Ancient Piñon-Juniper Forests of Mesa Verde and the West: A Cautionary Note for Forest Restoration Programs

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Abstract**—***Fuel reduction and fire mitigation activities may be linked to restoration of overall forest health, but the two goals do not always coincide. We illustrate the importance of understanding both historic and contemporary fire regimes by evaluating the piñon-juniper forests of Mesa Verde National Park in southwestern Colorado. These dense forests are characterized by infrequent, severe fires occurring at intervals of many centuries. Stand structure, composition, and fire behavior have not been substantially altered by 20th century fire suppression, in contrast to other piñon-juniper systems. We hypothesize that three qualitatively different disturbance regimes characterize piñon-juniper ecosystems throughout the West.*

Introduction

A major effort is under way to reduce the fire hazard in western forests by thinning tree canopies, removing shrubs and coarse woody debris, and conducting low-intensity prescribed burning. Often, these fuel reduction or fire mitigation activities are linked to restoration of overall forest health (e.g., Covington et al. 1997). This combination of pragmatic objectives (reducing fire hazard at the wildland-urban interface) and ecological objectives (restoring ecological integrity and resilience) is quite sensible in forests that were formerly characterized by frequent, low-intensity fires, and where twentieth century activities like logging, grazing, and fire suppression have dramatically changed forest structure and function — e.g., in many western ponderosa pine forests (Hardy and Arno 1996, Covington et al. 1997). Indeed, the authors of this paper are currently involved in just such a program of thinning and burning degraded ponderosa pine forests in southwestern Colorado, both to achieve the pragmatic objectives of reducing fire hazard and providing material for the local logging industry, and to achieve the ecological objectives of stimulating the suppressed herbaceous stratum and providing habitat for cavity nesting birds and species that prefer open forest conditions (Lynch et al. 2000).

We are concerned, however, that the distinction between fire hazard mitigation and ecological restoration may become blurred, with sometimes unfortunate consequences for ecological integrity and resilience. In particular, because of pressures to meet treatment targets under the National Fire Plan (targets that may be defined primarily in terms of acreage treated per year), managers may be tempted to apply thinning and burning in forest systems where such treatments are unnecessary or even inappropriate from an ecological standpoint (Cole and Landres 1996). To illustrate this concern, we present a case study of the piñon-juniper forests of Mesa Verde National Park in southwestern Colorado.

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Piñon-juniper vegetation covers a vast area in western North America, and exhibits a wide range of stand structures and dynamics (Wangler and Minnich 1996, Miller et al. 1999). Recent research in the Great Basin has demonstrated clearly that piñon and juniper are increasing in density throughout much of this region. Many areas that were formerly dominated by shrubs are now being taken over by piñon and juniper, a trend that began in the late 1800s and is continuing. The causes of piñon and juniper expansion include livestock grazing, fire exclusion, and climatic changes (Miller and Wigand 1994, Miller and Tausch 2001). Some piñon-juniper and juniper savannas in New Mexico and Arizona also appear to have developed denser tree canopies in the twentieth century, or the trees have invaded grassland areas (Jameson 1962, Dwyer and Pieper 1967). Some former grasslands in Bandelier National Monument in northern New Mexico are now largely dominated by juniper and piñon trees <150 years old (C. Allen, personal communication). Because of these well-documented examples of piñon-juniper expansion that were clearly caused by fire exclusion and other human activities, many managers throughout the West have tended to view the entire piñon-juniper vegetation type as being degraded and in need of intensive restoration – usually by means of chaining, roller-chopping, hydro-mulching, and / or burning.

What is often missing in plans for restoration of piñon-juniper vegetation is recognition of the fact that throughout the West there are also ancient piñon-juniper stands with trees >400 years old (examples below). These stands were already well developed even before the late 1800s, and should not be regarded as abnormal consequences of grazing, fire exclusion, and climate change. Unfortunately, thinning and burning programs that would be appropriate and effective in piñon-juniper stands that have developed abnormal tree density during the last century, are being proposed or implemented in old-growth piñon-juniper stands that probably need no restoration. The result of such a well intentioned but misguided restoration effort is likely to be degradation of a relatively rare vegetation type (i.e., old-growth piñon-juniper forest) that contributes much to the biological diversity of western North America. As the pace of fuel reduction and restoration programs accelerates under the National Fire Plan, we have an urgent need to provide criteria for distinguishing between piñon-juniper stands that need treatment and those that do not. We believe that the situation we describe for piñon-juniper also applies to several other important forest types where mitigation and restoration plans may be under way.

This paper has two objectives. First, we describe the fire history, stand structure, and natural fire regime in old-growth piñon-juniper forests of Mesa Verde National Park (MVNP), as a case study to demonstrate that some piñon-juniper vegetation has not changed substantially in the last century, and therefore is not in need of broad-scale thinning or burning to achieve ecological objectives. Second, we develop a set of general hypotheses for predicting where in western North America we are most likely to find piñon-juniper vegetation that has undergone abnormal successional changes in the last century as a result of grazing, fire exclusion, and climate change, and where we are likely to find old-growth piñon-juniper stands that have not been degraded and do not require treatment to restore ecological integrity.

Fire History in Piñon-Juniper Forests of Mesa Verde National Park

Mesa Verde is a large, prominent cuesta in southwestern Colorado composed of uplifted and deeply eroded Cretaceous sedimentary rocks (Griffits

1990). Mesa Verde National Park (MVNP) occupies the northeastern portion of the cuesta. The remainder of the cuesta is mostly in the Ute Mountain reservation and is environmentally similar to the park. The two most extensive vegetation types are piñon-juniper forests (*Pinus edulis* and *Juniperus osteosperma*), found mostly on the southern end of the cuesta at slightly lower elevations, and Petran chaparral or oak-serviceberry shrubland (*Quercus gambellii* and *Amelanchier utahensis*), found mostly on the northern end of the cuesta at higher elevations. Floyd et al. (2000) mapped the major fires since the 1840s in the shrubland portion of MVNP, based on post-fire cohorts of re-sprouting oak, and determined that the average fire return interval is about 100 years. A graph of cumulative time-since-fire indicates little difference between late-nineteenth century and late-twentieth century area burned per decade. Thus, the fire exclusion policy in effect since the Park's establishment in 1906 probably has prevented many fires that would have remained small if not suppressed, but had little impact on the large fires that ignited under conditions of extreme drought and high wind. These latter kinds of fires, uncontrollable even with modern fire suppression technology, are infrequent but account for most of the area burned in a century — a situation similar to many boreal forests (Johnson 1992), subalpine forests (Romme 1982), and chaparral vegetation (Minnich and Chou 1997, Moritz 1997).

Floyd et al. (2000) presented preliminary data on fire history in the piñon-juniper forests of MVNP. We summarize those data here and augment them with additional, unpublished information to provide a fuller picture of the fire regime in the piñon-juniper forests. We structure our analysis around four questions: (1) Are low-severity surface fires an important component of the natural fire regime? (2) How frequent were fires of any kind before 1900? (3) Have piñon and juniper invaded other vegetation types since 1900? (4) Has tree density increased since 1900 in piñon-juniper stands?

Are low-severity surface fires an important component of the natural fire regime?

The large fires of the twentieth century in MVNP have all been stand-replacing crown fires, in both piñon-juniper and shrubland vegetation. Low-severity surface fires have occurred only at the margins of the crown fires as those fires were dying out. But were low-severity surface fires more common prior to Park establishment in 1906? We think not. Low-severity fires often scar susceptible trees, and indeed, the resulting fire scars are the basis of reconstructions of fire history in ponderosa pine and other forests characterized by frequent, low-severity fires. Despite explicitly searching for fire scars throughout MVNP during our 10 years of field work, we have not found any – aside from two trees having single basal scars that could be from fire but probably are from other causes. Piñon and juniper do not form the best scars for dendrochronological dating purposes, but they can be scarred by low-intensity fires (Tausch and West 1988). Moreover, numerous small patches of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) exist within and adjacent to the piñon-juniper forests, but these excellent recorders of low-severity fire also lack fire scars in MVNP. Given the paucity of fire scars, we conclude that low-severity surface fires simply were never extensive in piñon-juniper forests of MVNP.

However, we find ample evidence that stand-replacing crown fires occurred in the piñon-juniper forests even before 1900. Figure 1 is a photograph taken in 1934 (from MVNP archives) of an area that burned at some unknown time prior to Park establishment in 1906. The standing snags and the sharp border

Figure 1—Photograph taken in 1934 in the western portion of Mesa Verde National Park, near an area that burned in that year on Wetherill Mesa. The photo is not of the 1934 burn, but shows an area that was burned at an unknown time prior to Park establishment in 1906. Fire history reconstructions (Floyd et al. 2000) suggest that the area in this photo probably burned in the 1880s. Note the edge of dense, unburned piñon-juniper forest in the background.

of the unburned forest indicate clearly that this was a stand-replacing crown fire. From our fire history map (Floyd et al. 2000) and the general location of the photograph, we suspect that the fire occurred in the 1880s – some 50 years before the photo. Indeed, the scene looks much like areas today that were burned in the middle part of the twentieth century.

We also find patches of charred juniper snags within the piñon-juniper forests of MVNP. We took increment cores from piñon trees growing beneath or adjacent to the charred snags in one such patch on Chapin Mesa, known locally as “the glades.” The living trees that we sampled were so close to the snags that they could not possibly have survived the fire that created the snags. Some of the sampled piñons were >200 years old, indicating that the fire occurred in the 1700s or earlier (Floyd et al. 2000). This finding also indicates that evidence of past fires (in the form of charred snags) can persist for a very long time in this semi-arid environment.

How frequent were fires before 1900?

By measuring the extent of piñon-juniper forest burned during the twentieth century, and considering that twentieth century fire suppression probably did not have much effect on the few large fires that accounted for most of this burned area, we determined that the mean fire interval in piñon-juniper forests of MVNP is approximately 400 years (Floyd et al. 2000). In a landscape characterized by such long fire intervals, we would expect to find numerous stands that had remained unburned for even longer periods. Indeed, much of the piñon-juniper forest in MVNP contains no evidence of past fire whatsoever – no fire scarred trees, no charred snags, no charred logs. Tree ages (see below) also indicate that many of the stands are very old. Based on a convergence of several lines of evidence (paucity of fire-scars and charred wood, very old trees, and historic photographs – see below), we believe that much of the piñon-juniper forest in MVNP has not been subjected to any major disturbance since the ancestral Puebloan people (who built the famous cliff dwellings) abandoned the area 700 years ago.

Have piñon and juniper invaded other vegetation types since 1900?

Young piñon and juniper appear to be slowly increasing in some of the Park's shrublands. The stands so affected are developing after fires that occurred in the mid to late 1800s (Floyd et al. 2000). Given the naturally long intervals between fires in Mesa Verde's shrublands (mean of ca 100 years), this trend probably represents the natural course of post-fire succession rather than a true "invasion" by trees (Erdman 1970).

We also see young piñon and juniper establishing in some stands of big sagebrush (*Artemisia tridentata*) growing on small patches of deeper soils within the piñon-juniper forests. This may represent actual "invasion," since the trees are mostly young (<100 years old). However, it does not appear to be an anomaly caused by twentieth-century fire exclusion, because these areas apparently burned rarely even before 1900 (above). The extent of the area so affected within MVNP is very small.

Has tree density increased in piñon-juniper stands since 1900?

The piñon-juniper forests of MVNP are very dense in many places. Piñon generally has more stems per hectare, but juniper has greater basal area (unpublished data). Small and presumably young piñon are especially noticeable and give a visual impression of an ongoing increase in stand density.

However, old photographs from MVNP indicate that the piñon-juniper forests have been very dense since at least the early part of the twentieth century. Figures 2 and 3, taken in 1929 and 1934, respectively (from MVNP archives) show dense stands — much like what we see today. The stand depicted in figure 3 (from 1934) gives the impression of a two-tiered structure, with a sparse canopy of older trees and a thick understory of younger trees. However, without information on mortality rates in the understory, it is difficult to interpret long-term stand dynamics. We need detailed age structure data to confidently interpret trends in stand structure. We currently have age structure data derived from age-dbh regressions in one stand that appears representative of the old forests at the southern end of MVNP (Floyd et al. 2000), and we are in the process of directly determining age structure via ring counts in several additional stands. A plot of log(stems / ha) vs log(tree age) in this one stand is approximately linear for both piñon and juniper (figure 4) — a pattern associated with stable, old-growth forests that are not undergoing any major successional trends (Leak 1975). The largest piñon in figure 4 are >400 years old and the largest juniper are >600 years old.

We need additional detailed age distribution data to resolve the question of increasing stand density in piñon-juniper forests of MVNP during the last

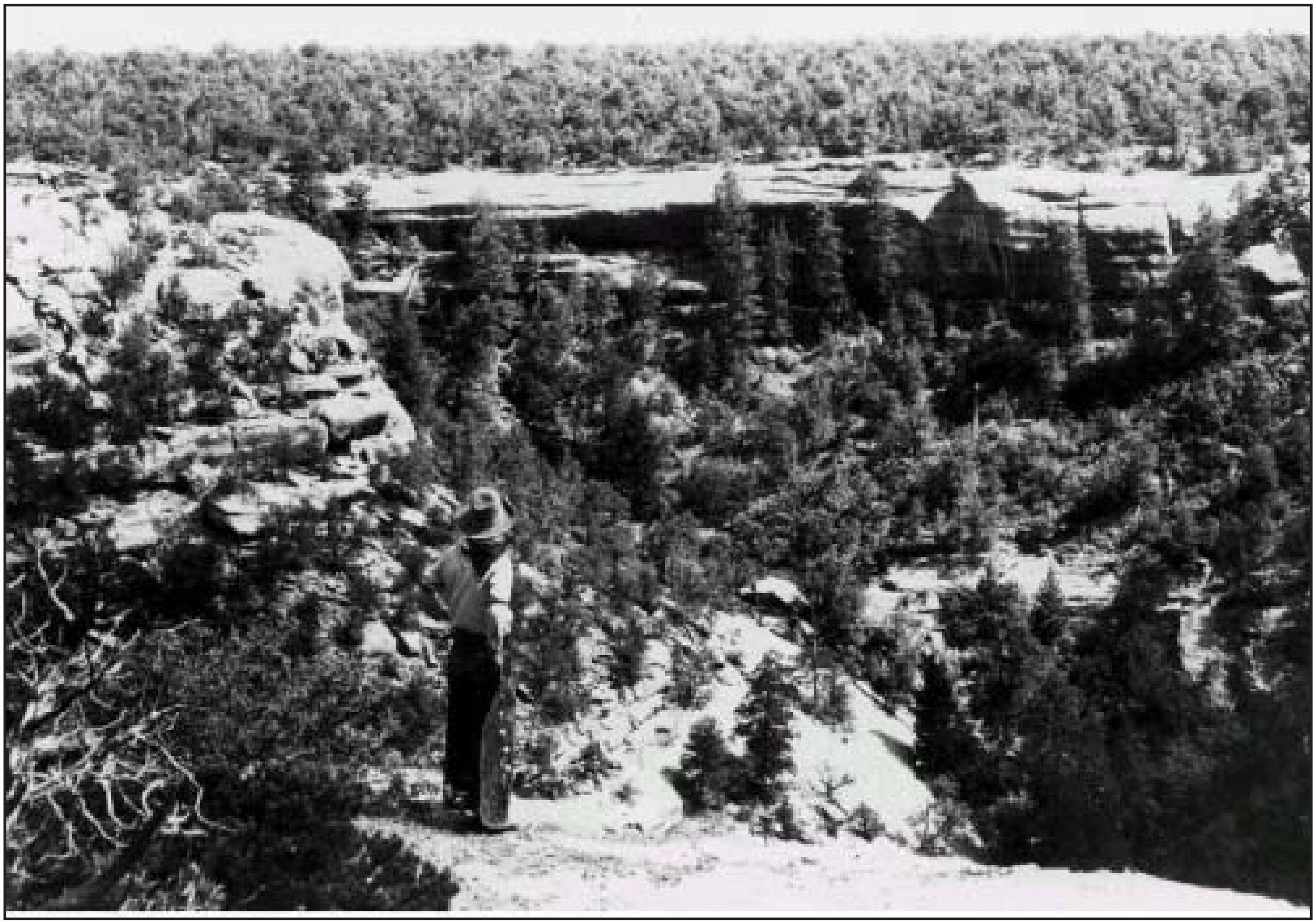


Figure 2—Photograph taken in 1929 of cliff dwellings in the southern portion of Mesa Verde National Park. Note the dense piñon-juniper forest on the rim above the ruins, a forest that does not look much different from the dense forests of today.

century. The abundance of small and young trees in the forests today does suggest that density has increased somewhat in the last 100 years. However, the old photos indicate that the magnitude of increase has not been great. And even if the forests have become more dense, the mechanism probably is related to climatic changes, direct effects of increasing atmospheric CO_2, or other causes (Miller and Wigand 1994)—but *not* to fire exclusion. Given that these forests rarely burned before 1900 (as argued above), post-1900 fire exclusion cannot be the primary reason for increasing tree density after 1900.

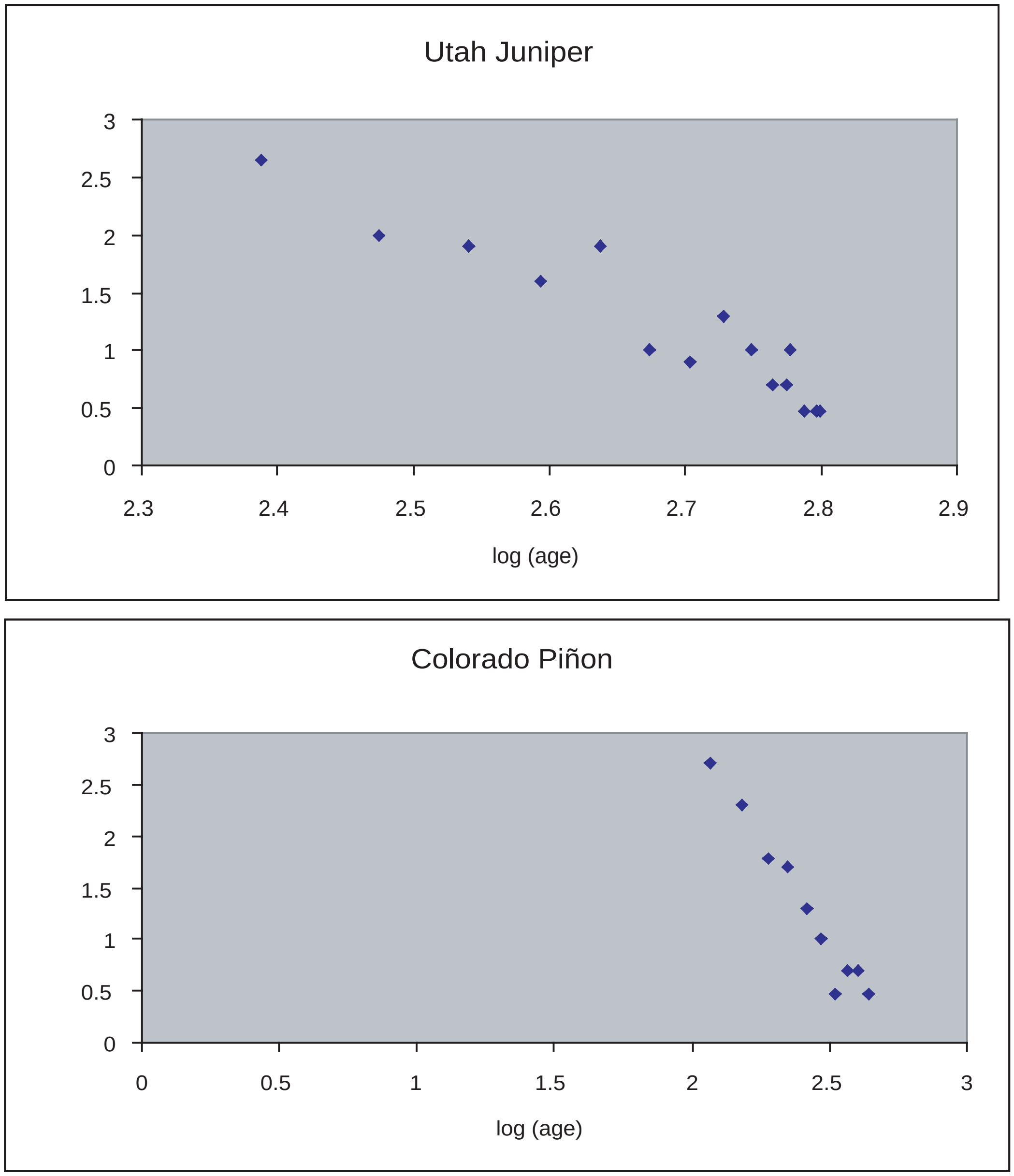
Reasons for the Distinctive Fire Regime in Mesa Verde

The evidence just presented indicates that the natural fire regime in Mesa Verde's piñon-juniper forests is characterized by occasional tiny fires (often a single lightning-ignited tree) but few fires of any significant extent. Most ignitions fail to spread, and much of the forest has not burned for at least 700 years. Large fires do occur periodically, however, under extreme weather conditions, and these rare fires are severe and stand-replacing. This fire regime probably has been altered only slightly by twentieth century fire suppression or other activities.

Figure 3—Photograph taken in 1934 in the western portion of Mesa Verde National Park, near an area that burned in that year on Wetherill Mesa. The photo was taken to show the kind of forest that burned in that year. Note the high density of the stand in 1934, similar to the dense stands in this area today.

Why do piñon-juniper forests of MVNP have such infrequent large fires? The reason is not a lack of fire starts: lightning ignites numerous fires every summer in the Park's piñon-juniper zone (Omi and Emrick 1980). However, the vast majority of these fires burn no more than an individual tree or snag before going out – with or without the intervention of a fire suppression crew. Even though the piñon-juniper forests in MVNP support enormous fuel loads of both dead and live material (Omi and Emrick 1980), the fuels are very patchily distributed. Patches of heavy fuels (a few square meters in extent) are separated by comparably sized patches of rock, bare ground, or sparse cover of herbs that do not carry fire readily. Because of the lack of horizontal fuel continuity, fire can spread from fuel patch to fuel patch only under conditions of strong winds and extremely low fuel moisture. In these circumstances, fire spreads through the crowns of live trees, generating extremely high energy release and displaying great rates of spread (personal observations). The necessary weather conditions for such fire behavior occur in only a few years of each decade, and coincide with local ignition only once every decade or two. Once such a fire is started, however, it may cover a large area, going out only when the wind dies down, rain falls, or the fire reaches an extensive area of non-flammable terrain. The deep canyons of MVNP, bordered by tall cliffs with poorly vegetated shale slopes at their bases, probably are significant

Figure 4—A plot of log(stems/ha) vs. log (tree age) for a stand of dense piñon-juniper forest at the southern end of Mesa Verde National Park. The linear relationship for *Juniperus osteosperma* (a) and for *Pinus edulis* (b) indicates that both tree species have an approximately stationary age structure of the kind that is associated with stable, old-growth forests (Leak 1975).



natural barriers to fire spread (figure 5). As one park ranger put it, "Fire in MVNP tends to burn either one tree or one mesa" (S. Budd-Jack, personal communication).

Heavy livestock grazing in the late 1800s and early 1900s altered fire regimes in many western forests by removing the grass and other fine fuels that formerly carried frequent, low-intensity fires (e.g., Miller and Wigand 1994, Covington et al. 1997). Heavy grazing also occurred in MVNP from around 1900 through the early 1930s (superintendents' annual reports and photos in MVNP archives). The reports are quite vague as to specific locations where cattle were grazed. However, we think that nearly all of the heavy livestock grazing occurred in the meadows and shrublands at the north end of the Park —not in the piñon-juniper forests at the south end. The homesteads, windmills, and stock tanks were all located in the northern area, and all of the old photos that we have located showing heavily grazed lands in MVNP depict meadows and adjacent shrublands. Heavy grazing in the piñon-juniper forests would have been problematic in any event because of lack of water on the dry

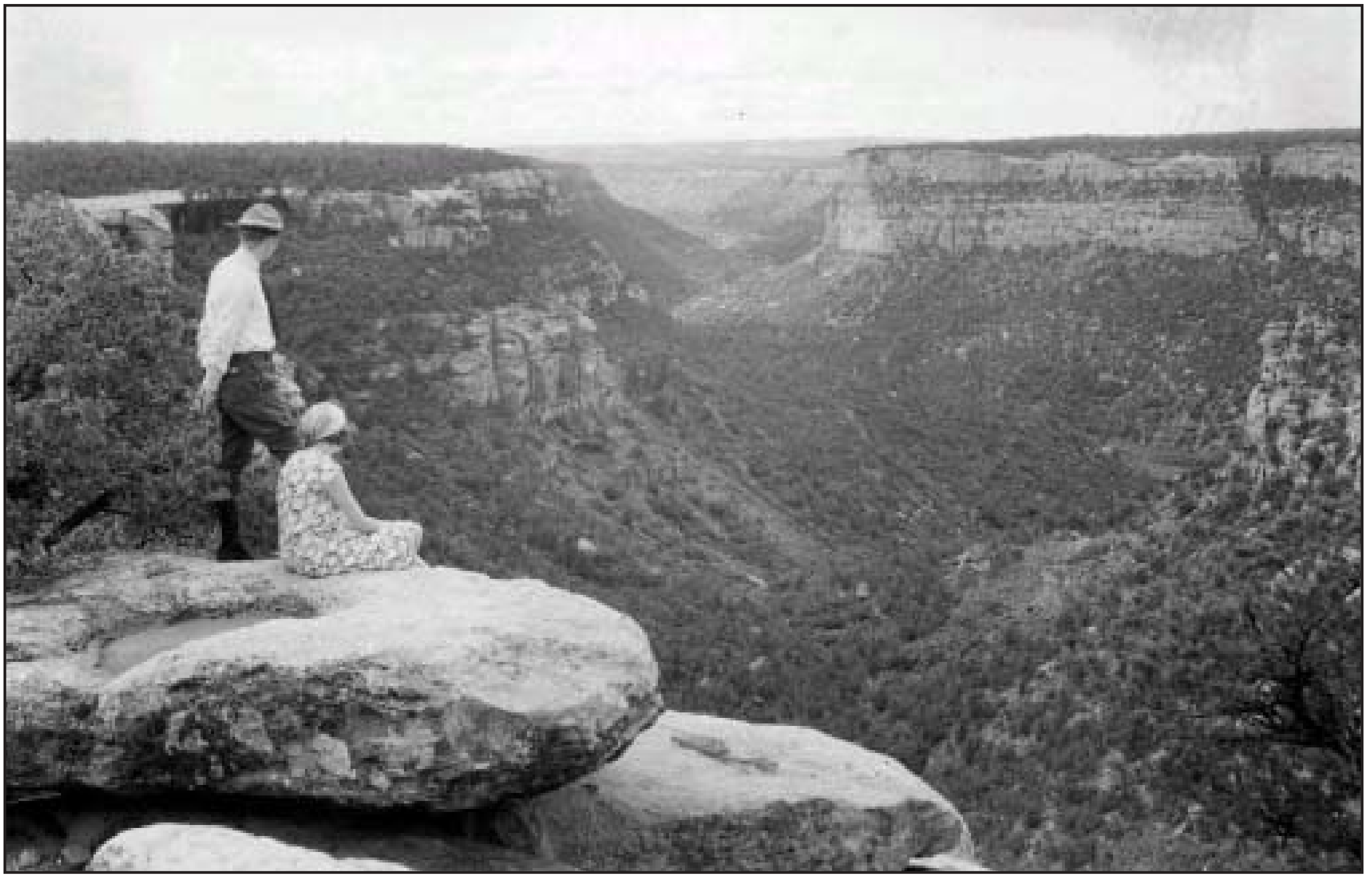


Figure 5—Photo taken in the southern portion of Mesa Verde National Park in the 1930s. Note the dense piñon-juniper forests on the mesa tops, which resemble the dense stands of today, and the cliffs and sparsely vegetated slopes that probably tend to prevent fire spread from one mesa to another.

mesa-tops and lack of forage. The heavily grazed meadows and shrublands have regained their grass cover in the 65 years since grazing was terminated in MVNP, but the old piñon-juniper forests still have only a sparse cover of *Poa fendleriana* and a few other native bunchgrasses. We doubt that grass cover was ever very great in the dry, shallow soils at the south end of Mesa Verde. Even if there was somewhat more grass prior to 1900, it apparently did not carry surface fires, because we find almost no fire scars (above).

Implications for Fire Management in Mesa Verde National Park

MVNP contains one of the greatest concentrations of prehistoric cultural sites and artifacts in North America. The Park was established in 1906 to protect these archaeological treasures, and protection of cultural resources remains the central mission of MVNP. Many of the most outstanding cultural resources are located in the piñon-juniper forests at the southern end of the Park and are vulnerable to damage or destruction by fire (Romme et al. 1993). Recognizing this dangerous situation, MVNP has implemented a fire mitigation program that emphasizes mechanical thinning of dense forests in the immediate vicinity of sensitive cultural resources.

We laud the proactive steps being taken by Park managers to protect the Park's special cultural resources and to provide for the safety of visitors and staff. However, we believe it is important to stress that fuel reduction in MVNP is strictly a program of fire mitigation—it is *not* ecological restoration. To remove >50 % of stand density and basal area from forests that have not been subjected to any major disturbance for 700 years is to create a stand structure that probably never existed previously—at least not within the last several centuries.

Because of the distinctive fire history of piñon-juniper forests in MVNP, especially the paucity of past fire occurrences in this system, we recommend against thinning and burning in areas remote from sensitive cultural sites. Not only would such a program create stand structures and disturbance regimes far outside the historical range of variability, but the treatments themselves would create at least two new problems for managers to deal with. First, where piñon-juniper forests in MVNP have burned or been cleared in the last century, they have not yet begun to recover their tree component. We have sampled all of the large burns of the twentieth century (1934, 1959, 1972, 1989, and 1996), and have found almost no re-establishment of piñon or juniper even in the oldest burns (unpublished data). The trees are thought to re-establish only after shrubs have recovered adequately to provide sheltered micro-sites for tree seedlings (Floyd 1982, Miller and Rose 1995, Wangler and Minnich 1996, Chambers 2001). However, we find no trees even in 50-year-old burns in MVNP, where the shrubs are well established, suggesting that additional mechanisms are involved in this area. We are initiating studies to elucidate the reasons for this poor regeneration of trees after fire, but at present we do not fully understand why piñon and juniper are so slow to re-establish after fire. Considering that these are some of the oldest forests in the southwest, and that they support a variety of old-growth fauna and flora (e.g., black-throated gray warbler and *Pedicularis centranthera*), their conservation value should be considered before subjecting them to what may be essentially irreversible changes.

Our second big concern about extensive thinning and burning of Mesa Verde's piñon-juniper forests is related to what we may get in place of young trees. Forests that burned in the 1930s through 1950s were replaced by shrublands, through what appear to be normal successional processes. Indeed, a major reason for the extensive shrublands at the northern end of MVNP is the extensive fires that have occurred periodically during the last two centuries and possibly earlier (Erdman 1970, Floyd et al. 2000). However, the piñon-juniper forests that have burned in the past two decades are being replaced by invasive non-native species, including muskthistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), wild lettuce (*Lactuca serriola*), and the annual mustard *Alyssum minor*. Various post-fire mitigation actions (aerial seeding of native grasses, mechanical removal, herbicides, and bio-control) have been effective in reducing the density of weeds after fire, but none of these techniques has prevented the weeds from becoming major components of the post-fire plant community (unpublished data). The burned areas also appear vulnerable to invasion by cheatgrass (*Bromus tectorum*), which readily carries surface fire. Cheatgrass invasion has caused drastic alteration of fire regimes in much of the northern Great Basin (Miller and Tausch 2001). Cheatgrass expansion in Mesa Verde may be limited by the area's cooler temperatures and higher summer precipitation, compared with the northern Great Basin (R. Tausch, personal communication). However, cheatgrass already dominates some overgrazed rangelands at lower elevations near Mesa Verde, and it is present, though not abundant, in the burned forests of MVNP. If it should increase in the park, it could carry ever more frequent fires into the Park's ancient forests.

Thus, even though mechanical thinning is a very appropriate technique for localized, small-scale protection of sensitive cultural resources, even in this context it will require careful monitoring and weed control. And a more ambitious program of extensive thinning and burning of piñon-juniper forests in MVNP could create an ecological disaster: weeds and more frequent fires could potentially destroy nearly all of the ancient forests within a few decades. Such a loss would be especially tragic if it resulted from well-intentioned but misguided efforts to "restore" the piñon-juniper ecosystem.

Implications for Piñon-Juniper Vegetation Throughout the West

The piñon-juniper "type" covers a vast area in western North America, but has received surprisingly little research attention given its ecological, economic, and aesthetic importance. In particular, the natural range of variability in disturbance regimes and post-disturbance recovery processes is poorly understood. We urgently need a more comprehensive understanding of piñon-juniper dynamics so that we can direct our restoration and fire hazard mitigation efforts towards those stands and landscapes where such efforts are most appropriate. As a first step, we suggest that it is useful to distinguish among three fundamentally different kinds of piñon-juniper stand structures and fire regimes, and to identify the environmental conditions with which each kind is associated (table 1). We regard table 1 as a set of *hypotheses*, and hope that this compilation will stimulate research to critically test these suggested relationships across the full geographic range of piñon-juniper vegetation in western North America.

The first type in table 1 is what we call **piñon-juniper grass savanna**. Vegetation of this kind has been described in northern Mexico (Segura and Snook 1992), Arizona (Jameson 1962, Dwyer and Pieper 1967), and New Mexico (Dick-Peddie 1993:87-93 (cited in Scurlock 1998: 206), C. Allen personal communication), in places where soils are fine-textured, topography is gentle, and summer moisture is relatively abundant. The well-developed grass component formerly carried frequent low-intensity fires that killed or thinned encroaching trees and maintained an open woodland structure. Many of these stands have been altered profoundly in the last century by grazing and fire exclusion, which led to loss of the grass component, abnormal tree densities, and abnormally severe fire behavior when the stands burn today. In such stands, fire hazard mitigation via mechanical thinning and prescribed burning can be linked to a broader goal of ecological restoration, and aggressive treatment of this kind is an urgent need in many places.

The second type in table 1 is what we call **piñon-juniper shrub woodland**. This kind of vegetation has been described in northern and central portions of the Great Basin (Koniak 1985, Tausch and West 1988, Miller et al. 1995, Miller and Tausch 2001) and probably also occurs in many portions of the Colorado Plateau, where precipitation occurs mostly in winter, on deep soils that support an abundant shrub layer (e.g., sagebrush). Shrublands generally support more intense fires than grasslands, and fires in this vegetation type probably always have tended to be stand-replacing. Prior to Euro-American settlement in the mid-1800s, trees would become established during the fire-free intervals that lasted from several years to a few decades, but nearly all of

Table 1—Structure and disturbance dynamics, distribution patterns, and current status of three contrasting types of piñon-juniper communities in western North America: a synthesis and set of hypotheses for further research. HRV = historic range of variability.

	Piñon-Juniper Grass Savanna	Piñon-Juniper Shrub Woodland	Piñon-Juniper Forest
Pre-1900 fire regime	frequent, low-severity, surface fires … carried by grasses	moderately frequent, high-severity, crown fires … carried by shrubs & trees	very infrequent, very high-severity, crown fires … carried by tree crowns
Pre-1900 stand structure	sparse trees, few shrubs, dense grass and other herbs	sparse to moderately dense trees, sparse to very dense shrubs, moderately dense to sparse herbs … all depending on time since last fire	dense trees, sparse to moderately dense shrubs, sparse herbs
Pre-1900 stand dynamics	low tree density and high herbaceous biomass maintained in part by recurrent fire	seral trend from herb to shrub to tree dominance, interrupted periodically by fire which returns a stand to early seral herb dominance	stable/stationary tree age structure and little change in shrub or herbaceous layers during the long intervals without fire … very slow recovery after fire
Post-1900 changes in disturbance regime	reduced fire frequency, great increase in fire severity	reduced fire frequency, small increase in fire severity	little change in fire frequency or fire severity
Post-1900 changes in structure	increasing tree density, decreasing herbaceous biomass	increasing tree density, decreasing shrubs and herbs	little change in tree density or in shrubs and herbs
Overall current status	outside HRV for disturbance regime, structure, & composition	outside HRV for disturbance regime, structure, & composition	still within HRV for disturbance regime, structure, & composition
Implications for restoration	urgent need for active restoration	urgent need for active restoration	no need for restoration … protect instead
Current stand age structure	very old trees (> 300 years) present, but not numerous … young trees (< 150 years) dominate stands	very old trees (> 300 years) absent or rare … young trees (< 150 years) dominate stands	very old trees (> 300 years) numerous … stands with all-aged structure, including old & young trees
Distribution: soil characteristics	deep, fine-textured soils	deep, fine-textured soils	shallow, rocky, or coarse-textured soils
Distribution: precipitation regime	summer peak in precipitation	winter peak in precipitation	variable
Distribution: topographic characteristics	gentle plains and broad valley bottoms, with few barriers to fire spread	gentle plains and broad valley bottoms, with few barriers to fire spread	rugged slopes, canyons, and mesa tops, with many barriers to fire spread
Distribution: adjacent vegetation types	grasslands, ponderosa pine, or other types that burn frequently	grasslands, big sagebrush, or other types that burn frequently	desert scrub, “slickrock,” or other types with sparse herbaceous vegetation that rarely burn
Geographic distribution	most common in northern Mexico, southern New Mexico & Arizona, northern NM, and possibly SE Colorado	most common in the northern and central Great Basin, and the Colorado Plateau	scattered throughout the Colorado Plateau, Great Basin, central Oregon, southern Rocky Mountains, and southern California mountains
Examples	Jameson 1962, Dwyer and Pieper 1967, Segura and Snook 1992, Dick-Peddie 1993, C. Allen personal communication	Tausch et al. 1981, Koniak 1985, Tausch and West 1988, Miller et al. 1995, Miller and Tausch 2001	Tausch et al. 1981, Tress and Klopatek 1987, Kruse and Perry 1995, Wangler and Minnich 1996, Miller et al. 1999, Tausch and Nowak 1999, Floyd et al. 2000, Waichler et al. 2001

the trees would be killed by the next fire. Fire exclusion during the last century has allowed this normal successional process to proceed to the point of tree dominance across large areas where trees were formerly sparse. Fuel loads have become very high and continuous, and some recent fires probably have been larger and more severe than would have occurred before the late 1800s (Miller and Tausch 2001). As with the piñon-juniper-grass savanna, fire hazard mitigation via mechanical thinning and prescribed burning (some of it designed to be stand-replacing) can be linked to a broader goal of ecological restoration in the piñon-juniper shrub woodland, and aggressive treatment of this kind is an urgent need in many places.

The third type in table 1 is what we call **piñon-juniper forest**. This kind of vegetation has been described in scattered locations throughout the Colorado Plateau (Tress and Klopatek 1987, Floyd et al. 2000), the Great Basin (Tausch et al. 1981, Miller et al. 1999, Tausch and Nowak 1999), central Oregon (Waichler et al. 2001), the mountains of southern California (Wangler and Minnich 1996, Minnich and Everett 2001), and in central Arizona (Kruse and Perry 1995). Rather than being associated with a particular soil type and climatic regime, piñon-juniper forest appears to be restricted to an unusual combination of soils and topographic conditions that protect the stands from frequent fires. Soils are too shallow or too coarse-textured to support a continuous cover of grass or shrubs, such that fires tend to spread through a stand only under conditions of extreme drought and wind. The topography is rugged and broken, with cliffs, bare slopes, or other natural barriers that tend to prevent fires from spreading into a stand except under conditions of extreme drought and wind. Thus, this kind of vegetation may escape fire for many centuries and develop striking old-growth characteristics, including a dense, multi-storied canopy with ancient living and dead trees. The old forests of Mesa Verde have these characteristics, and Waichler et al. (2001) describe western juniper forests in central Oregon that contain living trees >1000 years old and dead trees nearly 2000 years old. When fire does occur in old piñon-juniper forest stands, however, it tends to be very severe and stand-replacing. In dramatic contrast to the other two kinds of piñon-juniper vegetation (piñon-juniper grass savanna and piñon-juniper shrub woodland), most of the piñon-juniper forest type probably has *not* been substantially altered by fire exclusion in the last century, and probably is *not* outside its historic range of variability in stand structure, fire frequency, and fire behavior. Thus, these forests generally should *not* be subjected to extensive mechanical thinning or prescribed burning, although fuel reduction may be appropriate in localized areas to protect human lives, property, or other sensitive resources. Such localized fire mitigation treatments should be called just that – they should *not* be called “restoration” and they should acknowledge that relatively rare and ecologically significant old-growth characteristics are being sacrificed to protect other resources and values.

The *piñon-juniper grass savanna* (table 1) differs qualitatively from the other two piñon-juniper types, in that its pre-1900 fire regime was characterized by frequent, low-severity fires, whereas the piñon-juniper shrub woodland and the piñon-juniper forest were dominated by infrequent, high-severity fires. The piñon-juniper shrub woodland had shorter pre-1900 fire intervals than the piñon-juniper forest (mean fire intervals perhaps <100 vs >100 years, respectively), but both types probably followed similar successional trajectories after fire. However, the *piñon-juniper forest* type is distinct from the other two types today, in that its natural fire regime and stand dynamics have been disrupted to a far lesser extent by human activities of the past century.

We emphasize that all of the hypotheses in table 1 need further critical testing. We also point out that, although this paper has focused on piñon-juniper vegetation, its conceptual framework probably is broadly applicable to several other vegetation types. Despite the well-supported need for urgent restoration in many areas (e.g., Covington et al. 1997), we believe that there also are many ecosystems throughout the West in which Twentieth century alterations of community structure and function have been minimal. Systems that probably still remain within their historic range of variability include high-elevation spruce-fir and lodgepole pine forests, which are naturally characterized by infrequent but sometimes large, intense fires (Romme 1982, Veblen this volume). Richard Minnich (personal communication) also suggests that the fire regimes of numerous semi-desert and woodland vegetation types (including blackbrush scrub, Joshua tree woodland, and closed-cone conifer woodlands) have been altered very little in the past century – at least in places where non-native species invasions have not shortened fire intervals substantially. Even some ponderosa pine forests in northern Colorado and the Black Hills may have been altered less by twentieth century fire exclusion than is commonly believed (e.g., Shinneman and Baker 1997). These examples help to underscore the primary message that we hope to convey in this paper: that restoration treatments must be based on a good understanding of local stand history and historic range of variability. Above all, we must avoid the temptation to apply "one-size-fits-all" prescriptions for management.

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