Old-Growth Juniper and Pinyon Woodlands

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Abstract—The forestry, rangeland, and ecology communities have generally overlooked semi-arid old-growth woodlands. These ancient woodlands have some of the oldest trees in the Intermountain region, exceeding ages of 1,000 years. Old-growth are typically structurally more complex than postsettlement woodlands adding biological diversity to the landscape and providing an important source of habitat for many organisms. Mapping and inventorying old-growth woodlands are extremely important in developing management and land-use plans. Information is also needed on structure, function, gap dynamics, tree mortality, and succession following disturbance.

Old-growth juniper and pinyon woodlands in the West generally do not fit the typical image most people have of old-growth coniferous forests. In a recent symposium in the southwest, Swetnam and Brown (1992) stated; "Many peoples image of old-growth are the stately monarch trees with shafts of sunlight streaming down through tall, dense canopies. However, in the southwest, many of the old-growth stands do not fit this stereotype." Some of the oldest stands throughout the Intermountain West are low statured open semiarid woodlands composed of such species as bristlecone pine (Pinus longaeva), limber pine (P. flexilis), juniper (Juniperus sp.) and pinyon (Pinus sp.). Old woodlands usually differ in structure and function from postsettlement woodlands thus adding diversity at the community and landscape levels. Although considerable research has been conducted in old-growth for other conifer species, work addressing old-growth in juniper and pinyon woodlands is very limited. In addition, the concern over the rapid expansion of juniper and pinyon woodlands during this century has overshadowed the presence and values of these pre settlement woodlands. Ancient woodlands are frequently overlooked in management plans and inventories where they are often lumped with postsettlement stands. Wildlife studies conducted in juniper or pinyon-juniper woodlands have also generally not separated post from presettlement stands.


Old-Growth: A Generic Description

Old-growth work in the northwest United States has been focused on the more mesic heavily forested areas. In the Great Basin old-growth work is almost non-existent. The forestry, rangeland, and ecology communities have generally overlooked semi-arid old-growth woodlands. What is known about old-growth juniper and pinyon comes largely from anecdotal mentions in the literature, noting the occurrence of presettlement trees on rimrock, low sagebrush tablelands, and other fire resistant areas. Several attempts have been made to describe pinyon-juniper old-growth (Popp and others 1992, Mehl 1992) but little actual work has been conducted in these stands.

Old-growth forests are unique from younger forests in both structure and function (Mehl 1992, Kaufmann and others 1992). The U.S. Forest Service defines old-growth forests generally as ecosystems distinguished by old trees and related structural attributes. Their definition states that old-growth encompasses the later stages of stand development that typically differ from earlier stages in a variety of characteristics which may include tree size, accumulations of large dead woody material, number of canopy layers, species composition, and ecosystem function (USDA Forest Service 1993). Structural features important in characterizing old-growth in the Intermountain West vary widely across forest type, climate, site conditions, and disturbance regimes (Kaufmann and others 1992).

Functionally, ecological interrelationships in old-growth forests are more complex than younger forests (Mair 1992). Old-growth ecosystems are characterized by having a component of old trees that have a biochemistry of secondary metabolic products, some of which may provide high resistance to insects and disease. Relative to younger trees, the oldest trees have approached their maximum size and have
nearly ceased height growth, and the tree crowns may be in various stages of decline. On average, mortality and respiration offset the rate of production of new biomass, and net productivity of the ecosystem approaches zero (Kaufmann 1992).

Old-growth detrital food webs are usually more complex than found in earlier stages of stand development. Decay processes, some of which may involve nitrogen fixation, occur in snags, down logs, and dead portions of living trees. Arthropods and other microzoans occur in the forest litter and within decaying stems of old living trees, whose decay may involve nitrogen fixation. There may be mixed communities of cryptograms and associated invertebrates on tree branches and stems. The food web further includes fungal-small mammal relationships (Moir 1992).

Structural and functional complexity of old-growth ecosystems increases their biological value. Important values of these old stands include habitat for a variety of plant and animal species, climate reconstruction, pools of genetic resources (Kaufmann and others 1992), and wood for dating archeological sites. In addition, aesthetic and spiritual values are frequently mentioned in relation to old-growth stands.

Old-Growth Juniper and Pinyon Woodlands

Old-growth characteristics listed above may not directly apply to semi-arid woodlands in the Intermountain West. However, like other conifer communities, old-growth semi-arid woodlands should be defined on the basis of tree age, and stand structure and function. Nonetheless little to no information is available on stand structure, rates of mortality and decomposition, gap dynamics, thinning, food webs, and nitrogen fixation for old-growth juniper and pinyon woodlands. Information relating old-growth woodlands to wildlife values is also limited since very few wildlife studies have described stand structure or separated old-growth from postsettlement woodlands.

Single Tree Perspective

A frequently asked question is: “What is an old-growth juniper or pine?” One age separation may be made on the basis of tree establishment occurring prior to and following Eurasian settlement. In the central and northern portions of the Great Basin, the rapid expansion of western, Utah juniper, and pinyon coincided with Eurasian settlement in the late 1860s and 1870s (Burkhardt and Tisdale 1976, Tausch and others 1981, Young and Evans 1981, Tausch and West 1988, Miller and Rose 1995). Woodland expansion for much of this region began in the 1870s. Based on the chronology of past events throughout the northern Great Basin we would define postsettlement trees as having established sometime after 1870 and preschoolment trees establishing prior to 1870. However, old-growth can also be based on morphological characteristics of the tree, which develop slowly over time. As juniper and pinyon age, canopy morphology shifts from cone shaped to a rounded top. As age advances the tree may also develop a combination of the following characteristics: broad nonsymmetric tops, deeply furrowed bark (primarily juniper), twisted trunks or branches, dead branches and spike tops, large lower limbs, trunks containing narrow strips of cambium (strip-bark) (mostly in juniper), hollow trunks (rare in pinyon), large trunk diameters relative to tree height (in western juniper), and branches covered with a bright yellow green lichen (Letharia sp.) in both juniper and pinyon. Tree size, particularly height, is dependent upon site characteristics.

Tree age within the old-growth stand is an important index in assessing the stage of old-growth development (Swetnam and Brown 1992). Assessing stand age also determines the rarity or uniqueness of the woodland. Western juniper can easily attain ages exceeding 1,000 years (Miller unpublished data). The oldest living western juniper (Juniperus occidentalis ssp. occidentalis) currently reported is just over 1,600 years old. However, many old trees cannot be aged due to rotten trunk centers. Utah juniper can also exceed 1,000 years in age and pinyon can exceed 600 years (Tausch and others 1981).

A Woodland Perspective

At the community level, old-growth juniper woodlands should be described on the basis of the presence of old trees and structural characteristics such as standing and down dead, decadent living trees, cavities, and branches covered with lichens. The U.S. Forest Service definition based on such community structure characteristics has been applied to pinyon-juniper by the Rocky Mountain Region (Mehl 1992) and the Southwestern Region (Popp and others 1992) of the Forest Service. The resulting minimum structural attributes for this procedure are shown in table 1. In a narrative description, Popp and others (1992) stated, pinyon-juniper stands may consist of all ages or one age. Dominant trees are often 400 years old. Trees 800 to 1000 years old have been recorded. The trees can be single stemmed or have a sprawling multi-stemmed character. A few stands may have closed canopies with single or both tree species, with little or no understory, but most stands are open-grown with widely scattered trees of one or both species with a wide variety of understory vegetation. The pinyon-juniper type is climax, woodlands shifting to grasslands or shrub steppe only following disturbance, such as fire (Mehl 1992). In the absence of disturbance these communities will eventually return to pinyon-juniper woodland.

The above characteristics describing old-growth pinyon and juniper woodlands in the southwest and southern Rocky Mountains provide a good first attempt but are too generic and limited to appropriately fit all old-growth woodlands in the Intermountain West. Franklin and Spies (1986) state; a single set of attributes and quantities cannot classify all stands as either old or young. Old-growth juniper and pinyon woodlands occur across a wide range of parent materials, soils, aspect, slope, elevation, climate, and disturbance regimes (Kaufmann and others 1992). To account for some of this variation old-growth juniper and pinyon woodlands may be characterized into old-growth, woodland types. Woodland types would be separated out by such factors as ecological province, major landscape features including geology, parent materials, and landform. In addition to these physical parameters structural characteristics would also be used to classify old-growth woodland types.
Table 1—Minimum structural attributes used by the U.S. Forest Service in both the southern Rocky Mountain and southwestern regions to identify old-growth pinyon-juniper stands (derived from Mehl 1992 and Popp and others 1992).

<table>
<thead>
<tr>
<th>Live Trees</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree per acre</td>
<td>30</td>
</tr>
<tr>
<td>Diameter at root collar</td>
<td>12 inches, with variation in diameter</td>
</tr>
<tr>
<td>Age</td>
<td>200 years</td>
</tr>
<tr>
<td>Decadence present bole or root rot</td>
<td>Yes, dead, broken, or deformed tops and/or</td>
</tr>
<tr>
<td>Number of tree canopies</td>
<td>Single story</td>
</tr>
<tr>
<td>Other</td>
<td>Upper canopy trees are slow growing</td>
</tr>
<tr>
<td></td>
<td>Variation in tree diameter</td>
</tr>
<tr>
<td></td>
<td>Basal area of 23 square ft/acre</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dead Trees</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td></td>
</tr>
<tr>
<td>Number per acre</td>
<td>1</td>
</tr>
<tr>
<td>Diameter at root collar</td>
<td>10 inches</td>
</tr>
<tr>
<td>Down</td>
<td></td>
</tr>
<tr>
<td>Pieces</td>
<td>2 per acre (10 ft long segments)</td>
</tr>
<tr>
<td>Diameter</td>
<td>10 inches</td>
</tr>
<tr>
<td>Canopy closure</td>
<td></td>
</tr>
<tr>
<td>Total canopy cover</td>
<td>35 percent</td>
</tr>
</tbody>
</table>

Ecological provinces can provide a first separation in the classification of old-growth woodlands accounting for some of the heterogeneity across the Intermountain West. From eastern Oregon to southeast Nevada and into Utah rainfall distribution varies from almost all of it arriving in the winter to where up to a third or more of the annual precipitation comes in the summer. From north to south the environmental gradient varies from the cold deserts surrounded by coniferous forests in Oregon and Idaho to mountain slopes in the south that are surrounded by the Mojave Desert. The combination of these environmental gradients with the basin and range topography of the Great Basin, creates considerable environmental variation (West and others 1978). This environmental variation has been divided into ecological provinces (fig. 1) based on the floristic regions of Cronquist and others (1972), the Ecoregions described by Bailey and others (1980 and 1994), and soil-plant relationships in Oregon described by Anderson (1956). Ecological provinces differ somewhat in climate, topography, geology and soils, however, similarities and dissimilarities of vegetation between provinces are not always clear. Depending on management objectives further separation of old-growth woodlands is necessary.

We are currently working on a classification system for old-growth woodlands. In the proposed classification we consider; (1) community type, based on ecological province, landform, dominant shrub, dominant grass, soils, and topography (derived from West and others 1997), (2) tree age composition and structure, and (3) composition of the understory (fig. 2). The approach allows the composition of the understory and overstory to be evaluated separately but
Introduced

Perennial

Western Juniper (Juniperus occidentalis subsp. occidentalis)

This subspecies of western juniper is considered the northwestern representative of the pinyon-juniper woodland (Franklin and Dyrness 1973). The prehistoric record indicates the distribution and dominance of western juniper has greatly fluctuated during the past 5,000 years (Miller and Wigand 1994). Western juniper generally increased during periods of mild wet climate, declining with fire at the end of these wet periods. The pollen record indicates western juniper declined during the past 500 years prior to settlement. Old-growth stands in existence today are relics of the extensive stands that characterized the landscape over the past 4,000 to 5,000 years. In contrast, stands that have established after the 1870s appear to be considerably more dense and to have developed under different environmental conditions than the presettlement stands which preceded them during the past 5,000 years.

In Oregon, estimates of less than 3 percent of the current 5 million acres of western juniper woodlands are characterized by trees >100 years old (USDI-BLM 1990). Although not well documented similar proportions of western juniper old-growth are probably found in northeastern California, northwestern Nevada, and southwestern Idaho. However, the proportion of pre- and post settlement trees varies across ecological provinces. Acreage of old-growth is not known since mapping and inventory of old-growth western juniper woodlands is limited throughout its range. In the southwest, the occurrence of old-growth woodlands is rare (Svetnam and Brown 1992).

Old-growth western juniper stands grow on soils derived from three major parent materials, located in six ecological provinces, the John Day, Mazama, High Desert, Snake River, Klamath, and Humboldt (fig. 1). Old-growth stand structure is typically uniquely different between the different provinces and parent materials. The igneous zone dominates most of the landscape in the High Desert and Klamath ecological provinces, and the Owyhee Plateau in the Humboldt province. Igneous rock is also the most abundant parent material in the southwestern portion of the Snake River province, where western juniper occurs. In these provinces old-growth juniper typically grows widely spaced on shallow, rocky, heavy clay soils, or rimrock supporting limited fine fuels to carry a fire. Juniper Mountain, in Harney and Lake Counties, is a unique example of dense old-growth woodlands growing on deep well-drained soils, which typically supports mountain big sagebrush steppe community types. Sedimentary soils, primarily found in the John Day province, support widely spaced old trees with little understory to carry fire. The aeolian sands in the Mazama and eastern edge of the High Desert provinces support the most extensive stands of old-growth western juniper woodlands.

Igneous Zone of the High Desert, Klamath, Humboldt, and Snake River Ecological Provinces

Presettlement juniper trees are typically found on rocky surfaces or ridges (fig. 3), and low sagebrush (Artemisia arbuscula) tablelands in the High Desert, Klamath, Humboldt, and Snake River Ecological Provinces (Vasek and Thorne 1977, West 1984, Miller and Rose 1995). The low sagebrush tablelands occupied by presettlement juniper trees (fig. 4) probably account for the greatest proportion of old-growth juniper across these provinces. Old-growth juniper probably accounts for less than 3 percent of the woodlands across these provinces. The dominant grass is
typically *Poa sandbergii*, with *Festuca idahoensis* growing beneath the juniper tree canopies. These juniper low sagebrush tablelands often occupy extensive flats with less than 5 percent slope, although slopes can approach 30 percent. The rocky, shallow heavy clay soils are primarily of igneous (basalt, andesite, ryolite) origin. Although soils are shallow juniper roots often penetrate the fractured bedrock.

Tree canopy cover on the low sagebrush tablelands is highly variable and may approach 20 percent, but typically ranges below 5 percent. On the Devils Garden in northern California, 63 percent of trees aged between 200 and 500 years old. The remaining 37 percent were older than 500 years (Miller unpublished data). However, many trees could not be aged due to rot. Tree densities in a majority of these low sagebrush tableland communities have increased during the past 100 years (Young and Evans 1981, Miller and Rose submitted). Low pre-settlement tree densities in these communities can probably be attributed to limited tree establishment due to heavy clay soils, slow growth rates, and occasional fires. Lower CO$_2$ concentrations may have also attributed to slower rates of tree establishment prior to the 1900s (Farquhar, 1997). Occasional fires did burn across these low sagebrush Sandberg bluegrass community types (Young and Evans 1981, Miller and Rose submitted). In south central Oregon, two extensive pre-settlement fires burned across this type between 1700 and 1880 (Miller and Rose submitted). Mean fire intervals of 80 to 100 years were probably adequate to create a stand of widely scattered juniper trees. However, single tree lightening fires were probably more common occurrences across the juniper low sagebrush tablelands.

On the deeper igneous soils fire limited the development of old-growth western juniper woodlands (Miller and Wigand 1994). These soils typically support mountain big sagebrush steppe communities. Mean fire intervals between 12 and 25 years occurred in these shrub steppe communities (Houston 1973, Burkardt and Tisdale 1976, Martin and Johnson 1979, Miller and Rose submitted). However, Juniper Mountain located east of Alkali Lake in central Oregon is an exception (fig. 5) This site may serve as a model as to what most of the mountain big sagebrush type would have looked like if fire had played a minor role in the sagebrush ecosystem. Preliminary work indicates the age of overstory trees range between 350 and 600 years. Understory trees 3 to 5 ft tall were between 100 and 200 years old. This is the only old-growth stand we have measured throughout the range of western juniper that meets the criteria of canopy cover (>30 percent) defined by the U.S. Forest Service. On the north and northeast aspects tree canopy cover ranged between 35 and 50 percent. On south and southwest aspects tree cover ranged between 20 and 35 percent. Shrub cover accounted for less than 1 percent of the understory cover. Dominant herbaceous species were Idaho fescue (*Festuca idahoensis*) on the north aspects and Thurber needlegrass (*Stipa thurberiana*) on the south aspects.

**Sedimentary soils in the John Day Ecological Province**

Very little work has been conducted on old-growth juniper on these soils. The majority of these soils occupied by old-growth western juniper occur in the John Day province with limited amounts occurring in the High Desert and
Klamath provinces (fig. 1). These soils usually support a very low density of trees and sparse understory incapable of carrying fire (fig. 6). The accumulation of both down and standing dead and decadent trees on many of these sites indicates the presence of very old stands. Tree ages on these soils exceed 1,000 years. Dead trees may remain standing for hundreds of years. These old-growth stands probably account for less than 3 percent of the juniper woodland component.

**Figure 6**—Ancient western juniper tree growing on sedimentary soils in central Oregon.

**Figure 7**—Old woodland growing on aeolian sands. Tree canopy cover is 15 percent and dominant understory grass is Idaho fescue or western needlegrass.

**Wildlife Values**

It is important that future wildlife work describes both woodland structure and stand age. Old-growth woodlands are typically more structurally complex than postsettlement woodlands. More than 80 species of animals use living trees with decay, hollow trees, snags and logs in the interior Columbia River Basin (Bull and others 1997). Although this report excluded juniper species, our breeding bird surveys show old-growth western juniper woodlands provide important habitat for many bird species. Preliminary results from our songbird surveys indicate an increase in cavity nesters in old-growth compared to postsettlement woodlands. Densities of cavity nesting mountain blue birds, red- and white-breasted nuthatches have been consistently greater in old stands. Some of our highest mountain blue bird counts also occur in shrub steppe communities adjacent to old-growth stands. Our lowest counts have been recorded in closed postsettlement stands. At this time we have no information on cavity densities or minimum tree ages where cavities are typically found. However, the greatest number of cavities typically occurs on trees greater than 400 years. Wood rats also commonly nest in the hollow trunks of western juniper. In addition to wood rats, the abundance and diversity of small mammals is typically greater than in postsettlement woodlands (Willis and Miller, this symposium).

During the winter a large abundance of frugivores, including western and mountain bluebirds, cedar waxwings, American robins, and Townsend solitaires have been reported in the extensive juniper stands in central Oregon in the Mazama Province (Contreas 1997). These stands are predominately open old-growth woodlands, with 15 percent or less canopy cover supporting good crops of juniper berries. Dense woodlands produce very few berries (Miller and Rose 1995). We have observed heavy berry crops on trees over 500 years old growing in relatively open stands. Tree density appears to have a greater effect on the potential berry production than tree age.
Western Juniper (J. occidentalis subsp. australis)

This subspecies of western juniper, found in the Sierra Nevada Mountains south of about 40 degrees north Latitude (High Sierra Ecological Province, fig. 1), is seldom present in woodlands. This subspecies, usually found on rocky and shallow soil areas, is typically associated with various montane conifer communities. Old junipers tend to be common in these open, mixed conifer forests. There are at least two relatively large areas where the Sierra juniper is associated with singleleaf pinyon in woodland communities. One of these sites is in the lower drainage of the east and west forks of the Carson River east and south of Markleeville, California. These woodland areas are almost exclusively on rocky and shallow soil sites that have apparently greatly reduced fire frequency. Large areas of these woodlands, and possibly the majority, are old-growth communities dominated by large, old pinyon and juniper. The prehistoric record for these woodlands is unknown but because of their locations they may to be of relatively recent (late Holocene) origin.

Extensive singleleaf pinyon, western juniper (southern subspecies) woodlands also occur near the southern end of the Sierra Nevada Mountains. These are on large areas of rolling topography along the south fork of the Kern River, mostly the east side, from about Chimney Peak north to near Kennedy Meadows. Scattered occurrences of these woodlands may also be present along the east slopes of the Sierra Nevada Mountains above Owens Valley. Unlike stands further north, these are typical post-settlement woodlands dominated by younger trees, and their appearance resembles woodlands found throughout much of western Nevada. The proportion of old-growth in this location is unknown, but appears to be very limited. The prehistoric record of these woodlands is also unknown but appears to be largely of post-European settlement age.

Pinyon-Utah Juniper

Woodlands of the Great Basin of Nevada, western Utah, and eastern California cover a large land area (about 8 million hectares, 18 million acres) of considerable environmental complexity (Tueller and others 1979). The distribution, dominance, and species composition of these woodlands has seen even greater fluctuation over the last 5,000 years than the northern subspecies of western juniper. Pinyon, for example, was absent from most of Nevada and Utah during the Pleistocene and migrated into the area during the Holocene (Nowak and others 1994a,b). For some areas in western and northern Nevada, pinyon has been present for less than 2,000 years. The structure of the woodlands, and the overstory-understory competitive patterns are often different when pinyon is present than when it is absent.

Throughout the last 5,000 years woodland dominance has widely fluctuated and, following reduction during an extended drought, was slowly expanding over about a 400 year period prior to the mid nineteenth century (Wigand and others 1995). The rapid expansion that has occurred during the last century to century and a half (Tausch and others 1981, Tausch and West 1988) may be the largest of the Holocene. This expansion is continuing.

The environmental and topographic heterogeneity of provinces in the Great Basin of Nevada and Utah is generally greater than the provinces further north and east (fig. 1). Even though the ecological provinces of Nevada and Utah share many similar environmental conditions, there is a higher level of heterogeneity within as well as between, provinces (West and others 1979, West and others, in press). Soils are also highly variable, again both within and between provinces. Overall, the quantity of old-growth present is similar to the northern subspecies of western juniper, probably representing about 3 to 5 percent of the total woodland area. This is an approximation because past inventories have not distinguished between pre- and post-settlement sites. For some ecological provinces the total may be higher.

There is some commonality between old-growth woodlands across provinces. However, the amount of old-growth present, woodland structure, where woodlands occur, and the environmental conditions that support these woodlands vary between provinces. There are two general conditions in which old-growth most commonly occurs in the Great Basin of Nevada and Utah. The first of these categories are old-growth locations with shallow soils, rocky conditions, and steep topography that were relatively fire safe prior to recent tree expansion. These physical factors reduced the occurrence of fire allowing for some form of old-growth structure to develop. However, these combination of site factors occur over a wide range of elevation, topography, and environmental conditions that affect the structure, function, and appearance of the associated old-growth woodlands. As a result, this is the most variable category of old-growth woodlands found in the region. With the recent expansion of the woodlands many of these old-growth locations are now succumbing to crown fires carried by the increased density of younger trees (Gruell, this symposium).

The second type of site resulting in old-growth woodlands are sites where disturbances such as fire occur with some regularity but fuel levels are generally low enough to allow some tree survival, particularly for juniper forming communities similar to savanna in structure. These are generally lower elevation areas with relatively level to rolling terrain that prior to the recent tree expansion were open savannas with scattered older trees. Although the environmental heterogeneity is less than for the first type of site, considerable variation in conditions still exits within this category. The amount present also varies between ecological province. Here also the recent tree expansion, plus the increasing presence of invading annuals, is changing fuel conditions leading to the increasing loss of this type of old-growth by wildfire.

High Desert and Mono Ecological Provinces

These two provinces comprise the mountain ranges immediately east of the Sierra Nevada-Cascade Mountain chain and west of the Lahontan basin (fig. 1). Precipitation in this province comes almost entirely in the winter. With the exception of a few scattered locations of singleleaf pinyon at
the far south end, the woodlands of the High Desert Ecological Province contain only juniper (West and others 1978). In Oregon it is the northern subspecies of western juniper. In the south of the High Desert Province Utah juniper dominates the woodlands. By contrast, the Mono Ecological Province is dominated by singleleaf pinyon, and over large areas the woodlands contain only singleleaf pinyon (West and others 1978, West and others, in press). Old-growth woodlands of both categories occur throughout both of these provinces. Although rare, some very old (1,000 years old plus) juniper old-growth woodlands are present in the Mono Ecological Province.

The fire-protected category of old-growth sites appears to be more common than sites in the savanna category. Some large areas of old-growth juniper woodland occur on high mountain areas in the High Desert Ecological Province in Nevada that contain a good understory dominated by bluebunch wheatgrass (Tausch and others 1995). Large areas of old-growth pinyon woodlands, but with less understory (Robin Tausch and Robert Nowak, unpublished data), are found growing in similar environmental and topographic conditions in the Mono Ecological Province. In both provinces old-growth probably represents less than five percent of the total woodland area, but more locally its representation can be higher.

Lahontan Ecological Province

The Lahontan Basin is an open, low elevation area that extends north south through western Nevada from the Oregon border south to the Mojave Desert. Precipitation comes almost entirely in the winter. Woodlands on the mountain ranges in the northern half of this province are mostly Utah junipers, although scattered locations of western juniper and pinyon are present (Charlet 1996). In the southern portion the woodlands are either singleleaf pinyon dominated, if it is present, or have only Utah juniper. Two notable examples of mountain ranges with woodlands containing only juniper are the Pilot and Cedar Mountains east of Mina, Nevada. Mountain ranges to the immediate north, south, east, and west are pinyon dominated. As pinyon migrated into this Province in the mid Holocene the Pilot and Cedar Mountains.

Although both categories of old-growth woodlands occur in this ecological province, the savanna type is probably the most common. This occurs because of the aridity of the region from the rain-shadow of the Sierra Nevada Mountains, and the generally low elevations compared to surrounding provinces. Even in the higher elevation portions of the mountain ranges present, the woodlands are often more open with generally scattered trees. Maybe 10 percent of the woodlands in this province are old-growth. Essentially all the rest are post-settlement in age.

High Central and High Calcareous Ecological Provinces

These two Ecological Provinces, overall, represent the highest elevation areas of the Great Basin of Nevada and Utah. Some valley floors in the area exceed 7,000 ft and many of the highest peaks exceed 10,000 ft, with the highest over 13,000 ft (West and others 1978). Geology of the High Central Ecological Province is mostly of igneous origin. Limber Pine is the only other relatively common conifer in the area. Geology of the High Calcareous Ecological Province is mostly of sedimentary origin with a high abundance of limestone and dolomite present. This latter province has several species of conifer that are common in addition to pinyon and juniper (Charlet 1996).

Juniper was probably very restricted in its distribution, and possibly absent in much of the area, during the Pleistocene. Pinyon was entirely absent, not arriving in the area until or after about 6,000 years B.P. (Nowak and others 1994a,b). The majority of the old-growth in these two provinces is in the first category, and found most often on steep mountain slopes, generally with south and west aspects. This old-growth is predominantly pinyon dominated or pure pinyon. Some isolated locations of juniper old-growth are present on these upper elevations. Some Rocky Mountain junipers are scattered through the High Calcareous Ecological Province. This species often occurs along stream channels and in the highest elevations of the woodlands. Savanna type old-growth on the Bajadas and lower foothills are predominantly juniper dominated or only juniper is present. Old-growth of any type is rare, probably less than three percent of the total. All types of old-growth are increasingly at risk for loss by wildfire from both the recent increase in tree density and dominance, and the increasing prevalence of exotic annuals, particularly cheatgrass.

Bonneville Ecological Province

The Bonneville Basin is the eastern equivalent of the Lahontan Basin in the west. During the Pleistocene this basin had the largest lake in the region, Lake Bonneville. Shadscale desert covers large areas, isolating the mountain ranges that are present. This area is also rainshadowed by the higher mountains to the west. Summer precipitation increases in importance eastward across the region. The majority of the woodlands in this area have a high presence of juniper. Extensive areas of juniper savanna are present, and a large part of it is old-growth. Most of the old-growth is in the savanna category. Old-growth in the first category has rare occurrences on the higher mountains in the region. On average, the oldest pinyon and juniper in the Great Basin of Nevada and Utah are generally found in this province (Tausch and others 1981). Old-growth may exceed 10 percent of the total woodland area in this province. In the eastern half of the province hybrids between singleleaf and Colorado pinyon are present.

Humboldt and Raft River Ecological Provinces

Both of these provinces represent a transition zone of generally decreasing elevation between the high basin and range topography to the south, and the Snake River Plains to the north. Woodlands in the Humboldt Ecological Province are almost exclusively juniper, mostly Utah to the south and western juniper to the north (West and others 1978, Charlet 1996). The scattered pinyon that are present in the Humboldt province are only along the southern fringe of
the area. The southern half of the Raft River Ecological Province has large areas of woodlands with mixed singleleaf pinyon and juniper. In the northern half the woodlands contain only juniper.

Old-growth Utah juniper is rare in these provinces, probably less than three percent of the total. The majority of the rest of the woodlands are post-settlement in age. Both categories of old-growth are present but their relative abundance needs to be determined.

**White River Ecological Province**

This province is a transition of decreasing elevation southward from the higher mountains and valleys of eastern and central Nevada down to the Mojave Desert. The southeastern portion of this province can get about a third or more of its rainfall in the summer. Woodlands are found from the upper elevations of the mountains down to, and in some places in the eastern half, out onto the valley floors. Further west woodlands are more confined to the mid to upper elevations of the mountain ranges. Both categories of old-growth woodlands are present within this province. Large areas of former savanna on the valley floors and foothills have seen a strong increase in tree density from the recent expansion. Many of these areas are now experiencing intense crown fires that consume both the pre- and the post-settlement trees.

The highest mountain ranges have areas of old-growth on steep, rocky slopes. The south ends of the White River and Lahontan Ecological Provinces represent some of the most environmentally variable woodlands in the region. They have the highest diversity of plant species in woodlands of the Great Basin of Nevada and Utah (Tueller and others 1979, West and others 1978). This apparently results from their position of transition between the high mountains and valleys to the north and the Mojave Desert to the south. Climatic fluctuations throughout the Pleistocene and the Holocene has resulted in the migration of many plant species through these provinces (Nowak and others 1994a,b).

**Wasatch Ecological Province**

This province includes the west slopes of the Wasatch Front and the mountain ranges immediately to the west. Woodlands in this province have considerable floristic affinity with the Wasatch and Rocky Mountains. Most of the pinyon present is Colorado pinyon with the presence of some hybrids with singleleaf (possibly California) pinyon in the western edge of the province. Pinyon is also present primarily in the southern half of the province. Juniper is the most common tree in the woodlands of the northern half. Old-growth is limited in this province, probably less than two percent of the total. The majority of what is present is probably in the first category of sites that are relatively safe from fire.

**Mojave Ecological Province**

Woodlands in this province exist on the upper elevations of the higher mountain ranges that are like islands scattered through a sea of desert. The lowest valley elevations in the continental United States occur in this province, such as, Death Valley. Rainfall is almost exclusively in winter. Some of the valley locations in this province were refuges for singleleaf pinyon during the Pleistocene (Nowak and others 1994a,b). Despite the overall aridity of the region, all except the lowest elevations tend to be dominated by singleleaf pinyon. In addition to Utah juniper the highest ranges, such as the Spring and Sheep Ranges, also have scattered locations of Rocky Mountain juniper in their woodlands. Old-growth of both the fire safe and savanna categories is present throughout the region. Old-growth tends to be more common on lower elevation ranges than higher elevation ranges where the recent tree expansion has been more dominant. The savanna type of old-growth may also be more common. Overall, the amount of old-growth is low, but unknown. A large part of this province is within the boundaries of the Nevada Test Site.

**Management Considerations**

Before we can address how we should manage old-growth woodlands in the Intermountain West we must ask the question what should these old-growth stands be managed for? Old-growth juniper and pinyon woodlands make up a small percentage of the juniper and pinyon woodland. They are structurally and topographically more complex than the younger more abundant woodlands, adding biological diversity to the landscape and providing an important source of habitat for many organisms. Many of these stands are also very esthetically pleasing providing recreational, cultural and spiritual opportunities. Kaufmann and others (1992) states; “old-growth provide us with a tremendous opportunity for retaining or enhancing biological features unique to old-growth ecosystems.” We should evaluate fire policies influencing these old stands including both fire suppression and let burn. Recent changes in overstory and/or understory can alter the response of these communities to fire. However, continued fire suppression in some woodlands may increase the potential for large stand replacement fires. Fuel woodcutting also appears to be a rather wasteful use of this limited resource, unless cutting is designed to remove postsettlement trees and restore presettlement stand structure.

Studies are needed to determine and describe the range of old-growth characteristics throughout the Intermountain West. Mapping and inventorying old-growth woodlands is extremely important for developing management and land-use plans. Development of and old-growth woodland classification system used in inventories would prove helpful in developing management plans. We also need information on gap dynamics, tree mortality, and succession following disturbance. This information will allow us to predict how woodlands respond to disturbance. It will also allow us to evaluate pre- and postsettlement changes in community structure and composition that have occurred in old-growth stands, define desired future conditions, and develop management programs to restore or maintain old woodlands. Old-growth woodlands can not be managed on a single tree basis but only at the community and landscape levels to be successful. These old stands are an important landscape component in the Intermountain West, supporting many plant and animal species, and interacting with adjacent plant community types.
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