicate that

Ancestral Pueblo villagers supplemented naturally frequent fires during their occupation of these landscapes. These same proxies of local fire regime histories indicated that *unoccupied* and *short-occupied watersheds* experienced high-severity crown fire activity during the 15th century mega-drought (Stahle *et al.*, 2007) but there is no evidence for such altered fire behavior in the long-occupied watersheds (Roos 2008). In other words, anthropogenic burning by American Indian agriculturalists during the 14th century sustained frequent fires in occupied landscapes while climate-driven reductions in fire frequency increased the vulnerability of those areas that were no longer used or had never been occupied. The population density of the Arizona study area was well below the level of modern WUI definitions, however (Newcomb, 1999). As populations increase further, we might expect human activity to have a greater influence on fuel fragmentation and, thus, the positive feedback loop driving fire regime change and eroding ecosystem resilience. For these surface-fire adapted forests, this is a hypothesis that must be tested. The relative importance of ignition enhancement and fuel fragmentation in WUI contexts is vital for contributing to contemporary policy debates on how limited government resources can best be spent to reduce vulnerability of these forests and human communities in the context of climate change.

PROPOSED RESEARCH

In this study, we propose comparative empirical and modeling analyses of coupled human-natural systems from similar environments (ponderosa pine forests), with similar climate histories, but different land-use, occupational, and demographic histories. In this research we seek to evaluate three alternative hypotheses: 1) a null model of no human effect, 2) a hypothesis that humans and anthropogenic burning enhances resilience across demographic scales, and 3) that the human ecological footprint associated with WUI-level population densities erodes resilience in the mosaic of enhanced and suppressed fire activity. We have selected a project area that is uniquely suited to this analysis because it has archaeological evidence for centuries-long agricultural occupations at population levels equivalent to modern Wildland-Urban Interface contexts within a surface-fire adapted forest that has yielded centuries-long archives of ancient fire activity. New archaeological research will provide a chronological and demographic baseline for spatially explicit sedimentary and dendroecological fire history reconstructions. The coupled dendro- and paleoecology research will allow us to investigate long-term fire regime history at nested temporal scales and resolutions: annual fire activity over multiple centuries (dendroecology) and decadal fire regime variability over centuries to millennia (sedimentary paleoecology).

Through spatially explicit fire behavior and forest dynamic modeling, we will be able to investigate fire regime history across the larger Jemez Plateau landscape. With historical climate reconstructions as inputs, we can systematically vary human impacts (as ignitions and fuel disturbances) to explore the landscape consequences of human activities beyond our dendro and paleoecological sampling locations. By ground-truthing the modeling results with paleoecological data, we can further calibrate and evaluate the reliability of the models. Paleoecological and modeling research programs will allow us to evaluate our hypotheses at nested spatial as well as temporal scales.

Our knowledge of past human perceptions and decision-making regarding fire is limited. Early anthropological research was rarely concerned with fire and when its use on landscapes was recorded, these descriptions rarely included the decision-making or perceptions of local peoples about fire or fuels (Stewart, 2002). Given the state of scholarly knowledge of the subject, we think it prudent to avoid formally modeling human system feedbacks. Rather, we have engaged American Indian communities as research partners in an ethnoecology and oral history program within the project to 1) generate information on cultural attitudes towards wildland fire, fire use, smoke, and landscape fuel and stand conditions, and 2) collaborate with our American Indian partners in the interpretation of anomalous results in the paleoecological and modeling research programs (letters of support for the original submission of this proposal from each community are included in the supporting documents). In this manner, we hope to begin building the necessary information from which to build formal models of human system feedbacks in a coupled human-natural fire regime in the future.

Each of these research programs are part of an integrated interdisciplinary research project designed to evaluate the dynamic impacts of climate and land-use on fire regime variability across spatial and temporal scales in the ancient Wildland Urban Interface of the Jemez Plateau, New Mexico.

Study area

The Jemez Plateau, on the south side of the Valles Caldera in northern New Mexico has been home to Jemez people and their ancestors since approximately 1200 CE (Liebmann, 2006). Although largely neglected by academic archaeologists for nearly 60 years, the Jemez Plateau has witnessed an increase in attention over the past decade, including two recent dissertations (e.g., Kulisheck, 2005; Liebmann, 2006). Kulisheck's work provides a comprehensive overview of the known and interpreted Jemez chronology including all large villages and other known dwelling sites, and likely demographic changes based on syntheses of tree-ring, ceramic, and other evidence. Liebmann's work provides a detailed archaeological and historical narrative of the Pueblo Revolt period and subsequent *Reconquista*, when the Spaniards reestablished colonial control over New Mexico. Archaeological evidence of at least nine, very large (multistory, 500 to 1,800 room), ancestral Jemez villages in ponderosa pine landscapes of the Jemez Plateau provides a unique opportunity to reconstruct fire history in what was essentially a 14th to 17th century Wildland Urban Interface. Although the chronology is fairly coarse we know that some of the large villages were established early (in the 13th or 14th centuries), some villages were established later in the prehistoric period (in the 15th century), and some villages have evidence for reoccupation after the Pueblo Revolt (late 17th and early 18th centuries). The chronologies of these events for particular villages needs to be further refined, but will provide an ideal context for examining the impact of the key human occupation variables: population size, occupation duration, and the timing of occupation relative to climate and fire variability.

It is worth emphasizing again the unique opportunity that this archaeological and ecological context provides: These were among the largest Native American "townhouse" villages (if not the largest) known to have existed anywhere in western North America within pine-dominated, surface fire regime forests. The ancestral Jemez people found ways to live as dryland agriculturalists within these fire prone (and smoky) landscapes for centuries, through irregular pluvial and drought periods of varying magnitudes. Further, these villages and the surrounding forest areas were intensively occupied for generations then subsequently abandoned (with populations relocating to new villages in the region) and, in the case of some villages, were reoccupied briefly *during the historic period* when both documentary and tree-ring data sets can be brought to bear in our analyses.

1) *Archaeologically-Informed Paleoecology*

Establishing the basics of human occupation, demography, and land use through time in the Jemez Province is fundamental to the research design of this project. In order to understand the relationships between the prehistoric occupants of the Jemez region and fire regimes of the 14th-17th centuries in this area, two primary archaeological questions need to be addressed: 1) when and for how long were the archaeological sites of this region occupied; and 2) how many people were living at these sites at a given time? In other words, we need to establish occupation histories for the study area that detail the duration and intensity of inhabitation and provide rough population estimates. The answers to these questions will structure our paleoecological sampling design, provide data for our spatially explicit modeling activities, and serve as points of connection for our Tribal collaborators in the oral tradition and ethnoecology portion of the research project.

At present, the necessarily detailed answers to these questions of chronology and demography are unknown. Although the locations of large ancestral Jemez villages have been established for generations, almost none of these sites have been the focus of modern archaeological investigations (Elliott 1982; Kulisheck 2005; Liebmann 2006). For this reason, new archaeological research needs to be undertaken to establish the timing, duration, and density of occupation of these sites.

Archaeological Research: In order to investigate the history of fire regimes in the Jemez region, we are proposing to undertake new archaeological research at four large ancestral Jemez villages to establish when these sites were occupied, which areas within the sites were inhabited at a given time, and how many people were living there. We will address these questions through the collection of two primary categories of data: architectural/topographic data (i.e. high-resolution mapping of these sites) and ceramic data. Although many archaeology projects involve time-consuming and costly excavations, the surface survey proposed here is the most efficient way to collect the volume of spatial and ceramic data we need to address our research questions. We will be able to cover a far greater area--and ultimately a greater number of sites--by utilizing a strategy of surface survey rather than the much more costly and time-consuming methods of excavation. The value of surface archaeology to provide extensive information regarding spatial and temporal variation of past land use is well established (Sullivan 1998), particularly on ancestral Pueblo sites in northern New Mexico (Ramenofsky et al. 2009). The ubiquity of broken ceramics on Pueblo sites, which can be classified on the basis of their painted designs, textures, and rim form, provide an accessible means for dating sites due to their association with datable materials in other contexts (Mills and Herr, 1999)

We have selected four large village sites in the Jemez region (see Figure 3) for the proposed research based on preliminary estimates of their occupation histories (Elliott 1982) and tribal recommendations: Tovakwa (LA 483), Wabakwa (LA 478), Kwastiyukwa (LA 482), and Boletsakwa (LA 136). Of these, Tovakwa bears evidence for extensive early occupation (AD 1300-1450); Wabakwa and Kwastiyukwa appear to span the Classic-Historic Period (AD 1500-1650) and Boletsakwa was founded, occupied, and abandoned after the establishment of Spanish missions in the region. These four sites should provide a purview into the entire sequence of occupation from prehistoric times up to the 18th century.

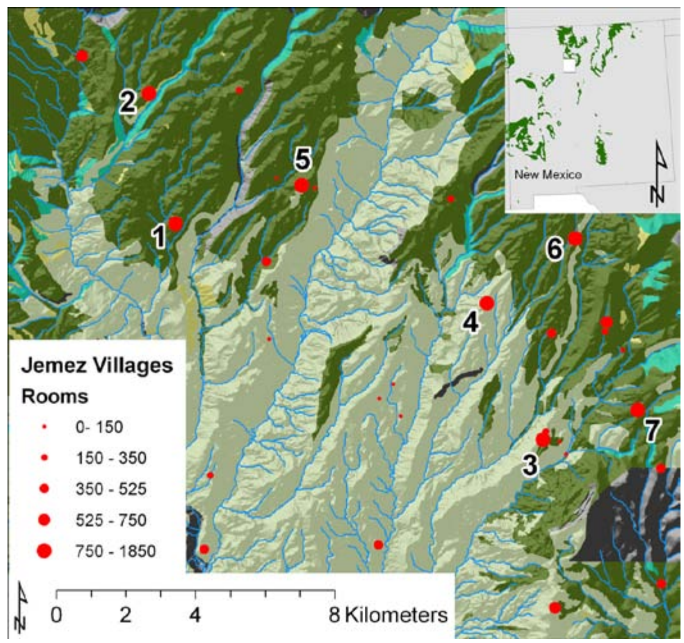

Figure 3. Location of Jemez villages relative to *P. ponderosa* forests in New Mexico and within the Jemez region (dark green in both map and inset). Probable study sites include Kwastiykwa (1), Tovakwa (2), Boletsakwa (3), Wabakwa (4), Amoxiumqua (5), Seshukwa (6), and Pejunkwa (7).

The first step in studying each of these villages will be the production of high-resolution topographic maps to provide information regarding the size and distribution of architectural remains as well as spatial control for the ceramic sampling phase of investigations. Building upon the mapping techniques implemented by Liebmann in his 2006 architectural study of ancestral Jemez sites, we will record the three-dimensional location of a series of discrete points across the surface of each village using a Leica GPS-1200 Real-Time Kinematic mapping system. This state-of-the-art mapping system is capable of sub-centimeter precision and will produce accurate topographic maps with 20-cm contour intervals. The result will be highly detailed maps of the ground surface at each site, allowing us to estimate the extent of the architectural remains at each village, including the total number of rooms and the number of stories in each roomblock. When combined with the ceramic data, this architectural data will aid in reconstructing the demographic histories of each of these sites.

In order to establish chronological control over each of these villages, we will look to the abundance of broken pottery scattered across the surface of these sites. The residents of ancestral Pueblo villages disposed of their broken pottery in trash areas known to archaeologists as "middens," typically adjacent to the architecture in which they lived. Today, these trash areas are still intact, with hundreds of thousands of pieces of broken pottery visible on the modern ground surface. In the northern Rio Grande, much of the pottery in these middens is temporally diagnostic--that is, ceramic styles changed through time, and previous studies have correlated these changes with calendar dates (using a variety of cross-dating techniques, including radiocarbon dating and dendrochronology). In particular, the Rio Grande Glazewares changed with remarkable regularity, allowing us to classify them into distinct phases: early Classic (Glazes A and B, 1300-1450), late Classic (Glazes C and D, 1425-1550), and Contact/Historic (Glazes E and F, 1550-1700). By studying the ceramics at Tovakwa, Wabakwa, Kwastiyukwa, and Boletsakwa, we can begin to discern when these sites were established, when they were abandoned, and where people moved within the site during its occupation.

Normally archaeologists would excavate a midden area in order to discern the entire sequence of occupation at a long-lived archaeological site. However, previous research in the Jemez region by Haas and Creamer in the late 1980s (Haas and Creamer, 1992; Creamer et al., 2002) indicates that the largest Jemez villages have "horizontal stratigraphy," meaning that these settlements spread horizontally through time, with new construction added next to older structures as populations increased or immigrants joined the community (rather than growing vertically, with new construction placed on top of earlier deposits). Recent archaeological investigations of surface ceramics at other large pueblo sites in the Rio Grande valley have confirmed this pattern, as well as the viability of producing fine-grained occupational histories based on the investigation of Rio Grande Glazewares in surface contexts (Ramenofsky et al., 2009).

The methodology we will use to investigate the ceramics of these sites is based on the techniques developed by Liebmann (2006, 2008) for his investigations of historic-period Jemez villages. Following the establishment of initial base maps of each site, we will establish a 20-meter grid over the surface of each settlement, utilizing a stratified unaligned systematic sampling protocol to collect all surface ceramics from within a 1 m^2 sample area within each 20-m unit. This sample will provide a reasonably clear picture of surficial artifact distributions. To increase the sample size of temporally diagnostic artifacts (Rio Grande glazeware bowl rims), a second surface collection will be conducted by collecting all temporally-sensitive ceramics within 5 m^2 units in each of the 10 areas of highest artifact density at each site.

Following the collection of the spatial and ceramic data, all artifacts will be cleaned, sorted, and classified according to type, variety, and vessel form. These data, along with measurements of vessel thickness and the number and weight of each type/variety will be recorded in a Microsoft Access digital database. When plotted according to their original distributions across the surface of the sites, these data will identify which parts of each site were occupied during discrete time periods: early Classic (Glazes A and B, 1300-1450), late Classic (Glazes C and D, 1425-1550), and Contact/Historic (Glazes E and F, 1550-1700). They will also provide a window into the relative demographic histories of each site, tracking the population growth that characterized the initial settlement of the area and the demographic decline of Native populations that accompanied European colonization.

Where possible, we will also conduct dendroarchaeological analysis of remnant architectural wood on the surface of the occupied villages and obtain pith dates for trees growing on each of these archaeological sites, which will provide further chronological control for occupation and estimates of population size for sub-periods of occupation on each archaeological site. From site visits, we know that these possibilities exist in some cases.

Paleocology: The occupation histories of the four large villages will allow us to define four types of study locales for paleoecological sampling. Specifically, we will use archaeological information to define study locales that were 1) early occupied village locales (e.g., the 14^{th} century occupation at Tovakwa and Boletsakwa) that overlap with the 14^{th}-15^{th} century decline in climate-predicted fire activity and the 15^{th} century megadrought (Roos and Swetnam, 2010; Stahle et al. 2007); 2) village locales occupied after the 15^{th} century megadrought (i.e., Kwastiyukwa and Wabakwa) but overlapping the 16^{th} century megadrought; 3) late, short occupied village locales (i.e., late established and late depopulated; e.g., the late reoccupations of Boletsakwa and Kwastiyukwa) that postdate these megadroughts but coincide with the adoption of sheep grazing by Jemez people; and 4) locales that lack village sites that will serve as "control" sampling locations for uncoupled, "natural" fire regime histories. The Monument

Canyon Research Natural Area restoration project area (Allen, 2002; Falk and Swetnam, 2003) has already been the subject of intensive fire history and stand-age dendroecological research and will be used as a “control” locale in this study. Small, temporary residences referred to as “field houses” have been recorded by archaeologists in the area, but Monument Canyon lacks the large, permanently occupied villages of the other study locales. Collection and analysis of ceramic data from these field house sites near Monument Canyon will provide data for a graduate student project. The second “control” locality will be determined in consultation with archaeologists from Santa Fe National Forest and Jemez Pueblo during the course of the project. As mentioned above, the occupation histories of our archaeologically defined sampling locales overlap in significant ways with long-term reconstructions of fire-climate variability (Figure 4).

Methods for distinguishing human impacts in historical fire regime data take two forms: 1) temporal comparison of fire-history proxies to paleoclimate reconstructions (i.e., a “climate anomaly” methods) and 2) spatial comparisons of fire-history proxies from “control” areas that are presumed to have a natural signal with fire histories from areas with historically or archaeologically known occupations (i.e., “spatial anomaly” methods). Our research is designed to use both methods, thus allowing us to describe fire regime variability across spatial variability in human land-use history and allowing us to discriminate variation in the consequences of climate on local fire regimes without assuming that any fire-climate anomaly must be anthropogenic. This approach will allow us to improve confidence in our inferences of climate and human influence on reconstructed fire regime histories. Additionally, by using multiple methods to infer fire regime histories, we can better infer multiple properties of fire histories that include fire frequency, seasonality, and severity.

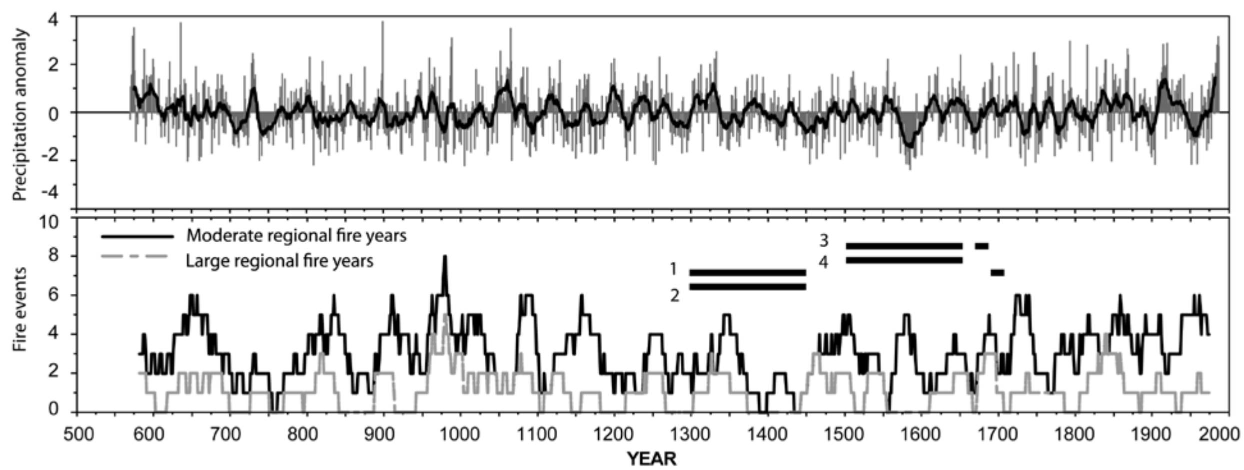

Figure 4. Long-term variation in the frequency (sum of events in 25 year moving windows) of moderate (>17% probability of fire) and large (>25% probability of fire) fire years predicted by antecedent climate (Roos and Swetnam, 2010) and standardized precipitation anomaly for the southern Colorado Plateau (top). Rough estimates of the occupation spans for project area villages are indicated.

Dendrochronology provides a powerful tool for investigating fire regimes over decades to centuries prior to modern fire suppression (Swetnam et al., 1999). Low-intensity surface fires may result in the localized damage to cambial tissue resulting in the production of a fire scar or “cat-face”(Arno and Sneck, 1977). By cross-dating the growth rings of the tree, the occurrence of the scar-creating fire can be determined to the year and, in many cases, to part of the growing or dormant seasons (Dieterich and Swetnam, 1984). Not all trees will record surface fires in its vicinity, however, and the analysis of a spatially-distributed set of fire scar specimens is necessary to produce a reliable composite fire history for a given area (Falk, 2004; Farris et al., 2010).

Variability in the archaeologically-based occupation and land-use histories will be used to provide spatial controls and the sampling of stands for fire scar chronologies. A combination of targeted and random/systematic sampling of fire-scarred trees will provide spatially-explicit, plot-based and stand-level fire chronologies (e.g., following Falk, 2004; Brown *et al.*, 2008; Farris *et al.*, 2010). The composite fire histories from different locales and area-specific fire frequency estimates (e.g., number of fires/time period/area in ha) will be compared to each other on the basis of spatial proximity to archaeological settlements as well as to precipitation and drought indices (e.g., Grissino-Mayer, 1996; Cook et al., 2004) and composite fire-climate reconstructions (Roos and Swetnam, 2010). Analysis of the distribution of seasonal timing of fire scars (e.g., Dieterich and Swetnam, 1984; Brown, 2006) will be used to evaluate possible changes in fire seasonality during nearby occupation and abandonment periods (e.g., Kaye and Swetnam, 1999). At village localities, we will employ radial fire scar collection transects traversing increasing distances away from the villages (up to 5 to 10km). Systematic coring of trees in the vicinity of fire scar samples will allow us to reconstruct and evaluate the forest demographic consequences of climate variability and local disturbance histories (Brown and Wu, 2005; Brown, 2006; Brown et al., 2008). In total, we anticipate sampling up to 400 fire-scarred trees for fire history analyses, and up to 2,000 trees for age structure/demography analyses.

Aggregate tree demographic data from each sample plot will be compared to local fire frequencies, sedimentary data, and tree-ring width based climate reconstructions (e.g., Ni et al., 2002; Cook et al., 2004) to examine the long-term impact of contingent disturbance, land-use, and climate histories on recruitment and survival of canopy species. Stratigraphic proxies from nearby alluvial channel fans, when calibrated with tree-ring data, will provide additional time depth for these analyses as well as independent data on the character of understory plant assemblages, the type of fuels consumed, and erosion responses.

The measurement of charcoal accumulation in sedimentary contexts provides an opportunity to reconstruct millennial length fire-histories (Whitlock and Larsen, 2001; Allen *et al.*, 2008; Anderson *et al.*, 2008). Sedimentary charcoal analysis has largely been developed for low-energy, closed basin contexts such as lakes and wetlands (Whitlock and Anderson, 2003), which are exceptionally rare in semi-arid, fire prone ponderosa pine forests. Roos adapted traditional sedimentary charcoal approaches to the ubiquitous stream-laid sedimentary contexts by including independent geochemical and paleobotanical proxies of fire regime change (Roos et al., 2009). Once variation in the depositional energy has been controlled, charcoal accumulation varies by the amount and type (e.g., woody vs. herbaceous) of fuels. For immature alluvial soils, variation in phosphorous content is most likely the consequence of variation in the frequency of low-temperature biomass burning in the catchment (Covington and Sackett, 1990; Roos et al., 2009). Frequent fires maintain an herbaceous understory in ponderosa pine forests (Allen et al., 2002), which can be measured independently using stable carbon isotopes of soil organic matter (Biedenbender et al., 2004) and pollen assemblages (Campbell, 1999).

Using the same archaeologically-informed sampling design as the dendroecology research program, watershed scale study units of discontinuous, ephemeral streams will be defined for each of the four categories of sample locales. Alluvial deposits will be manually exposed and sampled continuously at 2 cm intervals for grain-size, organic carbon, stable carbon isotopes, macroscopic charcoal, and phosphorus content. Samples for palynology will be collected every 10cm. Bayesian calibrated radiocarbon dates (Buck et al., 1991) from detrital charcoal of short-lived tissues (i.e., *Pinus* needles) from every 10cm of depth will provide age control for stratigraphic proxies. To improve the confidence of sedimentary fire history reconstructions, at least two watershed localities will be sampled for each of the four village and two control sampling locales for a total of 12 localities.

2) Fire Behavior and Ecological Modeling

Our dynamic modeling program will allow us to connect our stand and watershed scale fire histories to the landscape scale. We will adapt a highly successful modeling platform that has been designed to iteratively generate fire regimes and ecological dynamics on real world landscapes (Keane et al. 1996, Keane et al. 1997, Keane et al. 1998, Keane et al. 1999, Keane et al. in press). The FireBGCv2 modeling platform contains a powerful mechanistic vegetation succession model, a spatially explicit fire model that incorporates ignition, spread, and effects on ecosystem components, and a detailed fuel treatment module, all with stochastic properties implemented in a spatial domain (Keane *et al.*, 1996a). The model simulates synergistic and interacting effects of climatology, vegetation growth, and human interaction (through the fuel treatment module) on landscape structure and ecosystem processes.

We will use FireBGCv2 to test scenarios of human impacts on fire frequency, intensity, size, and vegetation cover and structure. We will construct scenarios that describe varying levels of human-caused fire ignitions and modifications to fuel structure, as well as a null model that excludes human-landscape interactions and where vegetation growth and structure and disturbance dynamics are driven by climate regimes alone. Specifically, these scenarios are:

Scenario	Disturbance drivers	Fuel drivers	Climate drivers	Archaeological drivers
Null model	Wildfire ignitions dictated by fuels and weather	No fuel treatments implemented	Historical climate	Archaeological structures not present
Structure model	Wildfire ignitions dictated by fuels and weather	No fuel treatments implemented	Historical climate	Archaeological structures present as potential firebreaks
Human interactions model 1 (Moderate)	Wildfire ignitions dictated by fuels and weather	Moderate fuel treatments implemented near archaeological structures*	Historical climate	Archaeological structures present as potential firebreaks
Human interactions model 2 (Heavy)	Wildfire ignitions dictated by fuels and weather	Heavy fuel treatments implemented near archaeological structures*	Historical climate	Archaeological structures present as potential firebreaks

*Fuel treatments include reductions in fine fuels and coarse woody debris and prescribed fires.

Simulations will span 1,000 years and will incorporate spatially explicit fire regime histories, climate change inputs from dendroclimatic reconstructions, and potential levels of anthropogenic ignitions and fuel fragmentation, derived from archaeological data. Goals of this portion of the study are to evaluate fire spread and behavior characteristics, and resulting effects on landscape vegetation patterns and processes, under different densities of trees and amounts and continuity of herbaceous grass cover. We will utilize these simulations to assess likely effectiveness of human fuel manipulations (e.g., tree harvesting, fuelwood gathering, purposeful burning) on excluding wildfire, or sustaining surface fire regimes. We will also use these simulations to evaluate fuel and weather (climate) relations that lead from surface to crown fire behaviors, based on variable tree densities and vertical/horizontal fuel loads and continuity, along with fuel moisture and wind conditions.

We will then develop metrics of landscape resilience that will be used to evaluate the role of coupled human-natural dynamics in influencing landscape vulnerability both across space and through time. The first stages of model development will be focused on building the simulation landscapes, including fieldwork to initialize the model with region-specific vegetation and fuels data and ecological parameters; and spatial data layer development to anchor the simulation landscapes in a real-world spatial context. We will also build spatial layers of human interaction by defining areas likely to have experienced greater or lesser degrees of human "footprinting" – these will be informed by the archaeological and ethnoecological project dimensions. Subsequent modeling efforts will include model calibration and validation, and statistical analysis and summary of model results.

The modeling project will provide quantitative data on the sensitivity of fire behavior and fire frequencies at the landscape scale to variance in the human footprint from the known archaeological landscapes. By ground-truthing the model with paleoecological data, we can use the landscape scale simulations to quantify spatially explicit fire frequencies beyond our sampling locales and quantitatively assess the tipping points of fire regime shifts from frequent low severity to infrequent high severity in terms of climate change and human impacts. Our modeling efforts will likely reveal human-landscape interactions that foster resilience *or* enhance vulnerability of natural landscapes (and associated ecological patterns and processes that define these states); these can be used to help inform future landscape planning efforts, especially under climate change conditions likely to trigger ecosystem instability.

3) Oral Tradition and Ethnoecology

American Indian societies have complex and enduring oral traditions that include and encode information about their history, environment, and land use. These traditions are particularly strong among the Pueblo and Apache Indians of Arizona and New Mexico, who have inhabited the region for centuries. Oral traditions provide insight into culturally embedded conceptualizations of the nature and role of fire--what we call "fire ideologies." More specifically, oral traditions offer fine-grained layers of place names for landscape and water features, stories of population movements and interactions, and accounts of cataclysmic natural events, including forest fires (Basso, 1996; Coder et al., 2005; Pilsk and Cassa, 2005; Kuwanwisiwma and Ferguson, 2009). Our methodology recognizes that oral traditions have limitations as well as strengths (Vansina, 1973; Henige, 1974, 1982; Vansina, 1985). As is true for other data types, oral traditions about environmental change cannot be interpreted uncritically. The position of the narrator, the style and context of the narration, the roles oral traditions play in societies will all be interrogated to contribute information about ethnoecology pertinent to fire regimes.

As studies in Australia, China, and South America demonstrate, traditional knowledge used in tandem with scientific data can help identify and correct "blind spots" which ignore the impact indigenous land use has had on ecological processes of environmental change, including burning practices associated with managing highly fire prone environments (Chandler, 1994; Russell-Smith *et al.*, 1997; Bowman, 1998; Sarmiento, 2002). Indigenous knowledge systems use categories derived from the historical context of a particular people and their interaction with their localized environment. Understanding how indigenous knowledge is situated in the use of lands and resources will provide insight into why certain actions are taken and how they are linked to forest and woodland ecosystem dynamics, thus offering an important frame of reference for scientific interpretation and modeling.

We will conduct a series of semi-structured interviews, focus group sessions, and workshops with cultural advisors from the White Mountain Apache Tribe, Pueblo of Jemez, Pueblo of Zuni, and the Hopi Tribe to elicit information about the role of fire in developing and maintaining anthropogenic forest environments. Our tribal collaborators have joined the research team because archaeology and oral tradition document connections between Hopi, Zuni, and prehistoric village populations of the Mogollon Rim region (Welch and Ferguson, 2007) and this area has been the historic and contemporary homeland for White Mountain Apaches (Basso, 1996). The ancestors of these contemporary groups are implicated in research that indicated anthropogenic burning enhanced ecosystem resilience (Roos 2008). The Jemez study area itself has been occupied and used by Jemez people and their ancestors for at least eight centuries (Kulisheck, 2005; Liebmann, 2006).

EDUCATION AND OUTREACH PLAN

Our Education and Outreach Plan includes nested hierarchies of training and education including postdoctoral and graduate research associates as well as secondary school educators and their students. Rachel Loehman will be a postdoctoral associate and will contribute to the management, analysis, and dissemination of results of the project. Additionally, we will fund two graduate students for three years each and a third graduate student for more than two years to pursue thesis projects at the University of Arizona and Southern Methodist University, respectively.

We will build connections with secondary school educators from Jemez Valley School and the Charter School at Jemez Pueblo to develop and evaluate one- to two-lesson units for interdisciplinary science and history classrooms that we will revise and refine over the course of the project, resulting in the training of more than 20 secondary school educators in Southwestern communities to integrate the concerns of fire, climate, and society in their classrooms. In addition to promoting education and awareness on these issues in science classrooms, we are targeting this program for schools in the tribal communities associated with this project in an effort to increase recruitment of American Indian students to postsecondary education in environmental sciences and natural resources management. We will solicit feedback on the success of lesson-plans during the course of the project and use pre-post surveys of students involved in the project and in project-developed lesson plans on the state of their knowledge and their college plans.

In community outreach, we build on Liebmann's project that involves high school and undergraduate students from Jemez Pueblo in archaeological field research. As many as 16 students from the Pueblo of Jemez will be employed and trained in archaeological mapping techniques, controlled collection of surface artifacts, and ceramic analysis. Additionally, we will partner with the Pecos Pathways Project, an annual educational and cultural exchange program that brings high school students from Jemez Pueblo together with students from Phillips Academy (Andover, MA) in New Mexico and Boston each summer. Students will work with project staff on the surface collection and ceramic analysis and will also have an opportunity to work with the dendrochronologists in sampling fire history and other tree-ring specimens. Annual public presentations at the Pueblo of Jemez Visitor's Center will update the local community on the ongoing research and results.

At the conclusion of the project, senior scientists and co-PIs will collaborate in writing short articles for a special issue of *Archaeology Southwest*, produced by the Center for Desert Archaeology for its members. We will produce an additional 4000 copies to distribute in community centers, museums, and tribal government offices for each of our four tribal partners (1000 copies for each tribe). The articles for this periodical will also form the basis for developing poster displays summarizing our research and tribal involvement for collaborating tribal museums at Hopi, Zuni Pueblo, Fort Apache, and Jemez Pueblo.

PI Swetnam and co-PI Keane maintain very active science translation and collaborative exchanges with fire and forest managers throughout the western US. The findings from the project will be incorporated into lectures and workshops that Swetnam presents, for example, at the National Advanced Fire and Resource Institute in Tucson to more than 300 managers annually. Swetnam, Roos and Liebmann will also coordinate with USFS archaeologists Bremer and Kulisheck in communicating results to Southwestern Region managers and community groups, and will aid in developing planning documents for forest and landscape-scale restoration projects.

EXPECTED SIGNIFICANCE AND BROADER IMPACTS

The proposed research project will have significant impacts in a number of scientific, policy, and social dimensions. We expect to substantially improve our understanding of the fire-climate-society nexus by evaluating specific examples of the dynamics of coupled-human natural, surface-fire adapted forests in the context of climate changes. Our aim is to use our paleoecological and archaeological findings in designing and testing several model scenarios, and from these results we expect to make useful contributions toward the development of general theory of human-fire regime interactions. Our project will provide results that contribute to contemporary policy discussions on management of fire and fuels at the Wildland-Urban Interface throughout the range of pine-dominated surface-fire adapted forest in Western North America and Northern Eurasia. It will support the research of three early career scholars and the development three graduate students. The education program will involve more than 20 science and history teachers in rural schools that cater to underrepresented students environmental science. The project will improve the representation of American Indians in scientific research by including 32 American Indian research partners in the ethnoecology research and as many as 18 tribal members in the archaeological research, thus building stronger connections between the scientific, land management, and local communities that will likely be necessary to successfully implement fire and ecosystem management policies (Chapin *et al.*, 2006; Schoennagel *et al.*, 2009).

This project will also be the first of its kind to combine archaeology, dendroecology, paleoecology, ecosystem modeling, and ethnoecology to investigate the novel dynamics of coupled natural-human forests to climate and fire regime changes over multiple spatial and temporal scales. This research has the opportunity to contribute uniquely to our understanding of landscape level forest and fire dynamics over multiple centuries that include variable climatic and human histories. The outcomes of this project may be particularly beneficial for informing adaptation strategies for contemporary communities at the Wildland Urban Interface throughout the range of *P. ponderosa* in North America and *P. sylvestris* in Eurasia.

In addition to quantitative knowledge of complex dynamics, useful for basic scientific understanding and scenario modeling of potential future outcomes, our ancient case studies offer the opportunity to provide compelling historical lessons for the public, managers and decision makers. The broad interest in historical narratives of human-environment relationships, especially as discovered and evaluated via the scientific method, can be quite effective in engaging people in scientific learning. We expect that we (scientists, students, managers, etc.) will learn from the past successes and failures of generations of human occupation of semi-arid, fire prone forests during prolonged droughts and demographic upheavals. Specifically, this project expects to provide information necessary to make informed and public-collaborative decisions about the outcomes of alternative restoration scenarios that will be considered by the USDA Forest Service as a result of its recent restoration mandates and authorizations by Congress.

Our project will also help shape the careers of at least six young scholars, including three graduate students and three scientists at the beginning of their careers, including a postdoctoral associate, by providing them training and mentorship in interdisciplinary research, outreach, and education concerning the novel dynamics of socionatural systems and the importance of such research for contemporary adaptation and mitigation of climate change effects. The outreach and educational impacts of this project will extend into secondary schools in our project areas as well. More than 20 science teachers from secondary schools in the Jemez area will participate in workshops on lesson plans designed to teach high school students about fire, climate change, and society. By grounding these lesson plans in the cultural heritage of local communities, we hope to encourage interest in environmental studies by students from impoverished and underrepresented communities in post-secondary education.

This project is also unique for its inclusion of participatory research with underrepresented communities in its design. As many as 32 elders and members of cultural advisory committees of our American Indian partner communities will be involved in the ethnoecology research as well as the final symposium discussing the interpretation of project results. This arrangement will promote positive relationships between interdisciplinary science communities and Southwestern American Indian communities. Native American perspectives will be included in the dissemination of project results to broad audiences, further reinforcing the importance of learning from the experiences of indigenous societies through archaeology and oral tradition for contemporary society. Additionally, the project will also offer employment opportunities to as many as 20 community members through fieldwork, particularly foresters, archaeologists, and students from the Pueblo of Jemez.

Our research strategy includes broad dissemination of our research outcomes. We will maintain a project web site that will provide information on project goals, outcomes, and implications for general audiences. The fire-climate-society lesson plans developed as part of this project will be made publicly available on the project website for use in schools throughout the country and will be provided to education and outreach coordinators at the National Advanced Fire and Resource Institute in Tucson, AZ. During the course of the project, senior scientists will give public lectures at community venues in the Jemez area and in Tucson. At the conclusion of our project, senior collaborators will co-author a special publication for broad dissemination to Southwestern communities and project research and outreach will be summarized in posters for display at tribal visitor centers and museums.

MANAGEMENT PLAN

Overall project management: *Swetnam and Roos*. Swetnam and Roos will be responsible for managing the project and integrating the diverse research strategies and data sets. Swetnam, a leader in the field of dendroecology and fire climatology, has more than 25 years experience in directing fire history research projects, and in collaborating and communicating with forest and fire managers. Roos has a decade of archaeological experience, and from 2005-2008 directed an interdisciplinary archaeology, fire history, and paleoecology project in eastern Arizona that serves as a model for the current research design. Swetnam, Roos, Ferguson, Welch, Liebmann, Loehman, and Keane will all contribute to the final reporting of the project.

Effective, regular communication between investigators at widely separated institutions will be necessary to ensure the successful integration of diverse, interdisciplinary datasets throughout the course of the project. Week-long intensive workshops are scheduled each year in which all senior collaborators and graduate students will apprise the entire project team of the status of analyses and discuss adaptive project management, publication, and interpretation with the entire team. Additionally, we will schedule monthly transfers/backups of all primary data and updates of synthetic time-series data to the project relational database (see Data Management Plan) to coincide with video conference calls that will include all senior collaborators and graduate students. The regularity of these video meetings will help synchronize the pace of analysis and interpretation in all project domains and allow for rapid, flexible, adaptive project management by Swetnam and Roos. Within the operation of the diverse subprograms within the project, project management responsibilities are delegated to senior personnel and Co-PIs with the appropriate research and management expertise.

Archaeology: ***Liebmann***, supported by ***Chris Toya***. Liebmann has more than ten years working with the Pueblo of Jemez, where he has served as Tribal Archaeologist and collaborated with the Pecos Pathways Project. He has more than a decade of archaeological experience in the area. Toya, who is the current Tribal Archaeologist for Jemez, will support Liebmann in the field.

Dendroecology: ***Swetnam***, supported by ***Baisan*** and a ***PhD student in the Laboratory of Tree-Ring Research***. Swetnam will direct dendroecological sampling and analysis with the support of Baisan, who has decades of experience in dendroecological field research and laboratory analysis.

Sedimentary paleoecology: ***Roos*** supported by a ***PhD student in Anthropology at SMU***. Roos will direct the alluvial paleoecology field and laboratory research, which will be assisted by a PhD level graduate research assistant at SMU.

Oral Tradition: ***Ferguson and Welch*** with the support of ***Liebmann, Roos, and a PhD student in Anthropology at UA***. Ferguson has more than two decades experience working with the Pueblo of Zuni and the Hopi Tribe. Welch has more than two decades of experience working with the White Mountain Apache Tribe and the Tribe's Heritage Program, and brings material support to the research, including a vast archive of land management documents and synergies with the Western Apache Atlas project and archaeological surveys near Fort Apache. Additionally, Ferguson and Welch have experience working together in oral tradition research with Hopi, White Mountain Apache, and Zuni (Welch and Ferguson, 2005, 2007).

Modeling: ***Keane and Loehman***. Keane has over three decades of experience in ecological modeling and fire dynamics research, and is the developer of the FireBGCv2 modeling platform. In addition to several years of archaeological experience, Loehman has over ten years of experience developing and implementing ecosystem models, particularly related to climate change and disturbance.

Secondary school education: ***Chavarria and a PhD student in Anthropology at UA***. Chavarria has nearly two decades of experience in archaeology and education projects and has been the Director of Outreach Education at the University of Arizona College of Education since 2006. Chavarria and the graduate research associate in Anthropology will work together with secondary school science teachers to develop lesson plans and classroom activities.

RESEARCH SCHEDULE

Year 1 (January – December 2012): During the Spring Semester (January – May), the Tree-Ring PhD student will begin to assemble the project website and the secure FTP site for the project database and file sharing between institutions. Also during the Spring Semester, the Anthropology PhD student will begin synthesizing archival material on cultural uses of fire from Fort Apache (assembled by Welch), Chavarria will conduct phone interviews with teachers from Jemez schools to select two Master Teachers for the first summer's education program, and the interview protocol will be developed for the ethnography fieldwork. From January to May 2012, senior collaborators will participate in monthly planning meetings via video-conferencing to evaluate progress on the website, secure data-sharing, database structure, and to organize the first field season of fieldwork. In May 2012, all senior collaborators and graduate students will participate in a one-week planning meeting in Tucson, AZ to finalize our initial strategy for fieldwork and data collection for the first full field season. This meeting will be followed by a four week ethnoecology field season (Ferguson, Welch, and the Anthropology GRA) that includes one-week each with the four participating tribes; an eight week field season of archaeological mapping and ceramic analysis (Liebmann, eight Jemez Students, Toya, and a Jemez supervisor) and six weeks of sedimentary paleoecological research at two localities (Roos, SMU GRA) with four weeks of tree-ring sample collection at two localities (Swetnam, Baisan, LTRR GRA); and a four week field season to generate basic data on the Jemez area forests to calibrate the initial run of FireBGC (Loehman and five person crew). During the field season, two Master Teachers will volunteer for two weeks of archaeological and paleoecological fieldwork and participate in an additional two weeks of lesson plan design with Chavarria and the Anthropology GRA.

During the rest of the year (August-December), Loehman will begin to adapt FireBGC for Southwestern ponderosa pine forest and fire dynamics; Roos will supervise the laboratory analysis of sediment samples collected during the summer by the SMU GRA; the Anthropology GRA at UA will begin transcribing interviews and annotating field photos; Swetnam will supervise the preparation and analysis of tree-ring samples by the LTRR GRA. During the Fall term, the Master Teachers will use the designed lesson plans in class and provide feedback through the website that will be reviewed by Chavarria. Collaborators will continue to participate in monthly video conferences to review progress and upload project data to the secure FTP site.

Year 2 (January – December 2013): Analyses begun in the previous Fall Semester will continue through May 2013, with monthly video conferences and reviews of shared data continuing as well. In May 2013, a weeklong collaborators meeting including all Senior Personnel in Tucson will include presentation of preliminary data from the first season of fieldwork and initial modeling runs and tests of model performance against previous fire-scar work. This meeting will be followed by a four week ethnoecology field season (Ferguson, Welch, and the Anthropology GRA) that includes one-week each with the four participating tribes; an eight week field season of archaeological mapping and ceramic analysis (Liebmann, eight Jemez Students, Toya, and a Jemez supervisor) and six weeks of sedimentary paleoecological research at two localities (Roos, SMU GRA) with four weeks of tree-ring sample collection at two localities (Swetnam, Baisan, LTRR GRA); Loehman and a five person crew will conduct four weeks of fieldwork for any additional data necessary to refine the modeling input. Prior to the start of the academic year, Chavarria, the Anthropology GRA, and the two Master Teachers will run two one-week workshops for a total of 10 additional teachers on fire-climate-society lesson units. Major analysis of collected samples will continue through the Fall Semester at the University of Arizona and Southern Methodist University. During the remainder of the calendar year, Keane and Loehman will begin the first round of model revisions based on feedback from the collaborators meeting. Ferguson, Welch, and the Anthropology GRA will begin synthesizing results from the two full seasons of ethnoecology research. In the fall, all 12 secondary teachers will deliver lesson units in their classroom along with pre-post survey of knowledge and college plans. Collaborators will continue to participate in monthly video conferences to review progress and upload project data to the secured FTP site.

Year 3 (January – December 2014): In the Spring Term (January-May) Chavarria will review feedback from the initial use of learning units in secondary school classrooms and major analyses of tree-ring and sediment samples will continue at the University of Arizona and Southern Methodist University. Collaborators will continue to participate in monthly video conferences to review progress and upload project data to the secured FTP site. In May 2014, a weeklong collaborators meeting including all co-PIs and Senior Contributors in Tucson will include presentation of the second phase of modeling simulations, and the first two seasons of archaeological, dendrochronological, and paleoecological data. The remainder of the collaborators meeting will be spent evaluating model performance with the first two seasons of paleoecological data and planning for model revisions based on the meeting. Ferguson, Welch, and the Anthropology GRA will work closely with Swetnam, Roos, Liebmann, Keane, and Loehman to develop presentations for tribal collaborators on project results through two years. In June

2014, Ferguson, Welch, and the Anthropology GRA will spend two days with each group of tribal collaborators to present the preliminary results and solicit feedback and interpretation from participating members of the Cultural Advisory Committees. In June and July, Swetnam, Baisan, and the LTRR GRA will conduct four weeks of dendroecological fieldwork at the final two localities; Roos and a graduate assistant will conduct six weeks of geoarchaeological fieldwork to collect sediments from the remaining two localities; Liebman, Toya, and a crew chief from Jemez will lead a team of eight students from Jemez Pueblo in archaeological fieldwork at the final two ancestral Jemez villages; and Chavarria, the Anthropology GRA, and the two Master Teachers will run two one-week workshops for a total of 10 additional teachers on fire-climate-society lesson units. In the fall term, all 22 secondary teachers will deliver lesson units in their classroom along with pre-post survey of knowledge and college plans (Chavarria).

Major analysis of collected samples will be completed at the University of Arizona and Southern Methodist University by November 2014. Keane and Loehman will begin the final round of model revisions based on feedback from the collaborators meeting. Ferguson and Welch will synthesize feedback from the follow-up meetings with collaborating cultural advisory teams concerning the paleoecology, archaeology, and modeling projects. In November 2014, a daylong symposium and discussion forum will be held at the University of Arizona with all Senior Personnel and the 32 members of the tribal cultural advisory committees who participated in the ethnoecology research. The symposium will be followed by a four days of meetings during which feedback from tribal collaborators will be considered in the planning for publication and dissemination. During this meeting, authorship responsibilities for final report writing in November and December will be assigned and timetables for publication will be developed. Publications for the general public will include contributions from all senior personnel for a special issue of *Archaeology Southwest* that will be finalized after the submission of the final report to NSF by January 1, 2015. Roos and Ferguson will serve as organizers and editors for this volume. Swetnam and Roos will serve as editors for a volume reporting the results of all components of the project, including co-authored chapters with tribal collaborators on indigenous perspectives on fire and climate change. Drafts of museum-quality poster displays will be prepared by Swetnam, Roos, and Ferguson in consultation with tribal collaborators.

RESULTS OF PRIOR NSF SUPPORT

PI Swetnam has conducted several NSF supported dendrochronology projects. These include studies focused on fire ecology, history and climatology in Siberia and North America: DEB 9307607 “Paleofire and Climate History in Siberia” [Grant Period: 07/15/93-12/31/94, $15,000], SBR-9719411, “Collaborative Research: Climate-Fire-Ecosystem Linkages on Decadal to Centennial Time Scales in the Northern Rockies” [Grant Period: 08/15/97-07/31/00, Total Funds: $196,463], and DEB-0105155 “Dissertation Research: Ecological Effects of Temporal and Spatial Variability in the Disturbance Regime of an Old-growth Ponderosa Pine Forest” [Grant Period: 06/01/01-12/31/03, Total Funds: $5,108]. These studies supported three PhD students mentored by Swetnam; two are now employed as faculty (Kurt Kipfmueller Univ. Minnesota, Don Falk, Univ. Arizona) and the third is a federal scientist (Matt Rollins, USGS). These projects directly resulted in eight publications, and provided data used in several others. Swetnam was also a Co-PI and Univ. of Arizona institutional Representative on DBI FIELD STATIONS 224851, “FSML: Promoting Biological Research on the Colorado Plateau with the Merriam-Powell Research Station” [Grant Period: 09/01/02-08/31/06, Total Funds: $249,010]. This project supported the construction of a field station near Flagstaff, AZ that is used for housing 100s of students and researchers conducting studies in the area annually. **Co-PI Liebmann** received a dissertation improvement grant from NSF Archaeology in 2003 (BCS-0313808). The results of this research have been published in a series of articles (in American Anthropologist, the Journal of Field Archaeology, and Kiva) and chapters in edited volumes (see biographical sketch), and is the focus of a book manuscript currently in preparation to be published by the University of Arizona Press in 2011. **Co-PI Ferguson** received NSF Grant BCS-0965949 on 10/1/2010, so there are no results to report at this time. **Co-PI Keane** is also Co-PI on NSF Grant CNH- 0903562 which began on 10/1/2009 and recently completed its first project year.

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University Education:

University of New Mexico, Dept. of Biology, Biological Sciences, B.S. 1977
University of Arizona, School of Natural Resources, Watershed Management, M.S. 1983
University of Arizona, Watershed Management, Laboratory of Tree-Ring Research, Ph.D.1987

Positions:

Director, Laboratory of Tree-Ring Research, 2000-present
Professor of Dendrochronology, Laboratory of Tree-Ring Research; joint professorial appointments in School of Natural Resources & Environment, Ecology & Evolutionary Biology, School of Geography & Development, 2000-present
Associate Professor of Dendrochronology, Laboratory of Tree-Ring Research, 1994-2000
Assistant Professor of Dendrochronology, Laboratory of Tree-Ring Research, 1988-1994

Honors & Awards (selected):

E.J. Taaffe Distinguished Lecturer, Dept. of Geography, Ohio State University, 2010
Henry Cowles Award, The Association of American Geographers, 2002
William Skinner Cooper Award, Ecological Society of America, 2001
E.H. Weaver Lecturer, School of Forestry and Wildlife Science, Auburn University, 2000
Walter Orr Roberts Public Lecturer, Aspen Global Change Institute, 1999

Research Interests:

Forest and fire ecology, fire history, fire and climate interactions, dendrochronology, forest insect outbreak dynamics, applied ecology and ecological restoration

Synergistic & Service Activities:

Member, Board of Trustees, Valles Caldera National Preserve (appointed by U.S. President William J. Clinton, 2000-2004); Member, Governor's Forest Health Advisory Council (appointed by Arizona Governor Janet Napolitano (2003-2006); Member, Governor's Climate Change Advisory Group (appointed by Arizona Governor Janet Napolitano (2005-2006); Member (and founder), Board of Advisors, International Multiproxy Paleofire Database, National Climate Data Center, NOAA (2002-present); Member & Chair, Board of Advisors, NOAA Paleoclimatology Program (2004-2005); Member of Executive Committee, Consortium for Integrated Climate Research in Western Mountains (CIRMOUNT) (2003-2010); Steering Committee of FireScape, a collaborative adaptive management initiative on fire and forest restoration in So. AZ 2007-present; Oral and written testimony to U.S. Congress, 4 times since 2000; Currently associate editor for *International Journal of Wildland Fire*, 1993-present; *Dendrochronlogia*, 2005-present; *Fire Ecology*, 2009-present.

Five Most Relevant Publications:

Swetnam, T. W., and J. L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate* 11:3128-3147.

Kaye, M. W. and **T. W. Swetnam** 1999. An assessment of fire, climate, and Apache history in the Sacramento Mountains, New Mexico, USA. *Physical Geography* 20(4):305-330.

Grissino-Mayer, H. D., and **T. W. Swetnam.** 2000. Century-scale changes in fire regimes and climate in the Southwest. *The Holocene* 10(2):207-214.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and **T. W. Swetnam.** 2006. Warming and earlier spring increase western U.S. wildfire activity. *Science* 313:940-943.

Williams, A.P. C. D. Allen, C. I. Millar, **T. W. Swetnam**, J. Michaelsen, C. J. Still, and S. W. Leavitt. 2010, In press. Forest responses to increasing aridity and warmth in the southwestern United States. *Proceedings of the National Academy of Sciences*.

Five Additional Publications:

Swetnam, T. W., and J. L. Betancourt. 1990. Fire-Southern Oscillation relations in the Southwestern United States. *Science* 249:1017-1020.

Swetnam, T. W. 1993. Fire history and climate change in giant sequoia groves. *Science* 262:885-889.

Swetnam, T. W., C. D. Allen, and J. L. Betancourt. 1999. Applied historical ecology: Using the past to manage for the future. *Ecological Applications* 9(4):1189-1206.

Kitzberger, T., P. M. Brown, E. K. Heyerdahl, **T. W. Swetnam**, and T. T. Veblen. 2007. Contingent Pacific-Atlantic ocean influence on multi-century wildfire synchrony over western North America. *Proceedings of the National Academy of Sciences* 104(2):543-548.

Bowman, D.M.J.S., J.K. Balch, P. Artaxo, W.J. Bond, J.M. Carlson, M.A. Cochrane, C.M. D'Antonio, R.S. DeFries, J.C. Doyle, SP. Harrison, F.H. Johnston, J.E. Keeley, M.A. Krawchuk, C.A. Kull, J.B. Marston, M.A. Moritz, I.C. Prentice, C.I. Roos, A.C. Scott, **T.W. Swetnam**, G.R. van der Werf, and S.J. Pyne. Fire in the earth system. 2009. *Science* 324:481-484.

Graduate Advisors:

Robert L. Gilbertson, Univ. Arizona, retired; Valmore C. LaMarche Jr., deceased; Gordon Lehman, Univ. Arizona, retired; Ann Lynch, US Forest Service, RM Station; Marvin Stokes, Univ. Arizona, deceased; Malcolm Zwolinski, Univ. Arizona, retired.

MS and PhD Students Advised (as primary advisor), Post-Doctoral Associates and current positions:

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T. J. FERGUSON November 2010

Professional Preparation

University of Hawaii at Hilo	Social Science	B.A., 1973
University of Arizona	Anthropology	M.A., 1976
University of New Mexico	Community and Regional Planning	MCRP, 1986
University of New Mexico	Anthropology	Ph.D., 1993

Appointments

2007-present	Professor of Practice, Department of Anthropology, University of Arizona
2004-present	Research Associate, Division of Anthropology, American Museum of Natural History
2002-2207	Adjunct Professor, Department of Anthropology, University of Arizona
2001-present	Owner, Anthropological Research, L.L.C.
1997-2001	Partner, Heritage Resources Management Consultants, L.L.C.
1995-2000	Sole Proprietor, Anthropological Research
1988-1995	Director of Southwest Programs, Institute of the NorthAmerican West
1985	Visiting Instructor, The Colorado College
1984-1988	Consulting Anthropologist, Albuquerque, New Mexico
1984-1985	Acting Director, Zuni Archaeology Program and Zuni Cultural Resource Enterprise
1982	Visiting Instructor, The Colorado College
1978	Instructor, UNM Gallup Branch, Zuni Extension
1977-1981	Director, Zuni Archaeology Program, Pueblo of Zuni, New Mexico
1979-1980	Acting Division Director, Division of Public Services, Pueblo of Zuni
1976-1977	Assistant Director, Zuni Archaeological Enterprise, Pueblo of Zuni, New Mexico

Publications Related to Proposed Project

2010 Intersecting Magesteria, Bridging Archaeological Science and Traditional Knowledge by Chip Colwell-Chanthaphonh and T. J. Ferguson. *Journal of Social Archaeology* 10(3):325-346.

2010 Consultation and Collaboration with Descendant Communities by Stephen W. Silliman and T. J. Ferguson. In *Voices in American Archaeology*, edited by Wendy Ashmore, Dorothy T. Lippert, and Barbara J. Mills, pp. 48-72. Society for American Archaeology, Washington, D.C.

2009 Improving the Quality of Archaeology in the United States through Consultation and Collaboration with Native Americans and Descendant Communities. In *Archaeology and Cultural Resource Management,* edited by Lynne Sebastian and William D. Lipe, pp. 169-193. School of Advanced Research Press, Santa Fe, New Mexico.

2009 *Hopitutskwa* and *Ang Kuktota*: The Role of Archaeological Sites in Defining Hopi Cultural Landscapes by Leigh J. Kuwanwisiwma and T. J. Ferguson. In *Archaeological Landscapes,* edited by Brenda Bowser and Nieves Zedeño, pp. 90-106. University of Utah Press, Salt Lake City.

2008 *Collaboration in Archaeological Practice, Engaging Descendant Communities*, edited by Chip Colwell-Chanthaphonh and T. J. Ferguson. Alta Mira Press, Lanham, Maryland.

2006 Memory Pieces and Footprints: Multivocality and the Meanings of Ancient Times and Ancestral Places among the Zuni and Hopi by Chip Colwell-Chanthaphonh and T. J. Ferguson. *American Anthropologist* 108(1):148-162.

2006 *History is in the Land: Multivocal Tribal Traditions in Arizona's San Pedro Valley*, by T. J. Ferguson and Chip Colwell-Chanthaphonh. University of Arizona Press, Tucson.

2001 Hopi and Zuni Cultural Landscapes: Implications of History and Scale for Cultural Resources Management by T. J. Ferguson and Roger Anyon. In *Native Peoples of the Southwest: Negotiating Land, Water, and Ethnicities*, edited by Laurie Weinstein, pp. 99-122. Bergin & Garvey, Westport, CT.

Other Significant Publications

2005 Working With and Working For Indigenous Communities by Joe Watkins and T. J. Ferguson. In *Handbook of Archaeological Methods*, edited by Christopher Chippendale and Herbert Maschner, pp. 1372-1406. Alta Mira Press, Walnut Creek, California.
2004 Academic, Legal, and Political Contexts of Social Identity and Cultural Affiliation Research in the Southwest. In *Identity, Feasting, and the Archaeology of the Greater Southwest*, edited by Barbara J. Mills, pp. 27-41. University Press of Colorado, Boulder. 2003 Archaeological Anthropology Conducted by Indian Tribes: Traditional Cultural Properties and Cultural Affiliation. In *Archaeology is Anthropology*, edited by Susan D. Gillespie and Deborah Nichols, pp. 137-144. Archaeological Papers of the American Anthropological Association No. 13. American Anthropological Association, Washington, D.C.
1996 Native Americans and the Practice of Archaeology. *Annual Review of Anthropology* 25:63-79.
1985 *A Zuni Atlas* by T. J. Ferguson and E. Richard Hart. University of Oklahoma Press, Norman.

Synergistic Activities

Member of Editorial Board of *American Anthropologist,* 2007-2010

Member of Executive Board of the American Anthropological Association, holding Professional/Practicing seat, 2008-2011

Collaborative research with Western Pueblo, Apache, and Tohono O'dham tribes to investigate the role that archaeological sites play in defining cultural landscapes and tribal history in the Southwest.

Conducts GIS mapping projects for historic preservation and cultural documentation projects.

Professional activities involved with developing models of mutually beneficial collaboration between American Indian communities and archaeologists in field research, museum practice, and assessment of cultural landscapes were recognized by award of the Solon Kimball Award for Public and Applied Anthropology by the American Anthropological Association in 2006.

Professional activities involved with effectively communicating to archaeologists the importance of understanding Native American views about archaeology; for seeking to make archaeology more directly useful and relevant to Native American communities; and for assisting tribes in developing their cultural resource management programs were recognized in a Presidential Recognition Award by the Society for American Archaeology in 1997.

Advisor: Wirt H. Wills, University of New Mexico

Advisees: Gina Richard

Collaborators: Mark Altaha (Apache), Roger Anyon (Pima County, AZ), Chip Colwell-Chanthaphonh (Denver Mus. of Nature and Science), Andrew Duff (Wash. St. U.), E. Richard Hart (Hart West & Assoc), Stewart Koyiyumptewa (Hopi), Leigh Kuwanwisiwma (Hopi), Micah Lomaomvaya (Hopi), Patrick Lyons (U. Arizona), Barbara Mills (U. Arizona), Robert Preucel (U. Penn), Gregson Schachner (UCLA), Tom Sheridan (U. Arizona) Stephen Silliman (U. Mass, Boston), Ronald L. Stauber (U. New Mexico), Joe Watkins (U. Oklahoma), Laurie Webster (U. Arizona), John Welch (Simon Fraser U.), Peter Whiteley (Am. Mus. Nat. Hist.), Michael Yeatts (Hopi)

ROBERT EDWARD KEANE
USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT

PROFESSIONAL PREPARATION

Bachelor of Science	1978	Forest Engineering	University of Maine, Orono ME
Master of Science	1985	Forest Ecology	University of Montana, Missoula, MT
Doctor of Philosophy	1994	Forest Ecology	University of Idaho, Moscow, ID

APPOINTMENTS

1990-Present. **Research Ecologist** US Forest Service Rocky Mountain Research Station
1985 to 1990 **Quantitative Ecologist**, Systems for Environmental Management, Missoula, MT
1982 to 1985 **Research Assistant**, School of Forestry, University of Montana, Missoula, MT
1981 to 1982 **Research Associate**, Greenwoods Project, School Forestry, Univ of Maine, Orono, ME
1980 to 1981 **Research Technician**, Forest Service, Intermountain Research Station, Moscow, ID
1978 to 1980 **Research Forester**, Gradient Modeling, Inc. Missoula, MT

PERTINENT PUBLICATIONS

Five most closely related

Keane, R.E., L. Holsinger, R. Parsons, K. Gray. 2008. Climate change effects on historical range of variability of two large landscapes in western Montana, USA. **Forest Ecology and Management 254:375-289**

Karau, Eva and Robert E. Keane. 2007. Determining the spatial extent of a landscape using simulation modeling. **Landscape Ecology 22:993-1006**

Keane, R.E., M.G. Rollins, and Z. Zhu. 2007. Using simulated historical time series to prioritize fuel treatments on landscapes across the United States: the LANDFIRE prototype project. **Ecological Modelling 204:485-502**

Keane, R.E., G. Cary, Ian D. Davies, Michael D. Flannigan, Robert H. Gardner, Sandra Lavorel, James M. Lenihan, Chao Li, T. Scott Rupp. 2004. A classification of landscape fire succession models: spatially explicit models of fire and vegetation dynamics. **Ecological Modelling 179(1):3-27**

Keane, R.E. and M.A. Finney. 2003. The simulation of landscape fire, climate, and ecosystem dynamics. Pages 32-68 In: Veblen, Thomas T., Baker W. L., Montenegro, Gloria, and Swetnam, Thomas W. (Editors). Fire and Climatic Change in Temperate Ecosystems of the Western Americas**. Springer-Verlag, New York, USA**. 422 pages.

Five other significant publications

Keane, R.E., G. Cary, Ian D. Davies, Michael D. Flannigan, Robert H. Gardner, Sandra Lavorel, James M. Lenihan, Chao Li, T. Scott Rupp. 2004. A classification of landscape fire succession models: spatially explicit models of fire and vegetation dynamics. **Ecological Modelling 179(1):3-27**

Keane, Robert E., Geoffrey J. Cary, and Russell A. Parsons. 2004. Using simulation to map fire regimes: An evaluation of approaches, strategies, and limitations. **International Journal of Wildland Fire 12:309-322**

Keane, R.E., P. Morgan, and J.D. White. 1999. Temporal pattern of ecosystem processes on simulated landscapes of Glacier National Park, USA. **Landscape Ecology 14(3):311-329**.

Keane, R.E., R.E. Parsons and P. Hessburg. 2001. Estimating historical range and variation of landscape patch dynamics: Limitations of the simulation approach. **Ecological Modelling 151(1):29-49**

Keane, R.E., Colin Hardy, Kevin Ryan, and Mark Finney. 1997. Simulating effects of fire management on gaseous emissions from future landscapes of Glacier National Park, Montana, USA. **World Resource Review** 9(2):177-205

SYNERGISTIC ACTIVITIES

Lead Scientist**,** LANDFIRE Prototype Project, ***Science Team*****,** Columbia River Basin Ecosystem Management Project, ***Associate Editor*****,** International Journal of Wildland Fire (2003-

Present), ***Secretary*,** US International Association of Landscape Ecologists (2000-2006)**,** ***Treasurer*** and ***Board of Directors Member*** Whitebark Pine Ecosystem Foundation (1998-Present), ***Project Leader*,** Fire Effects Research Project, RMRS (2005-2007), ***Deputy Program Leader*,** Fire Fuels Smoke Program, RMRS (2007-present).

COLLABORATORS & OTHER AFFILIATIONS:

P. Fule, Northern Arizona Univ.
P. Hessburg, R. Ottmar, R. Kennedy, D. McKenzie, PNW Research Station, US Forest Service
D. Fagre, C. Key, K. Kendall USGS, Glacier Field Station
P. Landres, A, Schottle, RMRS, US Forest Service
D. Tomback University of Colorado Denver
J. Keeley USGS California
J. Agee (retired), University of Washington
S. Running, H. Zuuring, B. Steele, R. Callaway, A. Sala Univ Montana,
G. Cary, I. Davies, K. King, R. Bradstock Australia National University Canberra, ACT
R. Williams, A. Liefloff, CSIRO, Darwin Australia
15 National Forests

GRADUATE AND POST-DOCTORAL ADVISORS:

M. Rollins (Univ Arizona Graduate)
V. Bacciu (University Sardinia Graduate)
R. Loehman (University of Montana Graduate)

GRADUATE STUDENTS ADVISEES**:**

P. Thornton, L. Kurtzahls, C. Seilstat, D. Ayers, C. Teske, C. Stalling, Nora Lahr University Montana
K. Brown, S. D. Michelson, Henderson Montana State University
Vicki Edwards, University Idaho

Biographical Sketch
MATTHEW J. LIEBMANN

PROFESSIONAL PREPARATION

Boston College	English and Theology	BA 1996
University of Pennsylvania	Anthropology	PhD 2006

APPOINTMENTS

2009-	Assistant Professor, Department of Anthropology, Harvard University
2006-2008	Assistant Professor, Department of Anthropology, College of William and Mary

PUBLICATIONS (i)

Liebmann, Matthew
2011 The Best of Times, the Worst of Times: Pueblo Resistance and Accommodation during the Spanish Reconquista of New Mexico. In *Enduring Conquests: Rethinking the Archaeology of Resistance to Spanish Colonialism in the Americas*, edited by M. Liebmann and M. S. Murphy. SAR Press, Santa Fe.

Liebmann, Matthew
2008 The Innovative Materiality of Revitalization Movements: Lessons from the Pueblo Revolt of 1680. *American Anthropologist* 110(3):360-372.

Liebmann, Matthew and Robert W. Preucel
2007 The Archaeology of the Pueblo Revolt and the Formation of the Modern Pueblo World. *Kiva: The Journal of Southwestern Anthropology and History* 73(2):195-217.

Liebmann, Matthew, T.J. Ferguson, and Robert W. Preucel
2005 Pueblo Settlement, Architecture, and Social Change in the Pueblo Revolt Era, A.D. 1680-1696. *Journal of Field Archaeology* 30(1):45-60.

Liebmann, Matthew
Under review (2011) Parsing Hybridity: Archaeologies of Amalgamation in Seventeenth Century New Mexico. In *Hybrid Material Culture: The Archaeology of Syncretism and Ethnogenesis*, edited by Jeb Card. Center for Archaeological Investigations, SIU-Carbondale.

PUBLICATIONS (ii)

Matthew Liebmann
2008 The Intersections of Archaeology and Postcolonial Studies. In *Archaeology and the Postcolonial Critique*, edited by M. Liebmann and U. Rizvi, pp. 1-20. Altamira Press, Lanham, MD.

Matthew Liebmann

2008 Postcolonial Cultural Affiliation: Essentialism, Hybridity, and NAGPRA. In *Archaeology and the Postcolonial Critique*, edited by M. Liebmann and U. Rizvi, pp. 73-90. Altamira Press, Lanham, MD.

Matthew Liebmann
2002 Signs of Power and Resistance: The (Re)Creation of Christian Imagery and Identities in the Pueblo Revolt Era. In *Archaeologies of the Pueblo Revolt*, edited by Robert W. Preucel. University of New Mexico Press, Albuquerque.

Matthew Liebmann
2002 Demystifying the Big Horn Medicine Wheel: A Contextual Analysis of Symbolism, Meaning, and Function. *Plains Anthropologist* 47(180):46-56

Matthew Liebmann
Under review (2011) The Rest is History: Devaluing the Recent Past in the Archaeology of Native North America. In *Lost in Transition: Decolonizing Indigenous Histories at the "Precolonial/Colonial" Intersection in Archaeology*, edited by Siobhan M. Hart and Maxine Oland. University of Arizona Press, Tucson.

SYNERGISTIC ACTIVITIES

2003-2005 Tribal Archaeologist, Pueblo of Jemez Department of Resource Protection
2000-2009 Project Collaborator, Pecos Pathways Project (helped to educate and train high school students from Jemez Pueblo and Phillips Academy, Andover, in archaeological methods and Southwestern archaeology)

COLLABORATORS & OTHER AFFILIATIONS

T.J. Ferguson (University of Arizona)
Melissa Murphy (University of Wyoming)
Robert Preucel (University of Pennsylvania)
Uzma Rizvi (Pratt Institute)

Graduate Advisor: Robert W. Preucel, University of Pennsylvania Department of Anthropology

Christopher I. Roos
December 2010

a. Professional Preparation

University of Cincinnati	Major: Anthropology (with high honors)	B.A., 2000
University of Arizona	Major: Anthropology (Archaeology)	M.A., 2002
University of Arizona	Major: Anthropology (Archaeology)	Ph.D., 2008

b. Appointments

2010-	Assistant Professor, Department of Anthropology, Southern Methodist University
2009-2010	Postdoctoral Scholar, Department of Anthropology, University of South Florida
2008-2009	Lecturer, Department of Anthropology, Ohio State University
2008	Assistant Director, Shumway Archaeology Project, University of Vermont
2007	Teaching Associate, Department of Anthropology, University of Arizona
2006-2007	Instructor, Department of Anthropology, University of Arizona
2005-2007	Project Director, Mogollon Rim Historical Ecology Project, University of Arizona
2003-2004	Assistant Director, Teaching Assistant, University of Arizona Archaeological Field School
2002-2003	Archaeologist, GIS Specialist, International Archaeological Research Institute, Inc., Honolulu
2002-2003	Archaeologist, GIS Consultant, Department of Anthropology, University of Hawaii

c.(i) Publications Most Relevant to the Project

1. **Roos, C.I.,** A.P. Sullivan, III, and C. McNamee (2010) Paleoecological Evidence for Indigenous Burning in the Upland Southwest. In *The Archaeology of Anthropogenic Environments,* edited by R. Dean, pp. 142-171. Center for Archaeological Investigations, Southern Illinois University, Carbondale.
2. Bowman, D.M.J.S., J.K. Balch, P. Artaxo, W.J. Bond, J.M. Carlson, M.A. Cochrane, C.M. D'Antonio, R.S. DeFries, J.C. Doyle, SP. Harrison, F.H. Johnston, J.E. Keeley, M.A. Krawchuck, C.A. Kull, J.B. Marston, M.A. Moritz, I.C. Prentice, **C.I. Roos,** A.C. Scott, T.W. Swetnam, G.R. van der Werf, and S.J. Pyne (2009) Fire in the earth system. *Science* 324:481-484.
3. **Roos, C.I.,** and T.W. Swetnam (in review) A 1416-Year Reconstruction of Annual, Multi-decadal, and Centennial Variability in Area Burned for Ponderosa Pine forests of the Southern Colorado Plateau Region, Southwest USA. *The Holocene*.
4. **Roos, C.I.** (2007) Were Wildland Fires "Natural" Prior to Late 19th Century Euroamerican Settlement of the Eastern Mogollon Rim Region? *Glyphs* 57(13): 5, 9.

d. Synergistic Activities

- From 2005-2008, I directed the Mogollon Rim Historical Ecology Project (MRHEP) that integrated archaeology, sedimentary paleoecology, and dendroclimatology to investigate the relative impacts of human land uses and climate change on ponderosa pine fire regimes over the last 1000 years. This project developed an archaeologically based sampling strategy for paleoecological research that has facilitated the development of the current proposal.

- As part of MRHEP, I adapted lacustrine sedimentary charcoal analytical techniques for use in alluvial sedimentary contexts to generate multi-century fire regime histories for semi-arid forests where lakes, ponds, and wetlands are exceptionally rare.

- Also during my time directing MRHEP, I established collaborative relationships with the Heritage Program for the White Mountain Apache Tribe. Through this collaboration we were able to productively adapt the field methodology for consistency with Apache ethics (i.e., avoiding archaeological sites and respecting sacred places) while generating new scientific knowledge that will help inform contemporary management of the surrounding natural environment.

- From 2003-2004, I served as a Teaching Associate and Assistant Director for the University of Arizona Archaeological Field School during a period in which it emphasized scientific ethics and collaboration with indigenous communities. During this time, I helped train tribal members from the White Mountain Apache Tribe, the Pueblo of Jemez, and the Coeur D'Alene Tribe in archaeological research while encouraging the pursuit of anthropology for undergraduate or postgraduate degrees among tribal members.

- From 2002-2003, I served as a Geographic Information Systems (GIS) specialist and Archaeologist for International Archaeological Research Institute, Inc. and as a consultant for the University of Hawaii where I supervised and conducted archaeological survey; geoarchaeological excavation; and GIS database design, management, and analysis for academic and cultural resources management projects in Hawaii.

e.(i) Collaborations (last 48 months):

Mark Altaha (Wht Mtn Apache Tribe); Owen Davis (U Arizona); Jeffrey Dean (U Arizona); John Dudgeon (Idaho State U); Julie Field (Ohio State U); Greg Hodgins (U Arizona); Kacy Hollenback (U Arizona); Vance Holliday (U Arizona); Nicholas Laluk (U Arizona); Philip Leckman (U Arizona); Calla McNamee (U Calgary); Barbara Mills (U Arizona); Philip Mink (U Kentucky); Mark Mitchell (PaleoCultural Research Group); Kevin Nolan (Ohio State U); Caitlin O'Grady (Virginia Dept. Historic Resources); Alan Sullivan (U Cincinnati); Thomas Swetnam (U Arizona); Scott Van Keuren (U Vermont); Steve Weiner (Weizmann Institute); Nieves Zedeño (U Arizona)

e.(ii) Graduate Co-Advisors: Vance T. Holliday (U Arizona); Barbara J. Mills (U Arizona)

Curriculum Vitae (abbreviated) November 2010

Christopher H. Baisan
Laboratory of Tree-Ring Research
University of Arizona
Tucson, AZ 85721
(520) 621-6463 cbaisan@ltrr.arizona.edu

University Education:

University of Arizona, School of Natural Resources, Watershed Management, B.S. 1991

Positions:

Principal Research Specialist, 2009-present
Senior Research Specialist, 2000-2008
Research Specialist, 1992-1999
Research Technician, 1987-1991

Honors & Awards (selected):

Graduated Summa Cum Laude, BS Watershed Management 1991
Phi Kappa Phi Outstanding Graduating Senior, 1991
Outstanding Senior in Watershed Sciences 1991
A.E. Douglass Scholarship 1988
E.S. Schulman Scholarship 1989
Dougherty Scholarship 1988,1989,1990,1991

Research Interests:

Dendrochronology applications in forest and fire ecology, fire history, fire and climate interactions, forest insect outbreak dynamics, climatology, hydrology, and archaeology.

Five Most Relevant Publications:

Swetnam, T. W. and **C. H. Baisan** 2003. Tree-ring reconstructions of fire and climate history in the Sierra Nevada and Southwestern United States. pages 158-195, In: T. T. Veblen, W. Baker, G. Montenegro, and T. W. Swetnam, editors. Fire and Climatic Change in Temperate Ecosystems of the Western Americas. Ecological Studies Vol. 160. Springer, New York.

Meko, D.M., Woodhouse, C.H., **Baisan, C.H.**, Knight, T., Lukas, J.J., Hughes, M.K., Salzer, M.W. 2007. Medieval drought in the upper Colorado River Basin. Geophysical Research Letters 34(10): L10705.

Allen, C.D., Anderson, R.S., Jass, R.B., Toney, J.L., and **Baisan, C.H.** 2008. Paired charcoal and tree-ring records of high-frequency fire from two New Mexico bog sites. International Journal of Wildland Fire 17(1) 115–130.

Touchan, R., Anchukaitis, K.J., Meko, D.M., Attalah, S., **Baisan, C**., Aloui, A. 2008. The long term context for recent drought in northwestern Africa. Geophysical Research Letters, v 35.

Troy A. Knight, Meko, D.M., and **Baisan, C.H.** 2010. A Bimillennial-Length Tree-Ring Reconstruction of Precipitation for the Tavaputs Plateau, Northeastern Utah. Quaternary Research, v73 (1) 107-117.

Five Additional Publications:

Baisan, C. H., and T. W. Swetnam**.** 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, USA. Canadian Journal of Forest Research 20:1559-1569

Baisan, C. H., and T. W. Swetnam**.** 1997. Interactions of fire regimes and land use in the Central Rio Grande Valley. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Paper RM-RP-330, 20p.

Meko D. M. and **Baisan C. H**. 2001. Pilot study of latewood-width of confers as an indicator of variability of summer rainfall in the north American Monsoon region. International J. of Climatology **21**, 697-708.

Brown, P.M., Kaye, M.W., Huckaby, L.S., **Baisan, C.H.** 2001. Fire history along environmental gradients in the Sacramento Mountains, New Mexico: influences of local and regional processes. Ecoscience 8(1): 115-126.

Swetnam, T. W., **C. H. Baisan**, and J. M. Kaib, 2001. Forest fire histories in the sky islands of La Frontera. Chapter 7, pages 95-119, In G. L. Webster and C. J. Bahre eds., Changing Plant Life of La Frontera: Observations on Vegetation in the United States/Mexico Borderlands. University of New Mexico Press, Albuquerque.

Sara Chavarria, November 2010

Professional Preparation
University of Texas at San Antonio, Department of Anthropology, B.A., 1988
University of Arizona, Department of Anthropology, M.A., 1995
University of Arizona, Department of Language, Reading, and Culture, PhD, 2000

Appointments
Director of Education Outreach, College of Education, University of Arizona (2006- present)
Teacher Institute Coordinator, Dept. of Anthropology, Tucson, Arizona (2004-2007)
Curriculum Design, College of Pharmacy, Tucson, Arizona (2003-2006)
Middle School Archaeology Visiting Teacher, International School of Toulouse, France (2000-2002)
Technical Editor, EUROpean Cloud Systems (EUROCS) Project, Météo France, France (2000-2002)
Project Director, Old Pueblo Archaeology Center, Tucson, Arizona (1994-1999)
Field School Instructor, Arizona State Museum, University of Arizona, Tucson, Arizona (1991-1996)

Publications (Curriculum and Outreach Materials Development)
UA for You Design Team, University of Arizona's new Outreach Portal http://uaforyou.arizona.edu
Passport to High School Summer Institute Teaching Manual (in progress), College of Education, University of Arizona, Tucson, Arizona
Hosting Mentors: A Handbook for Middle Schools (2008), College of Education, University of Arizona, Tucson, Arizona
Industrialization of the American Landscape (2006). PULSE Curriculum project, College of Pharmacy, University of Arizona, Tucson, Arizona.
Disease and Epidemics: Architects of History (2005). PULSE Curriculum project, College of Pharmacy, University of Arizona, Tucson, Arizona.
This Land is Our Land and *Dawn of New Revolutions* (2004). PULSE Curriculum project, College of Pharmacy, University of Arizona, Tucson, Arizona.

Synergistic Activities
Sara Chavarria has coordinated multifaceted outreach projects, including the development of Social Studies curriculum units for PULSE (Promoting Understanding and Learning for Society and Environmental Health), the development of Summer Institutes for High School Students and for Secondary School teachers, the design of a mentor hosting handbook for K-12 schools, and spearheading the creation of a grassroots university-wide outreach organization (The UA Collaborative for Community Outreach and Extension) at the UA. She is also a key member of the design team for the UAforYOU outreach portal, a university wide outreach search portal for community members to easily locate all outreach materials that the University of Arizona has to offer.

Dr. Chavarria's current outreach interests focus on supporting the development of university-wide outreach programs that are fiscally responsible and working towards the compilation of an outreach 'toolkit' of sustainable models in outreach best practices of program design and evaluation. She is also coordinating the efforts of a University of Arizona partnership with Wildcat Charter School (a secondary school in Tucson that targets underrepresented youth) in order to design a secondary school curriculum program that prepares 1st generation minority students for a successful higher education experience. As part of this same effort she is working with an outreach team from the 4 medical colleges (Medicine, Pharmacy, Nursing, Public Health) to design a program at Wildcat School that introduces middle school students to medicine related careers early on in their education. Coinciding with this project, she is very involved in exploring how to best attract and prepare underrepresented students for higher education success (Road Map to College project) by enhancing existing University of Arizona outreach programs to incorporate College Prep tutorials.

School of Anthropology Archaeology Scholarship program
This program will host 24 high school students each year for 4.5 years at the School of Anthropology. The program will introduce high school students to the interdisciplinary study of archaeology through classes, internships, and workshops. Funding will be private with a projected budget of $890,000.00 for the 4.5 years. The project is expected to begin January 2011 and end June 2015. The program would take place at the University of Arizona in Tucson, Arizona. Dr. Chavarria would be the Supervisor of the program committing .25 FTE of her time.

Collaborators and Co-Editors:

UAforYOU portal (Design Team): Barbara Hutchinson (College of Agriculture), Mary Bouley (College of Science), Marti Lindsey (College of Pharmacy), Sheila Merrigan (UA Cooperative Extension), Jeanne Pfander (University Libraries)

University Medical Colleges: Ana Maria Lopez (College of Medicine), Theodore Tong (College of Pharmacy)

Wildcat Secondary School Planning Team (Curriculum Design and Research): Ron Marx (College of Education), Luis Moll (College of Education), Lina Susee (Wildcat School Director), Walter Doyle (College of Education), Eniko Enikov (College of Engineering), Bruce Johnson (College of Education), Julio Cammarota (Mex-Am Studies), Carole Beal, (Computer Science), Richard Ruiz (College of Education), Rosario Carillo (Mex-American Studies), Vicente Talanquer (College of Science), Deb Temanek (College of Science) , Ingrid Novodvorsky (College of Science) , Cynthia Anhalt (Math), Carl Liaupsin (DPS), David Betts (College of Educaiton), Laura McCannon (Theatre Arts), Patty Anders (College of Education), Regina Deil-Amen (College of Education), Katrina Mangin (College of Science), Toni Griego-Jones (College of Education), Patty Anders (College of Education), Jessica Summers (College of Education), Sheri Bauman (College of Education), Jeff Milem (College of Education), Steve Russel (Family & Consumer Science)

RoadMap to College Project (Design Team): Rudy McCormick (UA Office of Early Academic Outreach), Rudy Molina (SALT Center), Lydia Bell (Center for the Study of Higher Education)

School of Anthropology Project: Mary Voyatzis, Ginny Healy, David Romano (currently at Univ. of Penn)

Graduate Students Advised:

Camille Cheatham, PhD student, Department of Teaching, Learning, and Sociocultural Studies, College of Education

Nicole Meador, PhD student, Department of Educational Psychology, College of Education

Miria Biller, PhD student, Department of Teaching, Learning, and Sociocultural Studies, College of Education

Rachel Andrea Loehman
Post-doctoral Research Ecologist, USDA Forest Service Fire Sciences Laboratory
Rocky Mountain Research Station, Missoula, MT 59808
406-829-7386 (phone); 406-329-4877 (fax); raloehman@fs.fed.us (email)

a. Professional Preparation

University of Montana-Missoula, Ecosystem Ecology, Ph.D., 2006
University of New Mexico-Albuquerque, Biogeography, M.A., 1999
University of New Mexico-Albuquerque, Anthropology, B.S., 1995

b. Appointments

- 2009 to present, *Post-doctoral Research Ecologist*, USDA Forest Service Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT
- 2007 to 2009, *Research Scientist*, Systems for Environmental Management, Missoula, MT
- 2007 to 2008, *Climate Change Analyst*, National Center for Landscape Fire Analysis, The University of Montana, Missoula, MT
- 2006 to 2007, *Post-doctoral Research Scientist*, Numerical Terradynamic Simulation Group, The University of Montana , Missoula, MT
- 2004 to 2006, *Ecologist-in-Residence*, National Science Foundation GK-12 Ecology Education Fellowship, The University of Montana, Missoula, MT
- 2000 to 2004, *NASA Earth System Science Fellow*, Numerical Terradynamic Simulation Group, The University of Montana, Missoula, MT
- 1997 to 2000, *GIS/Remote Sensing Specialist*, Sandia National Laboratories, Albuquerque, NM
- 1996 to 1997, *Archaeologist*, Lone Mountain Archaeological Services, Inc., Albuquerque, NM
- 1995 to 1996, *Archaeologist*, TRC Mariah Associates, Inc., Albuquerque, NM
- 1994 to 1995, *Archaeologist*, Office of Contract Archaeology, University of New Mexico Albuquerque, NM

c. Selected Publications

(i) Five most closely related publications

Keane, R.E., R. Loehman, and L. Holsinger. *In revision*. A research simulation platform for exploring fire and vegetation dynamics: The FireBGCv2 landscape fire succession model. USDA General Technical Report RMRS-GTR-xxx.

Loehman, Rachel A., A. Corrow, and R.E. Keane. *In review*. Climate change and disturbance interactions: Effects on whitebark pine (*Pinus albicaulis*) and implications for restoration, Glacier National Park, Montana, USA. Proceedings – Symposium on the Future of High-Elevation Five-Needle White Pines in Western North America. USDA General Technical Report RMRS-GTR-xxx.

Loehman, Rachel A., Joran Elias, Richard J. Douglass, Amy J. Kuenzi, James N. Mills, and Kent Wagoner. *In review*. Prediction of *Peromyscus maniculatus* (deer mouse) population dynamics in Montana, USA using satellite-driven vegetation productivity and weather data. Journal of Wildlife Diseases.

Loehman, R., R. Silverstein, R. E. Keane, and R. Parsons. *In prep.* Simulating effects of climate changes and wildfire on wildlife habitat suitability in Glacier National Park, Montana, USA.

Loehman, Rachel. 2010. Understanding the Science of Climate Change – Talking Points: Impacts to Arid Lands. National Park Service Natural Resource Report NPS/NRPC/NRR—2010/209. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Fort Collins, Colorado.

(ii) Five other publications

Loehman, Rachel and Greer Anderson. 2009. Understanding the Science of Climate Change – Talking Points: Impacts to the Atlantic Coast. National Park Service Natural Resource Report NPS/NRPC/NRR—2009/095. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Fort Collins, Colorado.

Loehman, Rachel. 2009. Understanding the Science of Climate Change – Talking Points: Impacts to Western Mountains and Forests. National Park Service Natural Resource Report NPS/NRPC/NRR—2009/090. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Fort Collins, Colorado.

Loehman, Rachel. 2009. Understanding the Science of Climate Change – Talking Points: Impacts to Prairie Potholes and Grasslands. National Park Service Natural Resource Report NPS/NRPC/NRR—2009/138. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Fort Collins, Colorado.

Loehman, Rachel. 2009. Understanding the Science of Climate Change – Talking Points: Impacts to the Gulf Coast. National Park Service Natural Resource Report NPS/NRPC/NRR—2009/137. U.S. Department of the Interior, National Park Service, Natural Resource Program Center, Fort Collins, Colorado.

Kang, S., S.W Running, J. Lim, M. Zhao, C. Park, and R. Loehman. 2003. A regional phenology model for detecting onset of greenness in temperate mixed forests, Korea: an application of MODIS leaf area index. Remote Sensing of Environment 86. 232-242.

d. Synergistic Activities

(ii) Selected Professional Services

- International Association of Landscape Ecologists, 2007-present
- University of Montana Climate Change Task Force, Member 2007-present
- American Geophysical Union, 2004-present
- Society for Conservation GIS, 1998-present
- Native Peoples/Native Homelands Research Group, 1998-2000
- National Assessment on Climate Change Research Group, 1998-2000

e. Collaborators & Other Affiliations

(i) Collaborators and Co-Editors

E. Heyerdahl, R. Parsons, B. Keane, JK Smith, S. Hood, A. Schoettle, V. Saab, USDA Forest Service Rocky Mountain Research Station; T. Venn, University of Montana; D. McKenzie, USDA Forest Service Pacific Northwest Research Station; D. Falk, T. Swetnam, University of Arizona; L. Welling, National Park Service; E. Smithwick, The Penn State University; T. Prato, University of Missouri

(ii) Graduate Advisors and Postdoctoral Sponsors

Dr. Robert E. Keane (post-doctoral sponsor, USDA Rocky Mountain Research Station); Dr. Steven Running, Dr. Carol Brewer (Ph.D. advisors, The University of Montana); Dr. Stanley Morain (M.A. advisor, University of New Mexico); Dr. Patty Crown (B.A. advisor, University of New Mexico).

(iii) Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of Ph.D. students advised: 1

John R. Welch
November 2010

a. Professional Preparation

Hamilton College, Clinton, NY	Major: Anthropology (with honors)	A.B., 1983
University of Arizona	Major: Anthropology (Archaeology)	M.A., 1985
University of Arizona	Major: Anthropology (Archaeology)	Ph.D., 1996

b. Appointments

2008-	Associate Faculty, Arizona State Museum, University of Arizona
2007-	Board Member and Secretary, Fort Apache Heritage Foundation
2006-	Fellow, Society for Applied Anthropology
2005-	Canada Research Chair in Indigenous Heritage Stewardship and Associate Professor, Simon Fraser University
2005-	Advisor, Heritage Program, White Mountain Apache Tribe
1998-2006	Ex Officio Board Member, Executive Director (pro tem), Fort Apache Heritage Fndtn.
1992-2005	Archaeologist, US Bureau of Indian Affairs (BIA), Fort Apache Agency, Whiteriver, AZ.
1994-2005	Tribal Historic Preservation Officer, White Mountain Apache Tribe, Whiteriver, AZ.
1996-2005	Founding Board Member, National Assn. of Tribal Historic Preservation Officers
1996-2000	Archaeologist, US Department of the Interior, Emergency Rehabilitation Team.
1994-2000	Associate Faculty, Northland Pioneer College, Holbrook, AZ.
1991-1994	Assistant Director, Lower Verde Archaeological Project. Statistical Research Inc., Tucson.
1992	Gila Resource Area Archaeologist, Safford District, US Bureau of Land Management.
1991	Agricultural Development Consultant, US Agency for International Development (Rabat, Morocco) & Bureau of Applied Research in Anthropology, University of Arizona.
1990-1993	Assistant Director, Roosevelt Rural Sites Study. Statistical Research Inc, Tucson.
1984-1989	Assistant Director, Survey Supervisor, Archaeological Assistant University of Arizona Archaeological Field School at Grasshopper.
1984-1990	Teaching Assistant, University of Arizona.

c.(i) 5 Publications Most Relevant to the Project

1. Welch, J.R., Ramon Riley and Michael V. Nixon (2009) Discretionary Desecration: American Indian Sacred Sites, Dzil Nchaa Si An (Mount Graham, Arizona), and Federal Agency Decision Making, *American Indian Culture and Research Journal* 33(4):29-68
2. Welch, J.R. (2008) Places, Displacements, Histories and Memories at a Frontier Icon in Indian Country. In *Monuments, Landscapes, and Cultural Memory*, edited by Patricia E. Rubertone, pp. 101-134. World Archaeological Congress and Left Coast Press, Walnut Creek, California.
3. Mills, Barbara J., Mark Altaha, J.R. Welch, and T. J. Ferguson (2008) Field Schools Without Trowels: Teaching Archaeological Ethics and Heritage Preservation in a Collaborative Context. In *Collaborating at the Trowel's Edge: Teaching and Learning in Indigenous Archaeology*, edited by Stephen W. Silliman, pp. 25-49. University of Arizona Press, Tucson.
4. Welch, J.R. (2007) 'A Monument to Native Civilization': Byron Cummings' Still-Unfolding Vision for Kinishba Ruins. *Journal of the Southwest* 49(1):1-94
5. Welch, J.R., and T. J. Ferguson (2007) Putting Patria into Repatriation: Cultural Affiliations of White Mountain Apache Tribe Lands. *Journal of Social Archaeology* 7:171-198.

c.(ii) 5 Other Selected Publications

1. Welch, J.R. (2009) Reconstructing the Ndee (Western Apache) Homeland. In The Archaeology of Meaningful Places, edited by Brenda Bowser and M. Nieves Zedeno, pp. 149-162. University of Utah Press, Salt Lake City.

2. Welch, J.R., (2008) Fort Apache and Theodore Roosevelt School National Historic Landmark Nomination. External peer review completed and under review by the U.S. National Park Service System Advisory Committee. National Park Service, Washington, D.C.
3. Welch, J.R., and Ramon Riley (2001) Reclaiming Land and Spirit in the Western Apache Homeland. *American Indian Quarterly* 25(1):5-12.
4. Welch, J.R.(2000) The White Mountain Apache Tribe Heritage Program: Origins, Operations, and Challenges. In *Working Together: Native Americans and Archaeologists*, edited by Kurt E. Dongoske, Mark Aldenderfer, and Karen Doehner, pp. 67-83. Society for American Archaeology, W.DC.
5. Anyon, Roger, T.J. Ferguson, and J.R. Welch (2000) Heritage Management by American Indian Tribes in the Southwestern United States. In *Cultural Resource Management in Contemporary Society*, edited by Francis P. McManamon and Alf Hutton, pp. 120-141. Routledge, New York.

d. Synergistic Activities

- Since 2005, as Simon Fraser U's Canada Research Chair in Indigenous Heritage Stewardship, I have developed new courses (*Indigenous Heritage Stewardship*; *Science, Traditional Ecological Knowledge, and Other Ways of Knowing*; and *Applied Archaeology*) and attracted students and funding to launch stewardship initiatives with the Katzie, Tla'amin, and Tahltan First Nations.
- As the Tribal Historic Preservation Officer (THPO) from 1994 to 2005, and as a duly designated White Mountain Apache Tribe Heritage Program advisor since 2005, I have facilitated Apache self-representation, self-governance, and self-determination in cultural and historic preservation and in culturally appropriate economic and community development. I created and advised ongoing programs for archaeological research, intergovernmental consultations, NAGPRA implementation, environmental protection, and the conservation of objects, sites, and traditions.
- As the Tribe's THPO from 1994 to 2005, I served as the preparer-principal investigator for about 20, grant-funded projects promoting the restoration of Apache control over and responsibility for Apache cultural and ecological heritage. Some project examples: *Bringing Home the Ancestors: The Western Apache Repatriation Working Group* (US National Park Service, $71,381); Undergraduate Research Experience in Native American Archaeology and Heritage Preservation (co-PI with Barbara J. Mills) (US National Science Foundation, $221,999); *Preservation Treatments to the Fort Apache Historic District* (Save America's Treasures Program, White House Millennium Council, Washington, D.C., $313,000); *Western Apache Placenames Survey* (Historic Preservation Fund Grants to Indian Tribes, National Park Service, Washington, D.C., $49,900). These projects and similar initiatives integrated Apache principles and priorities, created contexts for multi-level education in heritage stewardship method and theory, and documented culturally appropriate use of oral traditions, places and objects.
- From 1993 to date I have led diverse efforts to document, establish tribal control over, preserve, and interpret the Fort Apache and Theodore Roosevelt Indian School Historic District.

e.(i) Collaborations (last 48 months): Mark Altaha (Wht Mtn Apache Tribe), Garry Cantley (US Bureau Indian Affairs), Robyn Ewing (Simon Fraser U), T.J. Ferguson (U Arizona), Doreen Gatewood (Wht Mtn Apache Tribe), Karl Hoerig (Wht Mtn Apache Tribe), Nicholas Laluk (U Arizona), Barbara Mills (U Arizona), Robert Muir (Simon Fraser U), George Nicholas (Simon Fraser U), Ramon Riley (Wht Mtn Apache Tribe), Eldon Yellowhorn (Simon Fraser U), Dana Lepofsky (Simon Fraser U)

e.(ii) Graduate Advisor: J. Jefferson Reid (U Arizona)

e.(iii) Thesis Advisees: Vera Asp (Simon Fraser U), Karen Brady (Simon Fraser U), Karen Capuder (U Washington), Robyn Ewing (Simon Fraser U), Tanja Hoffmann (Simon Fraser U), Soudeh Jamshidian (Simon Fraser U), Lauren Jelinek (U Arizona), Steve Kasstan (Simon Fraser U), Mykol Knighton (Simpn Fraser U), Nicholas Laluk (U Arizona), Jenny Lewis (Simon Fraser U), Craig Rust (Simon Fraser U).

Total Graduate Students Supervised & Under Supervision: 12