Historic Pinyon and Juniper Woodland Development

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Abstract—Climate change influences the ecological processes driving regional vegetation change. With the paleoecological and geomorphological perspective of Holocene history, it is apparent that each vegetation change interacting with the environment sets the conditions for the next vegetation change. Because of interactions between vegetation change and environment, particularly for nontree species, pinyon-juniper woodlands of the Great Basin represent multiple communities and ecosystems. Multiple successional stages occur in repetitive, but constantly changing, mosaics across the landscape. Tree expansion over the last 150 years has set up the conditions for the possible decline in woodland area from large fires over the next 150 years. To manage these woodlands, better definitions of what is woodland versus other communities are needed that account for their long-term patterns of change and interacting cycles of disturbance and succession.

To understand the dynamics of Great Basin woodlands, knowledge of their development is necessary. At the core of current and historic woodland development is climate. Through the control of energy and water, climate is the most important factor in the occurrence and distribution of ecosystems and communities (Bailey and others 1994). Land form is the major modifier of climate. Climate change and its topographic modifications influence key ecological processes, driving both local and regional vegetation changes (Betancourt and others 1993; Woolfenden 1996). These changes cascade up and down between scales of space and time. History shows us that about the only thing we can predict about climate is that it will change. It is when and how it will change, and how communities will respond, that we largely do not know.

The combination of available paleobotanical proxy data from woodrat midden and pollen records from the late Pleistocene through the Holocene reveals that individualistic species responses to climate change have driven considerable vegetation change (Betancourt 1996; Betancourt and others 1990; Nowak and others 1994a; Tausch and others 1993; VanDevender and Spaulding 1979; Woolfenden 1996). These records are the most detailed for the last 4,000 to 5,000 years (Wigand and others 1995). Past environmental changes can also equal or exceed the importance of the current environmental conditions in determining the growth, development, and competitive and successional dynamics of current communities (Millar 1996, Woolfenden 1996). Each change in the vegetation, in turn, sets up the community conditions that interact with the next environmental change to set the direction and magnitude of the next vegetation change. Without an understanding of the history of past change, it is not fully possible to adequately explain current woodland patterns or ongoing changes. This is particularly true for the last 5,000 years and involves a shift in our perception of time to scales more appropriate to how Great Basin ecosystems function because functions change as an ecosystems respond to changing climate (Millar 1997, Tausch 1996).

With climate it is often the effects of its variability, and particularly its extremes, not the means, that have the most influence on community changes (Betancourt and others 1993). The types, frequencies of occurrence, outcomes of extreme events, and how vegetation responds vary with location across the Great Basin. Biological and ecological changes resulting from climatic variation have been studied primarily at the organismic and community level, and more rarely, at the ecosystem or regional scale (Betancourt and others 1993). Better understanding of historical climatic and community changes, and present ecosystem influences, at regional scales is central to successful ecosystem management.

On geologic time scales, most of the Great Basin is a region or zone of transition between northern coniferous forests and southern deserts that has shifted hundreds miles north and south during each glacial cycle. As community composition has continually changed, both between and within glacial cycles, these changes were modified by the topography of the region. There have been major shifts through time in the trees' location, their abundance, and their relative contribution to communities.

Historical Changes

Historical woodland development through the Holocene can be divided into 10 time periods. These periods have been based primarily on information provided by Wigand and others (1995) from the analysis of pollen data. I have modified the number and timing for these periods based on additional information from geomorphic studies of the Columbia River system (Chatters and Hoover 1992); from Betancourt and others (1993), from west and central Nevada woodrat midden (Tausch and Nowak 1998) and geomorphic and community studies (Chambers and others 1998), and from studies in the Sierra Nevada Mountains (Millar 1996, Woolfenden 1996).

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Pleistocene: More Than 11,500 Years BP

Semiarid woodlands were about 1,000 m lower in elevation and 500 to 600 km further south at the last glacial maximum about 18,000 years BP (Spaulding 1985; VanDevender and Spaulding 1979; Wells 1983; Wigand and others 1995; Woolfenden 1996). Woodlands during the Pleistocene were largely limber pine, bristlecone pine, and whitebark pine, and were largely open with the understory communities dominating the cover. The dense pinyon-juniper woodlands present today were mostly absent from the Great Basin until after about 10,000 years BP (Thompson 1990; Woolfenden 1996). Both western and Utah juniper were present in the Pleistocene but were apparently scattered around lower elevation areas of the Great Basin protected by topographically modified climate (Nowak and others 1994a; Thompson and others 1986; Wigand and others 1995). Pinyon was restricted to the valley floors and mountain slopes at the southern edge of the Great Basin (Nowak and others 1994b; Thompson 1990; Woolfenden 1996). Toward the end of this period, pluvial lake levels were dropping and many genera of large herbivores were becoming extinct (Betancourt and others 1993).

Early Holocene: 11,500 to 8,000 Years BP

The climatic conditions of the early Holocene were very different than in the previous 100,000 years of the Pleistocene. Climate during the Holocene, however, has also never been constant long enough for any strong interspecies relationships to develop. In southern Nevada, pinyon-juniper woodlands replaced limber pine at intermediate elevations as temperatures warmed (Thompson 1990; Wells 1983; Wigand and others 1995). This time period also saw the beginnings of the northward movement of pinyon into the Great Basin and expansion of juniper out of its more northerly refugia (Nowak and others 1994a,b; Woolfenden 1996). During this early Holocene period, pinyon was apparently a minor component of the juniper dominated woodlands (Spaulding 1985; Thompson 1990; Wigand and others 1995). The ability of both tree genera to dominate a site increased in the Holocene, especially in the absence of disturbance such as fire. The species composition of all communities continued to change over this period of the Holocene (Nowak and others 1994a,b).

Mid-Holocene: 8,000 to 5,500 Years BP

This was the warmest part of the Holocene. In the mid-Holocene the woodlands and upper tree lines were 300 to 500 m higher in elevation than today (Jennings and Elliot-Fisk 1993; Wigand and others 1995; Woolfenden 1996). Lake Tahoe was also 10 to 15 m below its geologic rim. Trunks of trees that established along the lower shoreline during this period, and were then drowned when the lake level rose, still exist in the Lake (Furgurson and Mobley 1992; Lindstrom 1990). Many desert shrub species in the Great Basin increased in abundance (Mehringer and Wigand 1990; Tausch and Nowak 1998; Wigand 1987; Wigand and others 1995). Some expansion in the range of the woodlands also occurred.

Early Late Holocene: 5,500 to 4,500 Years BP

A gradual but erratic increase in precipitation occurred following the mid-Holocene (Chatters and Hoover 1992; Davis 1982; Mehringer 1987; Wigand 1987), and there was additional migration of both juniper and pinyon northward into the Great Basin. This period also had the first evidence of western juniper in northeastern California and eastern Oregon (Mehringer and Wigand 1990; Miller and Wigand 1994; Wigand and others 1995). The range in woodland distribution continued to slowly increase during this time period.

Neoglacial: 4,500 to 2,500 Years BP

The Neoglacial period was much cooler and wetter than the mid-Holocene (Davis 1982; Grayson 1993; Wigand 1987; Woolfenden 1996). Western juniper expansion continued into the northernmost Great Basin (Wigand 1987), and this expansion accelerated in the middle of the period. Much of the remainder of the pinyon and juniper range expansion in Nevada and Utah occurred during this period and was accompanied by a reduction in desert shrub vegetation. Pinyon abundance increased relative to that of juniper (Thompson and Kautz 1983). The increase in range for the trees was largely at mid and low elevations (Mehringer and Wigand 1990). Woodland extent and density at mid to low elevations was possibly equal to that present today (Kinney 1996; Wigand and others 1995, Wigand 1998). Large increases in grass are associated with evidence of periodically occurring fire. Upper tree line lowered in elevation in the White Mountains (LaMarche 1973), in the Sierra Nevada Mountains (Scuderi 1987), and in the Canadian Rockies (Luckman 1990). The Great Salt Lake Desert apparently flooded during the latter part of the period (Mehringer 1977; Thompson and Kautz 1983), and Mono Lake reached its highest level since the early Holocene (Stine 1990).

Post-Neoglacial Drought: 2,500 to 1,300 Years BP

Following the Neoglacial there was a significant drop in precipitation, but temperatures apparently remained relatively cool (Chatters and Hoover 1992). Coinciding with this severe drought was a region wide decrease in woodland density and extent and increasing dominance of desert shrub vegetation that was dominated by Chenopods, particularly greasewood (Wigand and others 1995). Juniper declined less than pinyon (Thompson and Kautz 1983). Major geomorphic changes from floodplain construction and rapid alluvial fan development occurred to the north (Chatters and Hoover 1992). Similar alluvial fan building and aggradation of valley floors, along with reductions in plant diversity, occurred in central Nevada during this period (Chambers and others 1998).

Medieval Warm Period: 1,300 to 800 Years BP

This period had warmer temperatures (Grove and Switsur 1994) and an increase in precipitation from the previous period, but also saw a shift in precipitation with a greater proportion coming in late spring and early summer (Davis 1994; Leavitt 1994). Winter conditions may have also been milder (Wigand and others 1995), reducing snowpack and lake and stream levels (Born 1972; Stine 1994; Woolfenden 1996). These climate changes resulted in an increase in grass abundance (Wigand and Nowak 1992), and the presence of buffalo (Agenbroad 1978; Butler 1978; Schroedl 1973). About 1,000 years BP, there was a brief juniper woodland expansion in the north and the maximum dominance of pinyon was centered about 1,200 years BP (Wigand and others 1995). The Fremont Indian Culture, with its corn-based agriculture, occurred in many areas of the eastern Great Basin at this time.

800 to 550 Years BP

This is an unnamed dry period that is reflected in tree ring studies (Holmes and others 1986; Woolfenden 1996), and the reduction of lake levels (Stine 1990). It was also accompanied by cool temperatures and again had a decline in tree dominance (Wigand 1987; Wigand and Rose 1990), an increase in desert shrubs, and an increase in fire in some locations (Wigand and others 1995). Some of the previous extent in woodland distribution was also lost. The Fremont Indian Culture disappeared from the Great Basin during this time period.

Little Ice Age: 550 to 150 Years BP

The Little Ice Age was a cooler and initially wetter period during which glacial advances, possibly the largest of the Holocene, occurred (Naftz and others 1996; Woolfenden 1996). Upper tree lines were the lowest of the last 7,000 years in the Sierra Nevada and growing season temperatures were low until about 1850 (Stine 1996) A gradual increase in dominance and range of the woodlands began following the decline that occurred following the Neoglacial (Mehringer and Wigand 1990). This increase included western juniper in the north and primarily pinyon in the rest of the Great Basin (Nowak and others 1994a,b). This expansion in range, although not so much in density, was well underway when the first Europeans arrived (Wigand and others 1995).

We have some idea of the plant communities of the last 400 to 500 years of the Little Ice Age because it is the vegetation that was in the Great Basin when the first European explorers crossed through it. For climatic periods prior to the Little Ice Age, we have much less information on Great Basin communities, but they were different (Woolfenden 1996). Species presence information from middens (Tausch and Nowak 1998) tell us that during the Little Ice Age, the species composition of many Great Basin riparian communities was at least as diverse, particularly in herbaceous species, as in any other wetter period of the Holocene. These Little Ice Age communities were also different than what is present at the same locations today. Even though the Little Ice Age represents our best understanding of past vegetation, major gaps in knowledge are still present.

Despite a similar extent in woodland distribution, tree dominance patterns within that range were very different during the Little Ice Age compared to what is present today. Many sources of evidence, including relict woodlands, tree age-class ratios, fire scars, and historic documents (Gruell, this proceedings) indicate that particularly during the drier (Woolfenden 1996) part of the Little Ice Age woodlands were more open with the trees either found in savannas or confined to scattered fire-protected sites (Wigand and others 1995).

Throughout the Little Ice Age, the vegetation of the Great Basin has been represented by a matrix of nontree-dominated communities with pockets of woodlands and individual trees scattered through it. This appears to have been a dynamic equilibrium maintained by many factors including a cold, somewhat dry climate (Woolfenden 1996) and a higher fire frequency. These high fire frequencies did not occur everywhere. Maybe as much as one-fourth of the present woodlands fire return intervals may have been in centuries, rather than decades.

Overall, the geographic range of woodland trees during the Little Ice Age was close to what now exists, but the abundance within those areas was less. Interestingly, this is a pattern that is typically seen during the early stages of invasion by a new species. The advance does not occur as a solid front but first occurs as pockets or small populations establishing in scattered locations across the landscape. The scattered advance is then followed by a filling-in of the intervening spaces and eventual dominance of the area. The processes of this last step is what has been occurring in the woodlands since the end of the Little Ice Age.

Recent: 150 Years BP to the Present

The beginning of this period coincides with several important changes in the environment that occurred simultaneously. The most important of these changes were (1) cessation of the hunting, gathering, and burning by populations of indigenous people that had occurred during the Little Ice Age (Creque 1996), (2) a change in climate with rising temperatures (Ghil and Vautgard 1991; Woolfenden 1996), (3) the period of heaviest livestock use of the region following European settlement with its effects on plant competition and fire potential, (4) a decrease in wildfire frequency along with increasing wildfire suppression efforts in the latter part of the period (Bunting 1994), (5) increasing atmospheric CO_2 levels that are changing community competitive interactions (Farquhar 1997) and favoring the dominance of large woody perennials (Polley and others 1996), and (6) an increasing availability of nitrogen from air pollution.

Whatever the combination of factors were that had maintained the Little Ice Age prevalence of a scattered distribution of trees, they changed with the mid nineteenth century end of the Little Ice Age. With those changes, the ability of the trees to successfully establish into and dominate many new communities increased. Movement of woodlands into higher elevations, as well as to lower elevations, has accompanied these recent changes (Blackburn and Tueller 1970;

Miller and Rose 1995; Tausch and others 1981; West 1984; Wigand and others 1995). Dense, tree-dominated woodlands are now possibly as much as three times as common as at the end of the Little Ice Age (Tausch and others 1981).

Key to this expansion is the ability of the tree species to establish into many new communities (Chambers and others, this proceedings). They clearly have effective methods of seed dispersal that results in a sufficient number ending up in sites suitable for germination. Once germinated, many of the tree seedlings become established into the invaded communities and successfully compete with, and eventually dominate, the other plant species present (Nowak and others, this proceedings). With their longevity topping 500 years, the last ice advance ended only a few score generations ago for both pinyon and juniper (Betancourt and others 1993). This implies that the increased establishment rate is not a new adaptation by the trees, but the result of recent environmental changes.

For the last several thousand years, woodlands throughout the southwest have also been significantly affected by direct human manipulation (Denevan 1992; Kohler 1992) and the role of humans in past woodland dynamics must be considered (Betancourt and others 1993). The major differences between prehistoric management, and management occurring following European settlement, have been important contributors to the recent changes in the distribution, structure, and composition of the woodlands.

Current Situation

Knowledge of woodland history helps in understanding the woodlands of today in many ways. About half of the plant taxa present today in the Great Basin are found scattered through the woodrat midden and pollen paleorecord of the last 30,000 plus years (Thompson 1990; Nowak and others 1994a,b). All the associations of plant species with each other, and with the communities represented, have changed considerably and continuously. This is also true over the last 4,000 to 6,000 years and has included the distribution and density of both pinyon and juniper. These changes have occurred too frequently for clear links between soils and vegetation to form on a regional basis in Great Basin pinyon-juniper woodlands (West and others 1998).

Recent management activities have been largely based on a view that woodlands are the matrix, and imbedded within it are all the species assemblages found in the understory. This is a view based on what has been visible over only the last half to three-quarters of a century. With the full perspective of Holocene history, plant species found in the understory of today's woodlands, and in the majority of locations, have generally existed in a variety of shrub and grass-dominated communities for far longer periods of time than they have in tree-dominated communities. Because tree-dominated woodlands have been much more temporary or transitory, it is the nontree-dominated communities that are the matrix within which are imbedded pockets of woodlands of various successional stages.

Despite the similarity in appearance, pinyon-juniper woodlands of the Great Basin do not represent a single natural geographic division or natural land type. Both pinyon and juniper have large ecological amplitudes. Species of both genera can be found growing with other species ranging from Joshua trees at the lower elevations to limber pine and bristlecone pine at the upper elevations. Because pinyon-juniper woodlands of the Great Basin represent such a large area, they are an assemblage of many ecosystems at more regional and local levels that are dominated by one or more of the woodland tree species.

Many of the individual shrub taxa present in Great Basin communities can also have wide ecological amplitudes (West and others 1978; West 1984; West and others 1998). Although not as large as those for the trees, their range of occurrence still must be considered as reflecting real differences in broad-scale environments across the region that could be important for management. The same is true for many dominant perennial grasses. If the trees were not present, the Great Basin area now covered by woodlands would be an array of many different communities. This is consistent with the size of the region, the range of environmental conditions, and the species diversity present over the Great Basin.

One contribution to our lack of recognition of the shrub-grass communities in tree-dominated areas probably comes from a community interpretation where disturbance is something abnormal and external to, or separate from, the community. Although they are suppressed by the dominance of the trees, these communities are still largely there. All the environmental differences their presence represents are still important. The understory is central to the understanding of the ecology and ecosystem function of a site. This is probably why there are no species clearly identified with tree-dominated pinyon-juniper woodlands as can occur in many more mesic forest types. All other species present in the woodlands were also part of the sagebrush-grass dominated communities that preceded the trees. The trees can be a component of many communities, but history shows their dominance only represents one possible stage in the successional cycles of those communities. Thus, for most areas, and appropriate time scales, dominance by trees has been transitory.

The location in the basin, the topography, the soils, and the climate that dictates the differences between these communities still influence how the sites respond to changes, even when tree-dominated. The outcome of management activities, the affects of introduced exotics, and the types and successional patterns following fire are generally independent of the appearance of similarity in the structure in the tree layer. Understory community differences are more indicative of finer scale environmental controls and carry more information on how a specific site will respond if the trees are removed by some disturbance.

Additional community variation occurs because individual mountain ranges in the Great Basin are not independent. Their relative sizes and, in particular, their orientations to each other significantly affect each other's environment as they interact with storm system development and movement. These interactions between mountain ranges also affect how climate and vegetation change with position on a mountain. The environment and vegetation found at a specific location on one mountain can vary depending on the size, shape, and orientation of adjacent mountains. Interactions between altitude and physiographic position can also modify the effects of both latitudinal and longitudinal zonation. Because of the general north-south orientation, some very long ranges can encompass a considerable range of environments.

The same abiotic component may have a different influence in one species mix than in another, and in one location than in another, both between and within mountain ranges. Changes in the surrounding landscape can drive changes at the site level even if that site has seen minimal change. All interact through time to affect and drive future community changes. The level of influence that topography, soils, and environment have on ecosystems in the Great Basin varies with latitude and with altitude in complex interactions.

Within the context of the entire Great Basin, these variations are present as repetitive mosaics across the landscape. This complexity can be both increased and obscured by the many successional stages of each community. For example, long-term, self-reproducing woodland climax states have not existed except in very localized, specialized situations. They have been the exception. Functioning woodland and non woodland ecosystems and their respective successional stages have been connected on a landscape basis at multiple levels in complex heterogenous ways. Much of this variation is now being concealed by tree dominance. In the future, this complexity of communities and their interconnections will not be exact repeats of what occurred in the past (presettlement or Little Ice Age) , particularly because of ongoing climate change, the introduction of exotic annuals, and the increasing atmospheric CO_2. Attempts by management to restore those communities will usually not be successful (Millar 1997, Tausch 1996). How large an area is, its position on the landscape, the larger context of the associated communities in the surrounding the area, the presence of introduced species, and the potential interactions with those systems all need to be considered. Because no system exists in isolation, how a particular system responds to management is determined in many ways by its relationships with those systems that surround it.

Future Trends

The next step is to look ahead to what past trends and present conditions mean for future trends. There are direct implications in the history of long-term, ongoing changes in the successional processes of sites dominated by pinyon and juniper that are important for management. Most of what has been written about successional changes in pinyon-juniper dominated areas has the stated, or more often unstated, assumption that all sites where trees become established will end up tree-dominated and then stay that way. However, this assumes a stable climate and it ignores long-term historic fire patterns which have not been constant, but very different for different for past time periods preceding the Little Ice Age. These patterns can be expected to change again into the future as the Little Ice Age is left further behind. For example, as growth and successional patterns in the woodlands have changed over the last several decades, their susceptibility to fire, and the types of fire that occur, has changed. Evidence is now accumulating that the recent tree expansion and the successional changes involved are setting up the conditions for a new set of changes driven by large, stand-replacing crown fires that will take place over the next 150 plus years (Gruell, this proceedings; Tausch, this proceedings).

With the expansion of the woodlands, and an increased density and crown size of pinyon and juniper, distances between individual tree crowns have been decreasing. The result has been a steady increase in the evenness of crown fuels across larger and larger areas, particularly on more productive sites formerly dominated by sagebrush-grass communities. From the increase in crown fuels comes a steadily increasing risk of large crown fires that can rapidly cover those large areas. Such fires appear to be increasing in frequency, as well as size, as more and more woodland area matures to this condition and the contiguous areas involved become larger (Gruell this proceedings). Under the right conditions, many thousands of acres of mature woodland can now burn in a day.

In the woodland areas that were savannas during the Little Ice Age, the older trees, particularly juniper, have sometimes been observed to have several fire scars (Gruell, this proceedings). With the tree density increases of the last century, many of these former savanna sites often have an ingrowth of a high density of increasingly larger, younger trees, usually pinyon. Heat levels and flame lengths now being generated by these denser tree stands, particularly in areas with deeper soils, permit fire to carry up through many of the more open woodlands on the steeper adjacent slopes. These are some of the locations where fires often did not go when fire return intervals were more frequent. After more than a century of no fire, when fires do occur in these areas, they generally leave no surviving trees. This is the outcome from the greatly increased fire intensity that follows over a century of climate change, settlement impact, and tree expansion in the presence of a reduced fire frequency.

A large part of the historic establishment appears to have taken place in areas with deeper, more productive soils . These are sites in canyon bottoms and swales, and on alluvial fans where the available evidence appears to indicate that during the Little Ice Age, tree establishment and growth never got very far before they were removed by fire. Now, however, as a result of successful tree establishment, large areas of deeper soils are becoming dominated by trees. As a result, there are probably more acres of woodland, and a greater proportion of the total woodland area, now at risk for crown fire than at any time since the Neoglacial, and possibly longer. The amount of area in this condition is also steadily increasing.

The worst-case outcome of these changing community and associated fire patterns is that larger and larger areas of woodland could potentially cease to exist as more of the woodland area in the Great Basin becomes at risk and then burns. Currently, the area of woodland reaching tree dominance each year exceeds the amount burned. This may not long be the case, and the next 150 years could eventually see the area of the Great Basin that is dominated by woodlands decline. They will, in turn, be replaced by new shrub-perennial grass-dominated communities, or in the worse case, exotic annual-dominated communities.

Local topography, soils, associated species, environmental conditions, and disturbance types and frequencies can likely cause major changes in the way sites respond to a disturbance such as fire. Even on the more fire-protected types of areas, the relative proportions of various seral stages can be much different than what was present during the higher fire return frequencies that existed during the Little Ice Age. Control of reestablishment patterns after fire can be dependent on the composition of the understory community present prior to the fire. Clearly pre-identification of these areas by the understory communities and their different functional relationships will be necessary for determining proper management actions following fire.

Because of the extensive area of the Great Basin now dominated by trees, only on a small portion will it be possible to take management action to alter these trends. In the majority of the existing and future tree-dominated areas, it will be necessary to develop management strategies to deal with the results that follow these large fires. In burned areas where native shrub and perennial grass-dominated communities return following fires, the return of the woodlands is possible. Where the woodlands are being replaced following fire by communities dominated by exotic annuals, the return of the woodland could take several centuries or longer.

Despite the changes, there are areas that have been in the past, that are, and that are likely to remain in the future, generally immune to fire. These sites result in stands of trees that are more open or scattered and have a more sparse understory, and generally support a preponderance of the existing old-growth woodlands (Miller and others, this proceedings). In these stands, successional processes are often an internal patch dynamics type of regeneration.

The balance between tree and non tree-dominated communities has always been dynamic. Each has always been present and each has always had an important ecosystem role. Heavy dominance by one or the other, but particularly a monoculture of the trees, seems to have always been an unstable situation. We are only beginning to recognize the full complexity of the large array of communities that comprise Great Basin woodlands. Relatively little is known about the basics of that complexity, the range of future changes in woodland ecology, or of the range of possible management options that are likely in the future as conditions continue to change.

Composition changes, community type changes, and changes in species locations were dynamic throughout the Holocene. The pattern of woodland distribution and successional stage has never been random, but differed with the size, intensity, and frequency of fire interacting with differences in environment, topography, and soils. The higher fire frequencies of the past were also not uniform over time or across the landscape (Woolfenden 1996). But despite these continual disturbance and composition changes, a general pattern of a mosaic of variously interconnected communities and successional stages across the landscape appears to have remained. This is a dynamic state that Great Basin ecosystems appear to often develop, and which our management activities have often disrupted or simplified (Tausch, this proceedings). When this disruption or simplification of large areas of Great Basin ecosystems occurs, be it upland or riparian, unintended changes and consequences often result. When large-scale increases in community homogeneity happen, ecosystem function appears to be restricted or limited by the loss of the multiple interconnections between, and a reduction in, the range of communities and successional stages that are present. Usually, these unintended changes from ecosystem simplification, and the larger areas potentially affected by any disturbance, appear to be detrimental to long-term management goals.

Ecosystems occur at multiple levels of integration and nestedness. To be effective management must also occur at multiple levels of nested geographic scales. It requires awareness of landscape-scale non equilibrium dynamics (Betancourt and others 1993; Sprugel 1991; Tausch and others 1993) where both slow localized successional and large disturbance-related episodic changes in community composition and dynamics are present. Because ecosystems are spatially arranged and vertically nested, with complex relationships among the hierarchies, we need to provide a synthesis of information based on the interrelationships across each area or region of a landscape. In acquiring this information, it must be remembered that ecosystem boundaries are more open in the Great Basin than almost anywhere else (Bailey and others 1994).

To be successful, management in these woodlands needs to be on a landscape to regional scale that considers the heterogeneous, non equilibrium mix of disturbance and recovery situations they include. Central to this management of such heterogenous mixing of communities in the Great Basin will be a clarification of the definition of what is woodland what is not, where woodland is dominant and will remain so, and where it either is not or will not remain dominant. Such a revised definition needs to include the range of disturbance types and disturbance frequencies and how they change between communities and over time as environmental conditions change. It will be necessary, for example, to identify areas where the more frequent fires did or did not go in the past. To do this it will be necessary to identify the environment (particularly climate), topography, and community characteristics that have controlled the past fire patterns and frequencies. Some objective way of resolving definitions of woodland versus other communities that is dynamic and accounts for longer term patterns and cycles of disturbance needs to be found. Finally, because many aspects of future climate and plant community compositions and dynamics will be both new and unknown (Millar 1997, Tausch 1996), successful management can only occur by adequately monitoring the changes and responding accordingly.

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