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An Old-Growth Definition for Western Juniper Woodlands: Texas Ashe Juniper Dominated or Codominated Communities

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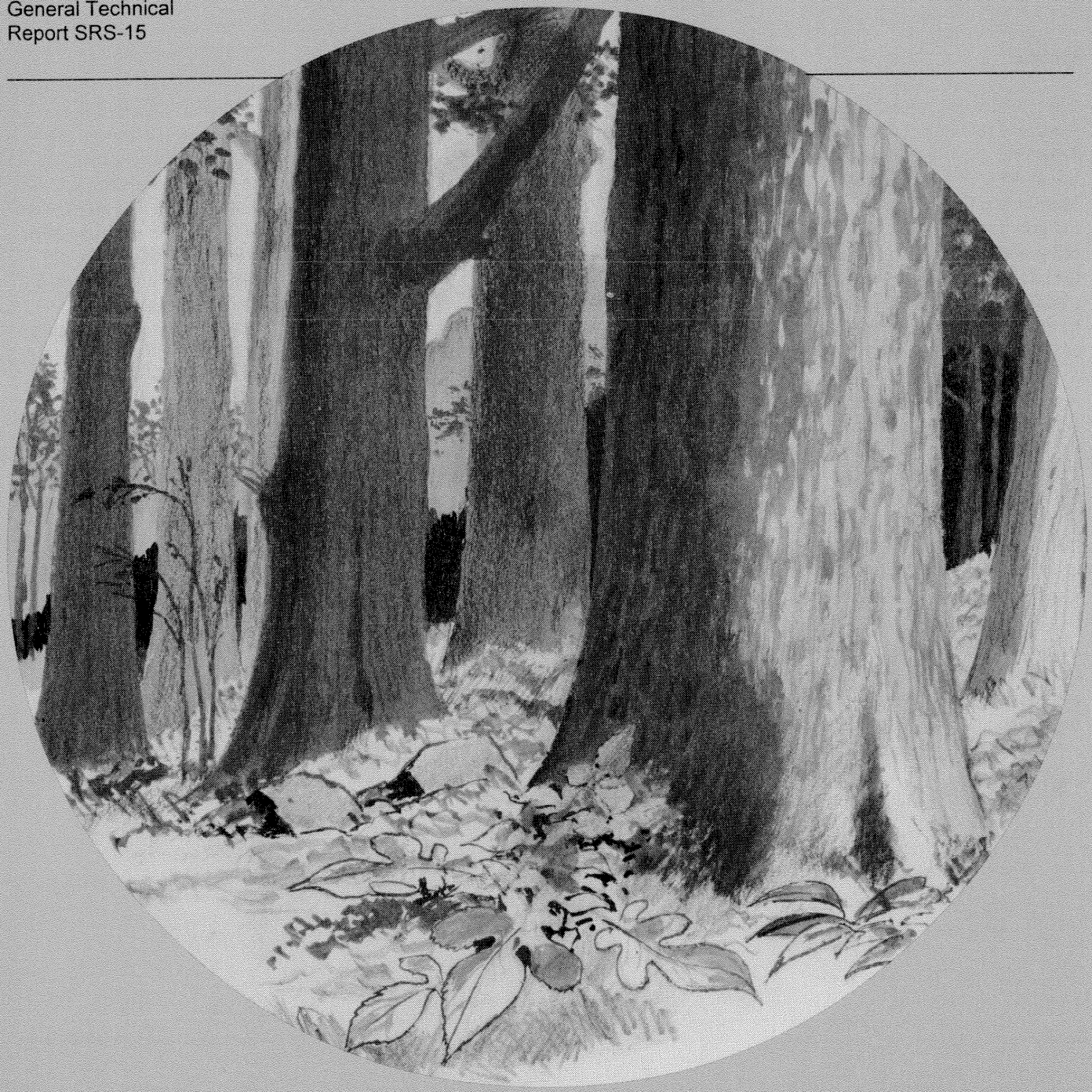

A Section of the Old-Growth Definition Series

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Preface

Old growth is widely acknowledged today as an essential part of managed forests, particularly on public lands. However, this concept is relatively new, evolving since the 1970's when a grassroots movement in the Pacific Northwest began in earnest to define old growth. In response to changes in public attitude, the U.S. Department of Agriculture, Forest Service, began reevaluating its policy regarding old-growth forests in the 1980's. Indeed, the ecological significance of old growth and its contribution to biodiversity were apparent. It was also evident that definitions were needed to adequately assess and manage the old-growth resource. However, definitions of old growth varied widely among scientists. To address this discrepancy and other old-growth issues, the National Old-Growth Task Group was formed in 1988. At the recommendation of this committee, old growth was officially recognized as a distinct resource by the Forest Service, greatly enhancing its status in forest management planning. The committee devised "The Generic Definition and Description of Old-Growth Forests" to serve as a basis for further work and to ensure uniformity among Forest Service Stations and Regions. Emphasis was placed on the quantification of old-growth attributes.

At the urging of the Chief of the Forest Service, all Forest Service Stations and Regions began developing old-growth definitions for specific forest types. Because the Southern and Eastern Regions share many forest communities (together they encompass the entire Eastern United States), their efforts were combined, and a cooperative agreement was established with The Nature Conservancy for technical support. The resulting project represents the first large-scale effort to define old growth for all forests in the Eastern United States. This project helped bring the old-growth issue to public attention in the East.

Definitions will first be developed for broad forest types and based mainly on published information and so must be viewed accordingly. Refinements will be made by the Forest Service as new information becomes available. This document represents 1 of 35 forest types for which old-growth definitions will be drafted.

In preparing individual old-growth definitions, authors followed National Old-Growth Task Group guidelines, which differ from the standard General Technical Report format in two ways—the abstract (missing in this report) and the literature citations (listed in Southern Journal of Applied Forestry style). Allowing for these deviations will ensure consistency across organizational and geographic boundaries.

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An Old-Growth Definition for Western Juniper Woodlands: Texas Ashe Juniper Dominated or Codominated Communities[1]

David D. Diamond

Description

Prominent juniper species that dominate or codominate woodlands or shrub lands of the American Southwest include Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), Pinchot juniper (*J. pinchottii* Sudw.), oneseed juniper [*J. monosperma* (Engelm.) Sarg.], alligator juniper (*J. deppeana* Steud.), Utah juniper [*J. osteosperma* (Torr.) Little], and Ashe (mountain-cedar, Mexican) juniper (*J. ashei* Buchholz) (nomenclature follows Correll and Johnston 1970). Among these, Ashe juniper is nearly restricted in the United States to the Edwards Plateau and Lampasas Cut-Plain of Texas, with outlier populations over limestone in Oklahoma and Arkansas (see illustrations of natural regions in Diamond et al. 1987, Riskind and Diamond 1988). As classified by the Society of American Foresters (SAF), this is an eastern forest cover type 66, southern region, Ashe juniper-redberry juniper (*J. Erythrocarpa* Cory) (Eyre 1980). I will not consider the SAF western cover types, Rocky Mountain juniper or pinyon (*Pinus edulis* Engelm.)-juniper, here. Also, although Pinchot juniper does grow in mixed stands with Ashe juniper and oaks (*Quercus* sp.) on the western Edwards Plateau, it is not a significant component in woodlands discussed here; this species may grow with oaks and Ashe juniper to form open woodlands in the far western Edwards Plateau, but such communities have not been described in the literature.

Ashe juniper communities are most common in the southern and eastern Edwards Plateau (Balcones Canyonlands, Texas hill country) and the Lampasas Cut-Plain to the north. Both regions are underlain by Cretaceous limestones, but these are of various types that weather to form different soils and a wide variety of different abiotic site potentials for any given geomorphic position. Thus, site potentials are not only controlled by slope and exposure, but also may vary across flat uplands, across gentle slopes, etc., due to subtle differences in substrate. Climate also varies across the range of Ashe juniper community types, with annual precipitation ranging from 20 inches [50 centimeters (cm)] in the west to 34 inches (86 cm) in the east and average January low temperatures from 37 °F (2.8 °C) in the south to 30 °F (-1.1 °C) in the north. Superimposed on these climatic, topographic, and edaphic variables are variations in land use; together these account for the communities on the contemporary landscape.

Extent of the Original Woodlands

Often-repeated dogma indicates that Ashe juniper has increased in importance in former grasslands (Amos and Gehlbach 1988), but the real extent of this increase and its impact on contemporary woodland and forest distribution and composition are unclear. Following are some accounts of the perception of the expansion or contraction of Ashe juniper communities and a discussion of the composition of woodlands and forests on uplands and on slopes and creek bottoms.

Ashe juniper is seen as economically undesirable on rangeland, and many of the early accounts of its increase may be traced to human impressions, range science literature, or other sources primarily interested in addressing the use of natural resources to generate economic income (Bray 1904, Beuchner 1944, Huss 1954, Harris 1958, Smeins 1980, Fuhlendorf 1992). Many of these sources, however, indicate the presence of a variety of natural juniper codominated communities, a decrease in "virgin cedar (old-growth Ashe juniper)" communities, and the use of juniper and other species for wood products. For example, Huss (1954) wrote of the use of juniper for posts and of accounts of the shipment of three trains per week out of Real County on which " . . . it was not uncommon for a single train to have a load of 40,000 posts." Contrary to showing a dramatic increase in juniper woodlands, he wrote,

[1] Literature search and preliminary description.

"It is difficult to believe that such timber once existed in the valley of the Nueces." As evidence that it did, he noted that one unusual 23,000-acre ranch in Edwards County still had virgin cedar and calculated its worth at over $1 million. Beuchner (1944) mapped all of Kerr County as some type of woodland and 24 percent as cedar brakes (dense forests dominated by Ashe juniper) and states that, " . . . a large part of the area now designated as cedar brakes was originally covered with cedar when white man made his first appearance . . . ."

As further evidence of the existence of extensive forests on the Edwards Plateau, Bray (1904) wrote that, "A large part of the support of the Hill Country population comes from the sale of wood for fuel," and that, "Cedar is handled at all points within hauling distance of brakes; but cedar timber large enough to furnish ties and poles is becoming scarce, except in remote districts." The following excerpt from Bray also provides additional insight into the historical extent of juniper codominated woodlands in the Edwards Plateau: "With the exception of cedar, the hill country timber finds a market chiefly as fuel, of which enormous quantities are consumed, both in stoves and grates and in the furnaces of lime and brick kilns, gin engines, etc. Cedar likewise is extensively consumed as fuel and in charcoal burning, but its great value lies in its yield of railway ties, poles, posts, sills, and innumerable other articles which utilize its great durability."

Pulich (1976), Clark (1985), Weniger (1988), Wahl et al. (1990), and Keddy-Hector (1992) all document or suggest a decline in woodlands on the Edwards Plateau. Weniger wrote that the Edwards Plateau was about half wooded and half open at the time of European settlement, based on analysis of survey notes from more than 6,500 witness trees. Rates of loss range from 20 percent of the "virgin cedar" from 1962 to 1974, based on Soil Conservation Service records (Pulich 1976), to 30 percent of all woodland lost in urbanizing counties from 1974 to 1990, based on remote sensing data (Keddy-Hector 1992). Most of this loss was due to land clearing for agriculture and urbanization.

Old-growth Ashe juniper stands are difficult to find in the contemporary landscape and may not even be easily recognizable; certainly, examples of all variants of different community types with Ashe juniper as a dominant or codominant do not exist. No accounts were found that specifically document old-growth stands. I have visited more than 100 sites that support Ashe juniper woodlands or forests, and have tentatively identified only 1 as old growth, and even it had small patches of disturbance (i.e., stumps from the removal of individual trees, apparently for posts). The reasons for disturbance presumably include the high value of Ashe juniper for timber products and, later, cedar oil, the extensive clearing of timbered land for use by domestic livestock, and the less extensive destruction of woodlands by urban growth.

Upland Woodlands

On disturbed sites, young Ashe juniper sometimes forms nearly pure stands or grows on repeatedly cleared rangeland. However, from Bray (1904), Beuchner (1944), Huss (1954), Wahl et al. (1990), and personal observation, at least two upland site types support natural juniper-oak woodlands. These include Bray's "hardscrabble" areas, with exposed, massive, cracking limestone at the surface. Hardscrabble areas sometimes occur within extensive uplands and are also prominent near the lip of canyon rims, usually extending no more than 100 feet [30 meters (m)] away from the rim and often restricted to within 33 feet (10 m) of the rim. This substrate supports mainly evergreen or mixed woodlands, including juniper-shin oak [*Q. durandii* var. *breviloba* (Torr.) Palmer] in the east and central Plateau, Vasey oak [*Q. pungens* var. *vaseyana* (Buckl.) C.H. Muller] in the west, or juniper-plateau live oak [*Q. virginiana* var. *fusiformis* (Small) Sarg.] communities throughout. Canopy cover reaches about 90 percent and height about 26 feet (8 m) in these communities. Lacey oak *(Q. glaucoides* Mart. & Gal.) may also be an overstory species in the south central and southwestern Edwards Plateau, especially on flats just above canyon rims. Cedar elm (*Ulmus crassifolia* Nutt.) and sugarberry (*Celtis laevigata* Willd.) are also sometimes important. Common understory shrubs include Texas persimmon (*Diospyros texana* Scheele), mountain-laurel (*Kalmia latifolia* L.), and eastern redbud (*Cercis canadensis* L.). Elbowbush (*Forestiera pubescens*), sumacs (*Rhus* sp.), and agorita (*Berberis trifoliolata*) may grow in openings, although apparently none of these is especially shade tolerant.

A second type of upland woodland with Ashe juniper as a component is described by Buechner (1944) and Huss (1954), and from a single stand by Wahl et al. (1990). Soils are described as red or reddish and may develop over siliceous limestone or "flintrock" (Hill and Vaughn 1897) or may represent ancient Pleistocene paleosols or "terra rosa" as described by Young (1986). These two different types of substrate may support slightly different types of woodlands, but, in either case, apparently post oak (*Q. stellata* Wangenh.) or blackjack oak (*Q. marilandica* Muenchh.) or both, are among the overstory dominants. I have also observed this type of community in which the canopy was

about 40 feet (12 m) and the community was relatively open. Huss reported on an Ashe juniper-blackjack oak community type on the "flintrock" divide of Real County and noted that Lacey oak, bigleaf shin oak (probably *Q. sinuata*), and Texas madrone (*Arbutus texana* Buckl.) were important components. Beuchner reported post oak, blackjack oak, and live oak as dominant in this community type in Kerr County; post oak and Ashe juniper dominated the stand sampled by Wahl et al.

Slope, Canyon, and Creekside Forests and Woodlands

Ashe juniper and deciduous species are seldom evenly distributed within uniform woodlands on slopes or in canyon systems. Rather, deciduous trees and shrubs often form rather narrow, distinct, linear, horizontal bands from perhaps 30 to 100 feet (9 to 30 m) wide, associated with seepage zones near the tops of slopes, and sometimes at intervals downslope, with wider, mostly evergreen Ashe juniper bands interspersed up slope and downslope. This type of banding is especially clear where massive, resistant limestone forms a thin cap over less resistant materials as in the vicinity of Post Oak Ridge north of Austin, TX, where Edwards limestone caps give way to Glen Rose limestone slopes. Indeed, landscape patterns (i.e., the degree of incision of canyons, degree of canyon slope, difference in elevation of plateau tops versus canyon bottoms, etc.) depend on geologic substrate as well as drainage patterns. The Balcones Canyonlands region along the southern and western boundary of the Plateau harbor some of the most spectacular ravines and the most extensive slope forests. Slope exposure also influences community structure, with south exposures more evergreen and approaching the look of upland woodlands, but with banding of deciduous trees sometimes still prominent. Deciduous trees also grow more abundantly in ravine bottoms, ravine heads, or near streams, and composition depends both on moisture regime and landscape/disturbance variables.

Recognition of distinct community types is problematic in many canyon systems. For example, a series of quadrants could be placed within deciduous-tree-dominated bands to define a deciduous forest or within mainly juniper-dominated bands to define an evergreen woodland on the same slope. Different authors have treated this variation differently; also, some have reliably recognized disturbed communities versus undisturbed stands while others apparently have not. I have tried to account for this type of variation in the following description of slope, canyon, and streamside community types. The descriptions are based primarily on data from Beuchner (1944), Huss (1954), Blair (1965), Kroll (1980), Van Auken et al. (1981), Gehlbach (1988), Riskind and Diamond (1988), Van Auken (1988), and Wahl et al. (1990). See especially chapters in Van Auken et al. (1979, 1980, 1981) and Amos and Gehlbach (1988) and for quantitative data.

A generalized description of slope woodlands in the Balcones Canyonlands would show Texas oak and Ashe juniper among the canopy dominant in most stands. Cedar elm is usually present in the canopy and is reported as a dominant in some stands. Plateau live oak, black cherry (*Prunus serotina* Ehrh.), Texas ash [*Fraxinus texensis* (Gray) Sarg.], scalybark oak [*Q. sinuata* (Torr.) C.M. Mull.] = shin oak = bigleaf shin oak = Durand oak (*Q. durandii* Buckl.), sugarberry, and Arizona walnut [*Juglands major* (Torr.) Heller] are often present in the canopy, and may be among the dominants. Lacey oak is important in the central and western sections. Chinkapin oak (*Q. muhlenbergii* Engelm.), Carolina basswood (*Tilia caroliniana* Mill.), and American elm (*U. americana* L.) are sometimes components in wet canyons or in streamside communities. These mesic forests may have a rather diverse understory composed variously of Texas persimmon, yaupon (*Ilex vomitoria* Ait.), American beautyberry (*Callicarpa americana* L.), hoptree (*Ptelea trifoliata* L.), Mexican-buckeye (*Ungnadia speciosa* Endl.), deciduous holly (*Ilex decidua* Walt.), redbud, and roughleaf dogwood (*Cornus drummondii* C.A. Meyer). Other understory species may include rusty blackhaw (*Viburnum rufidulum* Raf.), Carolina buckthorn (*Rhamnus caroliniana* Walt.), red buckeye (*A. pavia* L.), Texas madrone, Lindheimer's silktassel (*Garrya lindheimeri* Dougl. ex Lindl.), and kidneywood (*Eysenhardtia texana* Scheele). In a few deep, moist canyons, bigtooth maple (*Acer grandidentatum* Nutt.) is among the dominants and may form stands in which it comprises more than 70 percent of the relative cover as in Lost Maples State Natural Area. In the south central and southwest portions of the Edwards Plateau, isolated oak-juniper-pinyon and mainly evergreen woodlands grow on uplands, but are best developed in shallow canyons and canyon heads.

Table 1 summarizes communities and dynamics. Only Van Auken et al. (1981), Gehlbach (1988), and Van Auken (1988) have provided data on relatively mature stands, although perhaps none of the stands sampled could be characterized as old growth.

Old-Growth Definitions

Ashe juniper is a component of at least three different but related community types, including (1) upland mainly evergreen to mainly deciduous woodlands on fractured, massive limestone in flat uplands and on canyon rims; (2)

Table 1—Major pre-European woodland and forest community types of the Edwards Plateau with Ashe juniper as a component

Community type	Landscape position, soils, and geology	Characteristics of the community	Fire frequency and type	Relative diversity of woody species
Plateau live oak-Ashe juniper	Flat or rolling uplands; soils fairly deep and of relatively uniform depth	Open grassland or savannah with individuals or mottes of oak; Ashe juniper and other tree species in mottes	High; ground fires with few crown fires	Low
Post oak/blackjack oak-Ashe juniper	Flat or rolling uplands; soils over silica-containing limestone or composed of Pleistocene terra rosa	Savannah to well-developed woodland; Ashe juniper and other tree species in dense mottes or better developed woodlands	High to medium; few crown fires	Medium
Scalybark oak/Vasey oak (west)-Ashe juniper	Flat or rolling uplands or canyon rims; soils over massive, fractured limestone and of variable depth	Shrub land or woodland depending on fire frequency; Ashe juniper increasing with time since previous burn	Medium to low; some crown fires	Medium to high
Ashe juniper-Texas oak/deciduous tree species	Slopes, canyons, creek sides	Evergreen woodland (dry exposures/dry slopes) to deciduous forest (wet exposures, seeps, creek sides; vegetation forming horizontal bands)	Low to very low; crown fires at low return intervals	High

mainly deciduous woodlands over either terra rosa or silica-containing limestone on uplands; and (3) forests and woodlands on slopes, in canyons, and along streams. Generalized characteristics of these community types in terms of tree size and density for old-growth conditions follow. These, however, are based on the data available, and at best are hypothetical extrapolations, because few authors have described mature, let alone old-growth stands.

Upland Hardscrabble

Live oak and Ashe juniper were and are growing under less disturbed conditions, often the leading dominant of woodlands or mottes (clumps) on relatively deep, continuous soil of flat uplands on much of the Plateau, whereas scalybark oak and Ashe juniper dominated hardscrabble areas (Bray 1904, Beuchner 1944, Van Auken et al. 1981, Gehlbach 1988, Van Auken 1988). Scalybark oak, and perhaps Texas oak, apparently sometimes formed dense "shinneries" (Bray 1904) in which multiple-stemmed individuals formed low canopies in response to fire; Bray reports that these shinneries contained a mixture of species, including live oak, sugarberry, and sumac. Post oak and blackjack oak may also grow in these hardscrabble areas. The live oak-juniper woodlands may indeed represent former climax savannahs or grasslands and the shin oak-juniper climax woodlands. The mature canopy height of these communities is about 26 to 30 feet (8 to 9 m) (Kroll 1980, Wahl et al. 1990). Canopy closure in mature stands reaches about 90 percent and basal area about 40 to 50 feet^2 per acre [40 to 50 m^2 per hectare (ha)] (Van Auken 1988). Number of trees over 1.2 inches (3 cm) diameter at breast height (d.b.h.) ranged from 1,155 to 1,465 per acre (2,841 to 3,605 per ha) (Van Auken 1988). The average d.b.h. of

mature canopy trees reported by Gehlbach for scarp edges was 13 inches (34 cm) for scalybark oak, 14 inches (36 cm) for cedar elm, and 16 inches (41 cm) for plateau live oak. Harris (1958) reported that "little leaf shin oak" (probably *Q. vaseyana*) on the west central Edwards Plateau reached 6.5 inches (16 cm) d.b.h. and 76 years old on upland sites. Ashe juniper in Real County was 70 to 100 years old at 5 to 6 inches (13 to 15 cm) d.b.h. and reached 10.5 inches (27 cm) d.b.h. and 172 years old (Huss 1954). However, few or no "virgin cedar brakes" were found in Real County. Kroll (1980) found Ashe junipers as large as 16 inches (40 cm) d.b.h. and more than 100 years old.

Only one stand of this community type was apparently old growth among dozens I visited. Ashe juniper was the leading dominant occupying more than 80 percent of the relative canopy cover, which reached 26 to 30 feet (8 to 9 m). The d.b.h. of large canopy trees was estimated at more than 18 inches (45 cm), but many smaller individuals reached the canopy. Canopy trees were flat-topped (less mature junipers have pointed tops with easily identifiable apical growing points) and total canopy cover was estimated about 80 percent. Scalybark oak, Texas oak, and live oak were also in the canopy and the understory contained a few tall, spindly Texas persimmons. The aspect was open under the canopy, with few low branches; this contrasts with younger stands of juniper, which are often nearly impenetrable due to low branching of junipers or dense growth of many individual stems. Recruitment was mainly seedling Ashe juniper, but there were almost no sapling trees. Numerous large, downed junipers occurred (probably as many as 10 percent of the number of live trees standing) and I saw one standing dead tree. Despite this, I could detect no old light gaps, which suggests that the death of individual junipers, whose canopies are small, does not dramatically affect forest dynamics. The ground layer was lush; apparently enough diffuse light penetrated the canopy to support grass.

Upland Flintrock or Terra Rosa Soils

Over upland flintrock (siliceous limestone) or terra rosa soils, Ashe juniper occurs mixed with post oak and blackjack oak. Fire may have historically diminished the dominance of Ashe juniper. Buechner (1944) reported blackjack oak, live oak, and post oak in over 90 percent of the 5-acre stands of this community type sampled in Kerr County (number sampled not reported); canopy coverage was highest for blackjack oak and intermediate for post oak and live oak. Ashe juniper was present in 70 to 90 percent of the stands but provided less than 1 percent of the canopy coverage in 75 percent of those in which it occurred. Wahl et al. (1990) found post oak dominating one stand with a density of 180 trees per acre (73 trees per ha) and a mean height of 26 feet (7.9 m). Ashe juniper was the next most important species with a mean of 393 trees per acre (159 trees per ha) and a mean height of 17 feet (5.3 m). Total canopy cover of the stand at 16 feet (5 m) was 21 percent. The tallest post oaks were over 45 feet (12 m), whereas the tallest junipers were over 26 feet (8 m); this corresponds to observations of similar stands. My vision of this type of community in an old-growth stand is that of an open woodland with 40 to 60 percent canopy at about 45 feet (12 m) with scattered post oak and blackjack oak along with dense mottes of these species in which Ashe juniper is a component.

Slope, Canyon, and Creekside Communities

Van Auken (1988) reported north slope communities with a total basal area of 168 ft^2 per acre (38.6 m^2 per ha) and total tree density of 729 per acre (1,851 per ha). Gehlbach (1988) reported mean d.b.h. of canopy trees on slopes and floodplains in the range of 15 to 17 inches (38 to 44 cm) for Texas oak, Texas ash, sugarberry, cedar elm, and scalybark oak. Various sources report average canopy height to be 39 to 49 feet (12 to 15 m). An unusual stand dominated by bigtooth maple, Texas oak, and Lacey oak, sampled by Wahl et al. (1990), contained canopy trees 33 to 46 feet (10 to 14 m) tall and a total canopy cover of 145 percent, due to overlapping layers of tree canopy. My vision of an old-growth slope community includes a diverse, essentially interlocking canopy of mainly deciduous trees and Ashe juniper at about 49 feet (15 m) tall and a diverse understory of mainly deciduous shrubs. However, junipers and deciduous species are usually not evenly intermixed but form distinct patches or bands.

Forest Dynamics and Ecosystem Function

Fire greatly helped control the distribution of vegetation on the Edwards Plateau prior to European settlement. Smeins (1980) and Fonteyn et al. (1988) concluded that frequent fires, set by lightning or Native Americans, were so common on the Plateau that flats and rolling hills, especially outside of the hill country, were maintained as open grassland. Effects of fire on the Plateau are summarized by Amos and Gehlbach (1988):

> Indeed, fire may have been the single most important, non-edaphic factor controlling patterns of vegetation. The historic Plateau was likely a mosaic of woodland along the rocky scarps and in canyons (fires infrequent), forest along the creeks and rivers (also

infrequent fire), and grassland in the uplands where comparatively deep soil and fire were more frequent. Occasional trees, especially plateau live oaks, grew on the uplands, root- and stump-sprouted into clumps (mottes) due to fire and perhaps browsing disturbance and fostered the establishment of commensals like Ashe juniper and Texas persimmon because of the cool, moist, fire-resistant carpet of thick oak leaves.

Wells (1965) concluded that extensive scarp woodlands in the Great Plains are a result of the protection from fire. Similarly, the natural woodlands of the Edwards Plateau may likewise have been the result of protection of canyons and scarps from fire. Thus, mesic woodlands and forests codominated by juniper could have been protected from fire and maintained in canyons. Hardscrabble areas in the uplands, with massive limestone exposed at the surface, may also have prevented accumulation of fine fuel and prevented frequent fires. In fact, some hardscrabble areas are raised slightly above the surrounding flat uplands [perhaps 3 feet (1 m) on Post Oak Ridge north of Austin, TX] and, hence, not only act as scarps but actually are low scarps. But were fires frequent enough in these flat or rolling areas to exclude Ashe juniper, which is not resistant to fire? In some areas probably so, in others probably not. The dynamics no doubt were controlled by geologic/edaphic variables, such as (1) the size of the hardscrabble area; (2) the degree of exposure of rock or thin soil; (3) the water and nutrient relations of the soil and, hence, its ability to support trees; and (4) the lay of the land (i.e., distance to the nearest fire break in the form of a scarp or stream and its relation to prevailing winds, etc.).

Certainly, juniper is favored on the modern landscape not only by the absence of fire but also by its rapid seed dispersal and low palatability to browsers. However, even today in areas of continuous soils on the flat central and western Edwards Plateau, junipers are not as abundant as in areas of shallow or discontinuous soils. In fact, many areas approach the motte-like appearance described by Amos and Gehlbach (1988) where, except for the existence of junipers in mottes, the landscape has few junipers. Therefore, it is not hard to imagine how frequent fire could have excluded junipers from openings between live oak-Ashe juniper mottes on deeper or more continuous uplands (Smeins 1980).

Bray (1904) provides some clues to the timing and nature of large-scale community dynamics when he describes shinneries, which covered upland hardscrabble, as being composed of a mixture of species, some of which are not fire tolerant. Also, he notes that fire was so frequent in cedar (Ashe juniper) that "It is probable that during the past twenty-five years far more cedar timber has been burned than has been marketed, and vastly greater areas denuded by fire than by the axe." He goes on to state that cedar generally replaces itself on these burned areas. However, he quotes one "reliable" source as saying "When the (cedar) brakes are burnt out they never recover, but very soon grow up with different kinds of brush . . . . Some of my own cedar was burned about five years ago, and the ground is now covered with shin oak and Spanish oak sprouts."

Obviously, the oaks were a part of the "cedar brake" before it burned. Could this have been the formation of a new shinnery and might that area, if not burned for decades, have been reinvaded by juniper to form a cedar brake and perhaps then burned again to reform a shinnery? This type of decades-long dynamic is likely for upland woodlands of the Edwards Plateau. For example, Huss (1954) described the interaction of grazing by domestic livestock and fire and concluded that a juniper-oak community will succeed after burning to a new juniper-oak community within 60 years under various grazing regimes, although the abundance of secondary species can be controlled by grazing pressure. Presumably a canopy fire could restart the process at any stage, but would become more likely as the canopy of Ashe juniper closed.

The existence of blackjack oak and post oak communities containing Ashe juniper on uplands is probably explained by edaphic factors interacting with fire. Both of these oak species are known in Texas on deep, slightly acid soils of the Post Oak Savannah and Cross-Timbers. The terra rosa and siliceous flintrock soils on which post oak and blackjack oak communities grow best have slightly lower pH values (often below 7.0), a different nutrient content, and perhaps better moisture relations than do most "typical" limestone-derived soils. Both blackjack oak and post oak are fire tolerant and, thus, in pre-European settlement times may have grown as scattered individuals or may have formed mottes or rather extensive, diverse, deciduous woodlands or forests, depending on subtle differences in substrate, fire history, and landscape position.

Drought also greatly influences woodlands on the Edwards Plateau. The drought of the fifties killed many oaks and junipers. Harris (1958) wrote "During the periods of detailed study in 1952 and 1953 the extended drought had not hindered littleleaf shin oak (probably *Quercus vaseyana),* although many plants of live oak, Spanish (= Texas) oak, and large areas of cedar were dead from the drought . . . . In August 1957, after extended drought from

1951 through 1956, it was noted that many littleleaf shin oak mottes were dead."

Standing dead junipers can still be seen on the western Edwards Plateau. Young (1956) likewise noted changes in vegetation due to the drought of the early 1950's and chronicled the death of many woody plants on the Sonora Research Station in the west central Plateau.

Other than the obvious impracticality of allowing hot wildfires to burn in an urbanizing region, or at least of controlling large enough areas to make such a strategy practical and the inability to control drought cycles, the primary controllable influence on the current woodlands is browsing. Van Auken (1993) and a host of others (Amos and Gehlbach 1988) have noted that browsing by domestic livestock and white-tailed deer may reduce recruitment of palatable woody species such as Texas oak. Establishment of these species may have in the past responded to fire or drought cycles, and may have in the past 100 years responded to rapid human clearing of patches of from a few to hundreds of acres for range improvement or the harvesting of wood products. Certainly, browsing by confined domestic livestock and introduced feral species and the control of hot wildfires may change community composition over time. However, the type and extent of these possible changes is not certain. For example, the establishment of only a few trees may ensure their representation in old-growth communities, especially if these species have large, spreading canopies. Palatable species, such as Texas oak, cedar elm, and sugarberry, are still major components of mature woodlands and forests despite a 100-plus-year history of human settlement, land clearing, and grazing of domestic livestock. Thus, the effects of overbrowsing and control of wildfire could be less dire for these species than it might appear.

Conservation of Ashe juniper and related woodlands and forests of the Edwards Plateau is of high concern, according to Diamond et al. (1987) and the Texas Natural Heritage Program (TNHP)[2]. While not imminently imperiled, these communities are threatened by expanding urbanization and agriculture, especially land clearing for range improvement. Of 80 sites supporting variations of Ashe juniper codominated communities in the TNHP database, only 6 are listed as excellent or good to excellent quality (i.e., old growth).

[2] Texas Natural Heritage Program. 1992. Description of the natural communities of Texas, series level. 45 p. Unpublished manuscript. On file with: Texas Parks and Wildlife Department, 4200 Smith School Road., Austin. TX 78744.

Conserving the biodiversity within the major variants of Ashe juniper dominated or codominated woodlands would require managing representative examples of each major topographic and edaphic type (upland hardscrabble, upland terra rosa or flintrock, and slope/canyon/creekside) within different regions of the Edwards Plateau. Carefully located preserves might capture all three habitats within a single 30,000-acre (1,181-ha) area, although the immediate practicality of acquiring land from willing sellers or easements from private landowners so that such an area could be managed as a unit is questionable. The management strategies for such an area might include removing domestic livestock and reducing deer and feral ungulates, prescribed burning, and restoring heavily impacted woodlands to reduce fragmentation where forests have been cleared in the past. Recalling the importance of hot as well as cool fires in pre-European settlement times, an area large enough to allow such a burn policy would be practical only for a very large preserve, especially considering the likelihood of special management requirements for rare species.

The Edwards Plateau, in general, and especially the Balcones Canyonlands or hill country, have long been recognized as important centers of endemism and biological diversity for both plants and animals (Blair 1950, Amos and Rowell 1988). Ashe juniper codominated woodlands are the defining component of this region. Several rare or endemic endangered species are indigenous to these woodlands, including the golden-cheeked warbler (*Dendroica chrysoparia)* and the black-capped vireo *(Vireo atricapillus)*. These species are currently in the center of a controversy over the effects of the Endangered Species Act on private property rights in central Texas. Attempts to conserve juniper woodlands and forests in this region would need to address the habitat requirements of these species.

Representative Old-Growth Stands

Representative old-growth forests on the Edwards Plateau, southern Great Plains occur at the following locations:

- Balcones Canyonlands National Wildlife Refuge, Travis and Williamson Counties
- Bull Creek Drainage, Travis County
- Emmous Retreat, Travis County
- Guadalupe River State Park/Honey Creek State Natural Area, Comal County
- Fort Hood, Bell and Coryell Counties
- Garner State Park, Uvalde County
- Lost Maples State Natural Area, Bandera County
- Mother Neff State Park, Coryell County
- Pedernales Falls State Park, Blanco County

Consult TNHP database for locations of these and other examples of Ashe juniper-oak series woodlands and forests.

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Ashe juniper dominated or codominated woodlands are extensive within the Edwards Plateau in Texas. Almost all contemporary woodlands are the result of various disturbances, especially grazing and fire suppression. Old-growth examples are rare. Several different geomorphic situations once supported natural Ashe juniper communities with different dynamics and composition. These included mesic slopes and canyon systems, shallow-soiled uplands (hardscrabble), and deeper-soiled uplands. The most extensive and most diverse woodlands were in canyon systems, where Ashe juniper shared dominance with a diversity of oaks and other broad-leaved trees. Drier upland woodlands were less diverse, with live oak, shin oak, and Vasey oak variously important. Ashe juniper woodlands harbor a diverse biota, including rare and endemic species, and, thus, preservation of representative old-growth examples is an important conservation concern.

Keywords: Ashe juniper, Edwards Plateau, hill country, vegetation.

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