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Figure 1—Western juniper. Photo by Joseph M. DiTomaso, University of California-Davis, Bugwood.org.

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Revisions:
The Taxonomy, Botanical and Ecological Characteristics, and Fire Effects and Management sections of this Species Review were revised in March 2019. New primary literature and a review by Miller et al. [145] were incorporated and are cited throughout this review.

SUMMARY

Western juniper occurs in the Pacific Northwest, California, and Nevada. Old-growth western juniper stands that established in presettlement times (before the 1870s) occur primarily on sites of low productivity such as claypan soils, rimrock, outcrops, the edges of mesas, and upper slopes. They are generally very open and often had sparse understories. Western juniper has established and spread onto low slopes and valleys in many areas, especially areas formerly dominated by mountain big sagebrush. These postsettlement stands (woodland transitional communities) are denser than most presettlement and old-growth woodlands. They have substantial shrub understories in early to midsuccession.

Western juniper establishes from seed. Seed cones are first produced around 20 years of age, but few are produced until at least 50 years of age. Mature western junipers produce seeds nearly every year, although seed production is highly variable across sites and years. Gravity, water runoff, and animals disperse the seeds. Seeds are stored in tree crowns and soil. Seeds are dormant, with passage through animal digestive tracts speeding rates of germination. Early growth is concentrated in roots. Trees reach maximum height at 80 to 100 years old.

Western juniper occurs in all stages of succession. It is a topoedaphic dominant or "climax" species on rimrock and outcrops due to the lack of fuels needed to carry surface fires. Within its geographical range, it has been expanding into some adjacent shrub and bunchgrass steppes since the late 1800s. Expansion has been attributed to the coincident, interactive effects of reductions in fire frequency due to fire exclusion, cessation of Native American burning, livestock overgrazing and associated reductions in fine fuels, and climate variability (mild temperatures and above average precipitation in the late 1880s and early 1900s, and present trends in climate warming). Succession from a shrub steppe to a western juniper woodland transitional community is a slow process. The minimum time it takes for the western juniper overstory to begin suppressing the shrub understory is 30 to 50 years. It takes 45 to 90 years to approach stand closure on cool, moist sites and 120 to 170 years on warm, dry sites. Shrub cover declines as succession advances and western juniper canopies close.

Western juniper is sensitive to fire. Crown and severe surface fire kills tree of all age classes, although mature trees with thick bark may survive low-severity fire, and sometimes moderate-severity fire. Postfire establishment is by seed; this species does not sprout. Western juniper colonization of a burn occurs slowly, as its seeds disperse onto the burn and its seedlings establish and grow.

Western juniper communities experience both patchy, mixed-severity fires and stand-replacement surface and crown fires. While historical fire history is not well understood, limited data and models suggest fire intervals ranged from about 100 to >150 years in pure stands. Western juniper also occurs in communities with relatively frequent fire, such as ponderosa pine woodlands.

The nonnative annual grasses cheatgrass and medusahead have altered fire regimes in western juniper communities by providing more continuous fine fuels than what occurred historically, resulting in shorter fire intervals and longer fire seasons.

INTRODUCTORY

TAXONOMY

The scientific name of western juniper is *Juniperus occidentalis* Hook. (Cupressaceae) [71,89,90,109,214].

Sierra juniper was formerly classified as a subspecies of western juniper (*Juniperus occidentalis* subsp. *australis*) [80,223]. It is now classified as a distinct species (*Juniperus grandis*) [214] and is not covered in this Species Review.

Western juniper hybridizes with Utah juniper [85] and Rocky Mountain juniper. Hybridization in the *Juniperus* genus "abounds", so hybridization between western juniper and other juniper species is likely where western juniper and other juniper species cooccur [26].

Nomenclature:

Common names are used in this Species Review. See appendix A1 for a complete list of common and scientific names of plant and animal species mentioned in this review and for links to other FEIS Species Reviews.

The term "savanna" has been used to refer to both western juniper-bunchgrass [48] and western juniper-low sagebrush communities [145,187]. Where the plant community is not specified, "savanna" refers to both types. "Steppe" may refer to either shrub steppes or bunchgrass steppes [48]; where the plant community is not specified, "steppe" refers to both types. "Woodland transitional community" refers to communities in which western juniper is successionally replacing what had been a big sagebrush community.

Except when historical time frames are specifically provided in this synthesis, "presettlement" refers to the time period prior to European-American settlement in the Columbia and Great basins, which began around the early 1870s [145]. "Postsettlement" refers to the time after that.

SYNONYMS

Juniperus occidentalis subsp. *occidentalis* [80,223]
Juniperus occidentalis var. *occidentalis* [69,71,235]

LIFE FORM

Tree

DISTRIBUTION AND OCCURRENCE

SPECIES: Juniperus occidentalis

- **GENERAL DISTRIBUTION**
- **SITE CHARACTERISICS**
- **PLANT COMMUNITIES**

GENERAL DISTRIBUTION

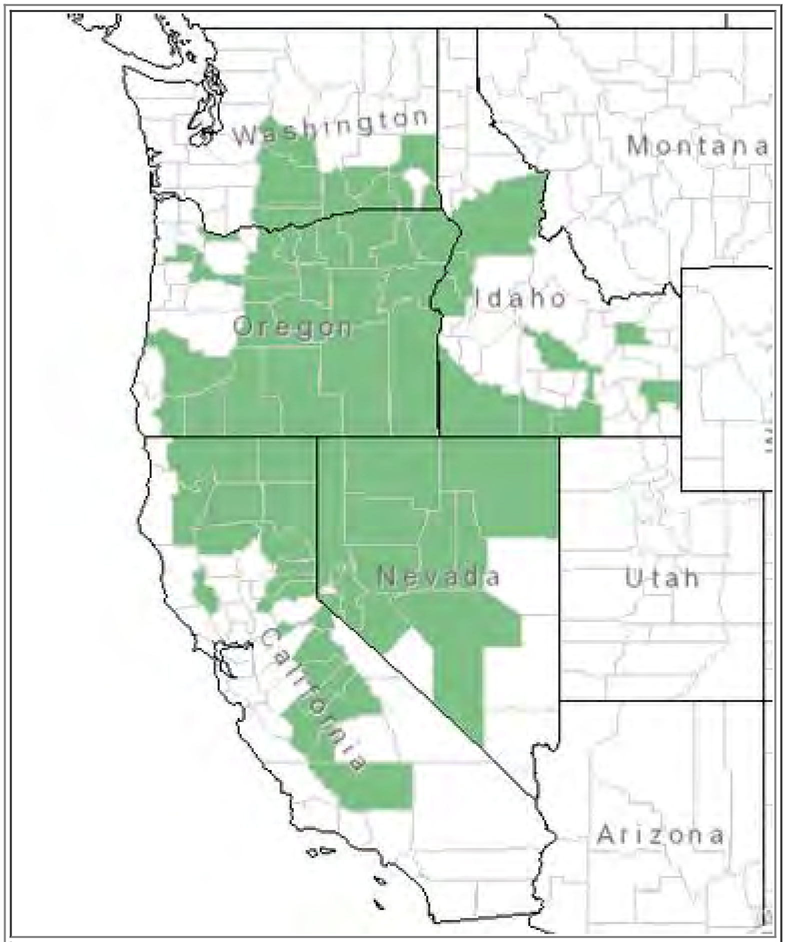

Figure 2—Distribution of western juniper. Map courtesy of Natural Resource Conservation Service, U.S. Department of the Interior [214] [2019, March 8].

Western juniper is native to the western United States. It is distributed from the Cascade Range in Washington east to southeastern Idaho and south to southern Nevada and southern California (fig. 2). In the early 1990s, the western juniper zone occupied approximately 42 million acres (17 million ha) across the Intermountain West [32,59,70] and approximately 4 million acres (1.6 million ha) in the Pacific Northwest [59].

Western juniper is expanding within the species' geographic range [145]. Miller et al. [145] described western juniper’s pace of expansion in the late 19th and 20th century as “unprecedented rates compared to any other time period during the Holocene”. Populations are expanding most rapidly and extensively east of the Cascade Range in Oregon [89,231]. In eastern Oregon, western juniper woodlands with >10% cover increased from 456,000 acres (184,500 ha) in 1936 to 2.2 million acres (890,000 ha) in 1988 (review by [145]).

States [214]:

CA	ID	NV	OR	WA

SITE CHARACTERISTICS:
Most of the western juniper zone has a continental climate with hot, dry summers and cool to cold winters, low mean annual relative humidity, low mean annual precipitation, and high winds [53,201,211]. Monsoons deliver summer rains in the eastern portion of western juniper's distribution [162], especially the eastern Great Basin [65]. Western juniper occurs in the most xeric of the tree-dominated zones [72]. Limited soil moisture [50] and shallow, rocky soils [57,145,149] are suggested as primary factors determining where western juniper established historically. Mean annual precipitation across western juniper zones ranges from around 8 to 13 inches (250-330 mm) [53,73,201]. Mean annual temperature ranges from 36 to 105 °F (2-41 °C), with an average July temperature of 66 °F (19 °C). The growing season rarely exceeds 130 days [201]. Mean annual precipitation in the western juniper zone of central Oregon ranges from 7.8 to 12.2 inches (198-310 mm), falling about equally as rain and snow [53,73].

Western juniper occurs from near sea level to more than 10,000 feet (3,050 m) elevation [201], but it generally dominates low to midelevation slopes [145,151]. Frosts and drought during the growing season generally restrict it to relatively narrow elevational belts [165], and cold winter temperatures keep it from growing at high elevations in northern portions of its range [145,151]. Elevations for juniper zones across the Columbia Basin range from <650 feet (200 m) for western juniper woodlands along the Columbia River in Washington [165] to >5,000 feet (1,500 m) for western juniper woodlands in central Washington [165,210]. The elevational climate gradient in the Great Basin is steep, with juniper zones above arid desert steppe zones and, on tall mountain ranges, below relatively mesic coniferous forest zones [139,162]. Elevations for western juniper zones of the Great Basin range from about 5,200 to 6,900 feet (1,600-2,100 m) [21,22,151]. Elevational ranges for western juniper in several states are as follows [84,201]:

3,000 to 10,000 feet (915-3,050 m) in California
3,000 to 7,500 feet (915-2,288 m) in central Oregon
600 to 1,800 feet (183-549 m) in eastern Washington [84,201].

Juniper woodlands occur in canyons and on flats, foothills, mesas, and playas [83,96,104,130,165,178,201] on all aspects and slope positions [49,50,53,83,96,104,130,164,178]. At low elevations, western juniper is most common on north slopes [73].

Soils of old-growth juniper woodlands are typically shallow [21,36,37,53,189,219,231] and low in organic matter content [189,219], and hence, unproductive [145]. Western juniper typically grows in soils with rapid infiltration, deep percolation, low evaporation, and low soil moisture [12,50], but it also grows on mesic and subirrigated sites [16]. It often grows on sites with perched water tables [72]. Soil depth in western juniper's root zone ranges from 10 to 15 inches (25-38 cm) to more than 48 inches (122 cm). Shallow soils may occur over broken, hardened subsoil layers or fractured bedrock [50]. Historically, juniper woodlands adjacent to shrub steppes, perennial bunchgrass steppes, or coniferous forests were usually restricted to rocky outcrops [104,165]. On the Deschutes and Fremont national forests, depths of <20 inches (51 cm) are reported for volcanic soils supporting western juniper/antelope bitterbrush/bunchgrass woodlands [224]. On the Wallowa-Whitman National Forest, soil depth ranges from 9 to 19 inches (23-48 cm) in western juniper/Idaho fescue-bluebunch wheatgrass savannas [104]. Western juniper does not grow on thin scablands of the Columbia Plateau [83,224], although it grows on adjacent deeper, more developed soils. Western juniper communities have expanded into big sagebrush communities with deep soils [92].

Western juniper grows on soils derived from igneous [48,53], sedimentary [83,161] and metamorphic [83] parent materials [44], including basalt, andesite, rhyolite, pumice, volcanic ash, and tuff [44,50]. These may be deposited in colluvial, alluvial, and eolian mixtures [23,65,92,165].

All soil textures are represented in the western juniper zone [21,23,53,65,83,104,178]. Soils are often medium-textured with abundant coarse fragments [48]. Western juniper-bunchgrass savannas often have fine-textured soils [174]. Surface soils are often slightly to moderately acidic sandy loams or coarse sands [72,219]. Western juniper dominates shifting sand dune communities in south-central Washington [2]. On steppes of southeastern Washington, western juniper/antelope bitterbrush-big sagebrush/cheatgrass communities occur on stable dunes widely separated by unstable dunes [48]. Western juniper also grows on finely-textured calcareous soils [5]. Levels of calcium, potassium, and pH are generally higher under mature western junipers than in interspaces [49,50].

PLANT COMMUNITIES:
Western juniper occurs in woodland, savanna, and sagebrush communities. Miller et al. [145] separate old-growth juniper communities into three categories based on stand structure:

- Small stands isolated on rocky outcrops and ridges. Understories are typically sparse.
- Woodlands with tree canopies of usually 10% to 20%, but occasionally >35%. Shrubs (usually big sagebrush) and bunchgrasses dominate the understory.
- Savannas with tree canopies of <10%. They are described as "savanna-like" with sagebrush (usually low sagebrush), perennial grasses, and forbs.

They use a fourth category describe postsettlement shrub steppes succeeding to juniper woodlands [145]:

- Woodland transitional; these are western juniper-big sagebrush communities in successional stages ranging from open stands of juniper with shrub and herb understories (early succession) to nearly closed canopies with sparse understories (late succession); herein, referred to as woodland transitional communities.

Western juniper woodlands and savannas usually occupy the zone above sagebrush or other shrubland vegetation [70,110] (fig. 3). At low elevations, western juniper communities are often intermixed with and grade into sagebrush steppes [9,165,210] or bunchgrass steppes [70,104,165,210]. On deep soils, deep-rooted bunchgrasses (e.g., bluebunch wheatgrass) generally dominate the ground layer of western juniper savannas [145]; on shallow soils, Idaho fescue generally dominates. In the Columbia and the northern Great basins, western juniper is usually the only tree present in the juniper zone [72,201]. It occupies the highest vegetation zone in central portions of the Columbia Basin. Western juniper woodlands adjoin higher-elevation ponderosa pine and ponderosa pine-lodgepole pine communities on the western [53,70,132,145,165,210] and eastern [29] boundaries of the Columbia Basin, the Great Basin [145], and in the Blue Mountains [83]; and finger into quaking aspen stands on mesic sites [72]. Pinyons are not as cold tolerant as western juniper, so they do not codominate with western juniper in most of western juniper's range. However, singleleaf pinyon codominates with western juniper on some sites in the Ruby Mountains of Nevada [130] and north-central Nevada [23].

The shrub and groundlayer understories are typically sparse in old-growth juniper stands. Dominant or important shrubs in western juniper communities include antelope bitterbrush, black sagebrush, curlleaf mountain-mahogany, low sagebrush, mountain big sagebrush, rubber rabbitbrush, scabland sagebrush, spiny hopsage, spineless horsebrush, Wyoming big sagebrush, and yellow rabbitbrush. Dominant or important herbaceous species include the native species arrowleaf balsamroot, basin wildrye, bluebunch wheatgrass, Idaho fescue, littleseed ricegrass, prairie Junegrass, needle and thread, Sandberg bluegrass, squirreltail [56,72,201], and Thurber's needlegrass; and the nonnative species herb sophia, tall tumblemustard [63,64,234], cheatgrass, and crested wheatgrass [53,94,165].

Figure 3—Mountain big sagebrush zone (foreground and middle ground) and western juniper zone (background) in central Oregon. Forest Service, U.S. Department of Agriculture image by Janet Fryer.

Western juniper is described as a dominant or indicator species in these vegetation classifications:

- International Ecological Classification Standard: Terrestrial Ecological Classifications of the United States and Canada [165]
- Woodland classification: The pinyon-juniper formation [108]
- Plant associations of the Wallowa-Snake Province: Wallowa-Whitman National Forest [104]
- Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington [83]
- A relict area in the central Oregon juniper zone [52]
- Plant associations of the Fremont National Forest [95]
- Plant associations of south Chiloquin and Klamath Ranger Districts, Winema National Forest [94]
- Great Basin pinyon and juniper communities and their response to management [65]
- Plant communities and habitat types in the Lava Beds National Monument, California [61]
- Forest/environment relationships in Yosemite National Park, California USA [170]
- A vegetation classification system applied to southern California [173]
- Vegetation types of the San Bernardino Mountains [97]

See appendix A2 for lists of plant community classifications in which western juniper occurs.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Juniperus occidentalis

GENERAL BOTANICAL CHARACTERISTICS

Botanical Description: This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [71,89,90,91]).

Western juniper has a rounded or pointed form (fig. 4). It typically grows 15 to 30 feet (4.5-9 m) tall [201] and rarely exceeds 60 feet (18.3 m) tall. The largest recorded specimen grows in Oregon; it is 78 feet tall (24 m), with a circumference of 19 feet (5.5 m) and crown spread of 42 feet (13 m) [4]. Trees develop full crowns and heavy lateral branches at maturity [49]. Bark is furrowed and shreddy [62]. It is thin on young trees, becoming thicker as trees age [54,201]. Foliage of mature trees grows in scales [91]. The female (seed) cones resemble berries. They typically contain 1 to 4 (rarely up to 12) seeds each [137].

Figure 4—Presettlement tree with rounded form and widespread lateral branches (upper image) and postsettlement trees with pointed form and upright branches (lower image). Forest Service images by Janet Fryer.

Western juniper has a well-developed root system; lateral roots are usually longer than taproots in shallow soils. Trees develop massive lateral roots and fine surface roots as they age. Young et al. [233] reported that in Lassen County, California, most roots of mature western junipers were located in the upper 30 inches (75 cm) of a 40-inch (100-cm) deep soil profile. Large lateral roots commonly extended to a distance that equaled tree height, but in some cases, roots extended as much as three times tree height [233]. Taproots averaged 51 inches (130 cm) deep on two wooded mountain big sagebrush shrublands in central Oregon. Root-to-shoot ratio decreased and root density increased with tree age [116].

Western juniper is slow growing and long-lived [62]. Individuals may exceed 1,000 years old [145,201]. The oldest known living western juniper grows east of Bend, Oregon, and is about 1,600 years old [145].

Stand Structure of western juniper woodlands is highly variable, ranging from very open to closed stands [53,132,145]. For juniper communities, cover of >40% is considered a closed canopy [210]. As western junipers increase cover, they generally outcompete understory vegetation for light, soil moisture, nutrients [66], and root space [210,231]. Presettlement, old-growth woodlands and savannas are generally very open [145,165], with western junipers assuming a rounded form. Miller et al. [145] noted that old-growth stands on Juniper Mountain, central Oregon, were "an exception", with denser canopy cover (25%-60%). Postsettlement stands may be closed, with pointed rather than rounded tree form [145,165] (fig. 4). Western juniper density in late-successional woodland transitional communities can exceed 500 trees/acre (1,200/ha) if subcanopy trees are included [145]. Because many of these trees are seedlings hidden beneath sagebrush canopies, these stands may not appear as dense as they really are [16].

Historically in central Oregon's pumice region, western juniper savannas and savanna-like communities (some shrubs but a mostly herbaceous understory) had <10% canopy cover, while old-growth woodlands had 10% to 25% canopy cover [165]. Stands on deep soils are susceptible to infill, with stands becoming increasingly dense over time [147].

Shrub steppes that are converting to woodland transitional communities are common in the Columbia Basin. NatureServe [145,165] reports that open, presettlement stands (those that established before the early 1900s) and younger, more closed postsettlement stands (established later) [145] of western juniper were about equally distributed in Columbia Basin in the 2000s [165]. Height and basal diameters of western juniper are usually less in dense, postsettlement stands than in open, presettlement stands [165]. Cover of shrub and herbaceous species declines as western juniper canopies close. With more than about 40% canopy cover, shrub and herbaceous layers generally become sparse to absent [210,227] (see Successional Status), although Idaho fescue may persist [210].

Raunkiaer [184] **Life Form**

Phanerophyte

SEASONAL DEVELOPMENT

Most western juniper seed germinates in spring [201]. In Oregon, seeds germinate in April [49], and foliage begins elongating in June. Sapwood growth starts in spring and usually ends in early to late August, depending on site and annual precipitation [145,176]. Branch and foliage growth peaks in June and July [142,145]. Across western juniper's range, annual turnover rate of leaf scales is 15% to 20% [144]. Cones develop from mid-April to mid-May [103,144,201], and pollen disperses in May [103,144,201]. Female cones develop 2 weeks after the male cones; female cones require 2 years to mature [26,144,195]. Female cones mature in mid-September of their second growing season [103]. The berry-like female cones are blue-green prior to ripening and bluish-black and glaucous when mature [103] (fig. 5). Female cones may persist on branches for 2 to 3 years [137].

REGENERATION PROCESSES

Western juniper establishes from seed. It produces few female cones until around 50 years old. Gravity, water runoff, and animals disperse the seed. Seed is stored in tree crowns and soil. Fresh seeds are dormant, and passage through animal digestive tracts speeds germination rate. Early growth is concentrated in roots. Maximum height is attained at 80 to 100 years old.

- **Pollination and Breeding System**
- **Seed Production**
- **Seed Dispersal**
- **Seed Banking**
- **Germination**
- **Seedling Establishment**
- **Plant Growth and Mortality**
- **Vegetative Regeneration**

Pollination and Breeding System: Western juniper is wind pollinated [192]. Junipers are monoecious or dioecious [26,213]. Western juniper trees may produce primarily female or primarily male cones, depending on genetics and site characteristics [16,57]. Environmental triggers for initiation of male and female cones had not been well-identified as of 2005 [145]. Studies in Oregon found that overall, 40% to 50% of trees in a given population produced only female cones, about 10% produced only male cones, and most of the rest produced both female and male cones. Trees under stress produced no cones or only male cones, while those in widely spaced woodlands, on woodland edges, or in small patches produced mostly female cones [16]. In southeastern Oregon, the ratio of male to female western junipers was higher in closed stands (3.8**:**1) than in open stands (1.7**:**1) [151].

Seed Production: Female cones are first produced around 20 years of age [231], but few are produced until around 50 to 70 years of age [57,59,151]. Cone production is tied to foliage development. Western juniper has polymorphic needles that develop with age. Foliage of juvenile trees is spiny, and trees do not produce cones while in the spiny-needle stage. Foliage of adult trees is scaly; trees begin cone production in the scaly-needle stage [231].

Mature western junipers produce seeds nearly every year [200], although seedcrop production is highly variable across sites and years. Mature trees bear some cones every year, with large crops every 2 to 5 years [213] for stands in midsuccession (10%-30% canopy cover). Bedell et al. [16] report that in Oregon, trees 30 to 40 feet tall (9-12 m), or about 90 to 100 years old, produce as many as 45,000 female cones in exceptionally productive years. Overall cone production is low in dense stands [16,145,153]. Western junipers bordering clearings or roads typically produce more female cones than trees in denser stands [57]. Cone production is "limited" in old-growth stands [127].

Seed Dispersal: Gravity, water runoff, and animals disperse western juniper seeds [137,145]. Many seeds fall beneath or near the parent tree (fig. 5). In southwestern Idaho, seeds dispersed an average of 4.7 feet (1.4 m) downslope and 2.0 feet (0.6 m) upslope over 4 months (summer-early fall), with an average dispersal distance of 4.2 feet (1.3 m) over 6 months. Dispersal from water runoff accounts for most downslope seed movement. Spring runoff traveling across frozen soil may account for high densities of western junipers along waterways [57] (fig. 6).

Figure 5—Western juniper female cones that fell in litter beneath the parent tree. Forest Service image by Janet Fryer.

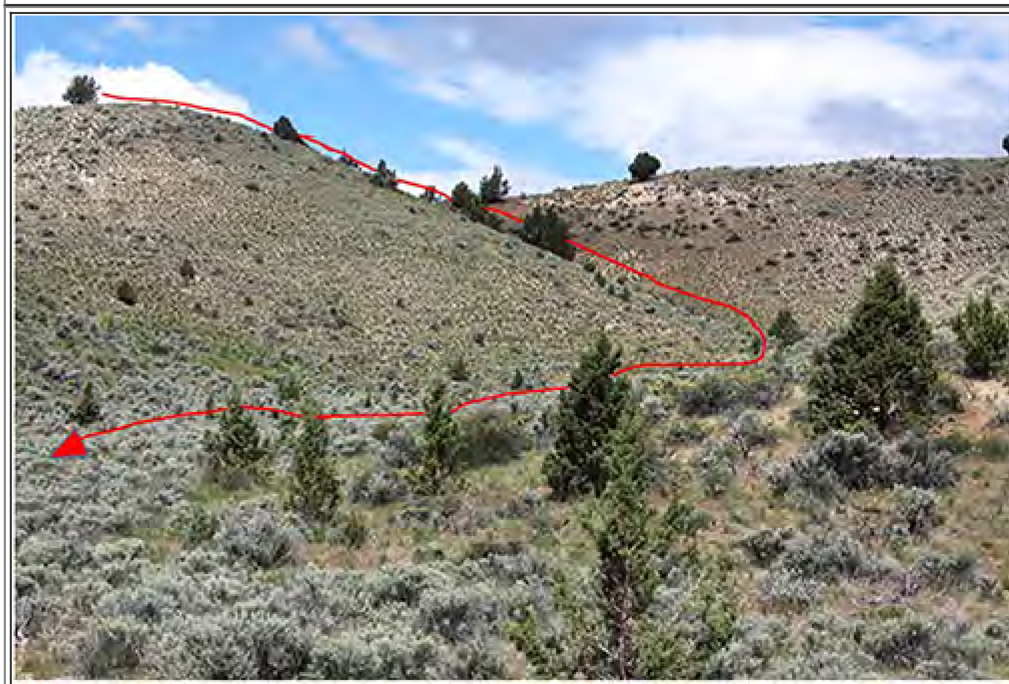

Figure 6—Downhill seed dispersal by gravity and water runoff likely assisted with western juniper establishment along these draws in central Oregon. Forest Service image by Janet Fryer.

Uphill and long-distance seed dispersal is primarily due to animals. On the Owyhee Plateau of southwestern Idaho, mean maximum seed dispersal was 4.66 feet (1.42 m) downslope and 1.97 feet (0.60 m) upslope. Downslope dispersal was attributed to gravity; upslope dispersal to animals [37].

Birds and mammals that feed on the berry-like female cones are important seed dispersers [51,145]. Wintering birds such as the California scrub-jay, Steller's jay, American robin, and Townsend's solitaire eat and disseminate large numbers of western juniper seeds [57,136,159]. Townsend's solitaries can consume over 80 female cones/day [145]. Most bird species have short gut-retention times and fly short distances to perch and digest the cones, which limits dispersal distance [41,145,194]. Elk, mule deer, coyote, lagomorphs, and rodents including woodrats and ground squirrels also disperse western juniper seeds [37,195]. Schupp et al. [195] report that coyotes are the most important mammalian seed dispersers. Livestock disperse the seeds via soil disturbance, but they generally do not ingest the seeds [37,145]. Burkhardt and Tisdale [37] stated that the lack of disjunct stands of western juniper in southwestern Idaho suggests that long-range seed dispersal by animals is infrequent there.

Seed Banking: Western juniper has a persistent, soil-stored seed bank [26,212]. Some mature seed is retained in crowns and branches for 2 to 3 years before cones disperse [137]. Information on longevity of soil-stored seed was not found in the literature as of 2019.

Germination: Germination of western juniper seeds is delayed due to impermeable seedcoats (physical dormancy) and temperature constraints (physiological dormancy). Fresh western juniper seed is dormant [26,145]. Germination has been described as "erratic and unpredictable" [232]. Tueller [212] reports that germination in junipers "is not a straight-forward process, but one that requires a specific sequence of environmental conditions for natural germination and seedling establishment." Prolonged cool-moist stratification enhances germination. Stratification is cumulative from year to year, suggesting that germination of a particular seed crop may span several years [145]. Passage through the digestive tract of animals speeds up rates of germination [37,202].

Seedling Establishment: Microsites that modify dry environments increase establishment, survival, and growth rates of western juniper seedlings [145]. Light shade, which is often provided by nurse plants, appears critical for juniper establishment [37,58,59,151,182]. In southwestern Idaho, soil surface temperatures under sagebrush or juniper canopies during the summer averaged 91 °F (33 °C) and 79 °F (26 °C), respectively, while those on bare ground reached 140 °F (60 °C). Microsites under big sagebrush and junipers accounted for <25 % of total area available, yet supported >75% of established western juniper seedlings [37]. In central Oregon and southwestern Idaho, most postfire juniper regeneration was confined to protected microsites under remnant live trees or dead tree crowns [182]. On the Owyhee Plateau, western juniper establishment was positively associated with valley slopes and bottoms and with areas rich in forbs. Cover of western juniper seedlings was higher under trees, shrubs, or bluebunch wheatgrass than on open, unprotected sites. Most seedlings established on the north side of existing trees, where they were protected from intense solar radiation [37]. In southeastern Oregon, juvenile western junipers grew faster under sagebrush plants than under either other junipers or in open space [151]. In central Oregon, seedlings established on different microsites as follows [57]:

under big sagebrush: 47%
under western juniper: 15%
under bunchgrasses: 14%
in the open: <1% [57].

Birds excrete while perching, and this aids seedling establishment by positioning seeds in protected microsites. Western juniper seedlings are often found along fences, hedges, or under shrubs and trees where large numbers of birds perch [137,201,231]. Both a disproportionate amount of western juniper seed excreted beneath shrubs and shrub nurse-plant facilitation are attributed to high rates of western juniper establishment under shrubs [145].

Relatively cool, wet summers favor survivorship of western juniper seedlings [145,199]. Limited information suggests that overall survival rates for western juniper seedlings are high [37,199].

Plant Growth and Mortality: Soils beneath a sagebrush canopy can have nearly twice the moisture content and nitrification than bare soils in interspaces [185], resulting in increased western juniper growth. In southeastern Oregon, growth rates of western juniper juveniles were higher under mountain big sagebrush canopies (1.34 inches (3.40 cm)/year) than in interspaces (0.95 inch (2.4 cm)/year) [151]. Cooler temperatures and higher relative humidity beneath sagebrush canopies provide conditions for more favorable transpiration by juvenile foliage, which has poorer stomatal control and lower water-use efficiency than foliage of mature western junipers [142]. In contrast, survival and growth rates of western juniper seedlings that establish beneath parent or other tree canopies were low [145].

Seedling growth is concentrated on root development [145]. During their first 10 years, western juniper seedlings develop a long taproot, and they have limited lateral root development [117,145]. Lateral root growth increases as trees mature. Lateral roots account for about 65% of total root biomass in trees 30 to 35 years old [140,145].

Aboveground growth is relatively slow for western juniper, averaging 1.18 to 1.58 inches (3.00-4.01 cm)/year in height for the first 10 years and increasing to 3.54 to 6.57 inches (8.99-16.69 cm)/year for trees up to 100 years old (unpublished data cited in [145]). In central Oregon, height growth averaged 3.5 inches (8.9 cm)/year for suppressed or subcanopy trees and 6.6 inches (16.8 cm)/year for dominant or canopy trees [58]. Annual incremental growth of western juniper woodlands and woodland transitional communities in central Oregon is shown in table 1. The author noted that these stands were "probably not very productive" compared to many western juniper stands in the area. He noted that on ponderosa pine-western juniper ecotones, western junipers sometimes exceeded 10 inches (25 cm) of annual incremental growth [57].

Table 1—Annual increment growth of western juniper woodland and woodland transitional communities near Prineville, Oregon [57].

Stand structure (western juniper successional position)	Western juniper height growth (inches (cm))	Western juniper diameter growth (inches (cm))
Open (dominant)	3.5 (9)	0.3 (0.8)
Closed (subdominant)	1.2 (3)	0.05 (0.2)
Closed (young)	3.5 (9)	0.1 (0.4)
Maximum	4.3 (11)	0.5 (1.3)

Annual tree ring growth (i.e., diameter growth) is strongly related to local climatic conditions [180]. Wet, mild conditions promote most rapid growth [75,93,145]). Diameter growth declines as stands close [145].

Western juniper typically reaches maximum height at 80 to 100 years old across its geographic range (unpublished data cited in [145]). Mean height of 80-year-old western junipers in eastern Oregon varied from about 18 to 50 feet (5-15 m) [77].

Excluding death from fire (see Fire Adaptations and Plant Response to Fire), mortality of western juniper is low past the seedling stage [221]. Relatively few pests or diseases affect this species [120] (see Other Management Considerations).

Vegetative Regeneration: Western juniper does not naturally reproduce vegetatively [49].

SUCCESSIONAL STATUS

Western juniper occurs in all stages of succession [145]. It is shade intolerant when mature [49,50]. Western juniper is an indicator of late succession in shrub steppes [132].

Isolated old-growth, late-successional western juniper stands are generally restricted to "fire-safe" rimrock, outcrops, the edges of mesas, and upper hillslopes [145,219,231]. Western juniper is a topoedaphic dominant or "climax" species on rimrock and outcrops due to the rocky substrate and lack of fuels needed to carry surface fire [2,36].

Seral or postsettlement western juniper stands generally dominate low slopes and valley bottoms adjacent to old-growth stands [219]. Multiple age classes are typically represented in seral stands [220]. With >100 years of succession, many postsettlement stands have transitioned from initial succession—where seedlings establish in shrub steppes—to mature trees with closed canopies [106,145]. A 2007 study in sagebrush-juniper zones of John Day Ecological Province, central Oregon, found only 26% of sites surveyed contained presettlement western junipers based on growth form (see fig. 4), and <5% of all western junipers surveyed were presettlement trees (n = 178 sites and 2,254 trees). Across sites, mean density of presettlement western junipers ranged from 1 to 7 trees/acre (2.5-18/ha), while that of postsettlement western junipers ranged from 30 to 185 trees/acre (75-457/ha) [191].

Western juniper has been expanding into some adjacent steppes and forests since around 1870 [17,145]. Across its geographic range, it is expanding into adjacent mountain, Wyoming, and basin big sagebrush, low sagebrush, scabland sagebrush, and curlleaf mountain-mahogany [145] shrub steppes; perennial grassland steppes [17,59,87,145,152,226]; ponderosa [88,145] and Jeffrey pine [147] forests; and quaking aspen stands [151,205]. Additionally, its density is increasing (infill) within western juniper zones [127,145]. Comparisons of extent of juniper communities in the late 1800s with that of the late 1990s found large increases in western juniper cover types in the Columbia Plateau, Owyhee upland, Snake Headwaters, Blue Mountain, Upper Klamath, and Northern Great Basin provinces ($P < 0.2$). Cover of the western juniper cover type approximately doubled in the Columbia Basin from the late 1800s to the late 1900s [87,88], particularly in central and eastern Oregon [188]. For example, near Prineville, Oregon, western juniper began expanding into an adjacent mountain big sagebrush/Sandberg bluegrass community in the early 1880s. None of the western junipers sampled (n = 645 total individuals on six 0.2-ha units) had established before 1880. By 1980, density of western juniper was >400 stems/acre (1,000/ha) [58]. Rate of expansion into low sagebrush communities has been slower than expansion into big sagebrush communities [3,152].

Western juniper expansion has been attributed to the coincident, interactive effects of reductions in fire frequency due to fire exclusion [87,152,226] and cessation of burning by American Indians [9]; heavy livestock grazing and associated reductions in fine fuels in the late 19th and early 20th centuries [59,87,151,152,226]; climate variability (mild temperatures and above-average precipitation in the late 1880s and early 1900s); and increases in atmospheric carbon dioxide that foster rapid western juniper growth [107,113,151,154,156].

Succession from a shrub steppe to a woodland transitional community is a slow process. The minimum time for the western juniper overstory to begin suppressing the shrub understory is 30 to 50 years [31,145]. It takes 45 to 90 years for western juniper to approach stand closure on cool, moist sites and 120 to 170 years on warm, dry sites [105,145]. Near Prineville, Oregon, postsettlement western junipers with a maximum age of nearly 100 years dominate former mountain big sagebrush communities [220].The successional progression from shrub steppe to woodland transitional community has been assigned to three or four phases (fig. 7):

- Phase I: Western juniper is present but shrubs and herbs are the dominant vegetation.
- Phase II: Western juniper codominates with shrubs and herbs.
- Phase III: Western juniper dominates; native shrubs and herbs are reduced, although cheatgrass is often present [127,145,153,190].

Shrub cover declines as succession advances and canopies close [1,34,36,145,153,185,193]. By phase III, shrub cover is typically <1% on dry sites with sagebrush and ≤5% on mesic sites with less drought-tolerant shrubs such as wax currant and mountain snowberry [153]. A closed canopy-stage is sometimes included:

- Phase IV: Western juniper dominates, shrubs are few (<10% cover) or dead, and cover of native herbs is scarce [153,160]. Cheatgrass may dominate groundlayer vegetation in phase IV (see fig. 7).

Herbaceous cover usually declines with canopy closure [145,153]. Studies in northeastern California and southeastern Oregon found cover of the dominant grass declined significantly as western juniper canopies closed on dry sites. On dry-site western juniper/mountain big sagebrush/Thurber's needlegrass communities, Thurber's needlegrass cover averaged 16% on plots in early succession (≤10% canopy cover) and 5% on plots in late succession (50%-80% canopy cover, $P = 0.001$). On mesic-site western juniper/mountain big sagebrush/Idaho fescue communities, however, there were no significant differences in Idaho fescue cover in early and late succession [153]. On Steens Mountain, Oregon, abundance and diversity of herbs increased after removal of the western juniper overstory. Herbaceous cover averaged 2% and biomass 34 lbs/acre (38 kg/ha) prior to tree removal. Two years after tree removal, herbaceous cover averaged 6% and biomass 293 lbs/acre (328 kg/ha, $P < 0.05$ for all variables) [14]. Miller et al. [145] suggest that herbaceous cover and biomass decrease as soil moisture decreases with increasing western juniper cover.

Figure 7—Stages of succession in woodland transitional western juniper/mountain big sagebrush communities in Oregon.

Phase I. Early succession in a potential western juniper/mountain big sagebrush community in central Oregon. Cover is mostly sagebrush with scattered juniper seedlings and saplings. Forest Service image by Janet Fryer.

Phase II. Midsuccession in a western juniper/mountain big sagebrush community near Lakeview, Oregon. Cover is about an even mix of sagebrush and juniper. Bureau of Land Management, U.S. Department of the Interior image by Todd Forbes.

Phase III. A western juniper-mountain big sagebrush woodland on Steens Mt., Oregon. Sagebrush cover is minimal. Agricultural Research Service, U.S. Department of Agriculture image.

Phase IV. Late succession in a western juniper/mountain big sagebrush/bluebunch wheatgrass-cheatgrass woodland in Wheeler County, Oregon. The western juniper canopy is closed and the sagebrush has died off. Forest Service image by Janet Fryer.

FIRE EFFECTS AND MANAGEMENT

SPECIES: Juniperus occidentalis

FIRE EFFECTS

Immediate Fire Effects on Plant

Crown and severe surface fires kill western juniper of all age classes [9,20]. Low- and moderate-severity surface fires kill most young trees, which have thin bark [201]. Several authors report that fire readily kills western junipers under 4 to 6 feet (1-2 m) tall [35,131]. Mature trees with thick bark, little fuel near the bole, and foliage that does not extend to the ground can survive low-severity surface fire [9,131,201], and possibly moderate-severity surface fire [147]. If the crown is scorched, the tree dies [131,134]. In general, the taller the juniper, the greater the intensity of the fire required to kill it [131]. In central Oregon, a prescribed headfire set in July—when air temperature was moderate (80 °F (24 °C)) and relative humidity low (10%)—killed all western junipers <15 feet (4.5 m) tall. Survival averaged 37% for trees >16 feet (4.8 m) tall [131].

Figure 8—Fire-caused mortality from scorching (background trees) and torching (foreground trees). Forest Service image by Janet Fryer.

On the Reynolds Creek Experimental Watershed, southwestern Idaho, vegetation type, tree height, percent bare ground, and firing technique were the most significant variables predicting western juniper mortality from fire. After prescribed burning on 16 and 24 September 2002, western juniper mortality was greatest in the antelope bitterbrush-mountain big sagebrush/bluebunch wheatgrass community, intermediate in the mountain big sagebrush-mountain snowberry/bluebunch wheatgrass community, and least in the bluebunch wheatgrass-Sandberg bluegrass-squirreltail bunchgrass community. Percent mortality decreased with tree height and increasing bare ground, and was greater for headfires than for backfires (table 2). The antelope bitterbrush community had the heaviest fuel loads, and western junipers in that community were eight times more likely to be killed by fire than western junipers in the mountain big sagebrush community, where fuel loads were lighter. Probability of mortality decreased by 28.8% for each 3-foot (1-m) increase in tree height. Trees exposed to headfire were three times more likely to be killed than those exposed to backfire [42]. See the Research Paper of this study for details.

Table 2—Mortality from tall (>4.50 feet (1.37 m)) and short (<4.50 feet) western juniper trees on the Reynolds Creek Experimental Watershed, Idaho. Data are means [42].							
Variable		Tall trees			Short trees		
		Dead (#)	Alive (#)	Mortality rate (%)	Dead (#)	Alive (#)	Mortality rate (%)
Firing technique	headfire	61	15	80.3	47	5	90.4
	backfire	17	13	56.7	15	3	75.0
Vegetation type	mountain big sagebrush	23	13	63.9	25	0	100
	antelope bitterbrush	45	5	90.0	26	0	100
	bunchgrass	9	7	56.3	10	7	58.8
Hillslope position	footslope	35	15	70.0	34	6	85.0
	backslope	38	11	77.6	20	2	90.9
	shoulder	4	0	100	3	1	75.0
	summit	1	2	33.3	5	1	83.3

Postfire Regeneration Strategy [204]

Tree without adventitious buds and without a sprouting root crown
Secondary colonizer (on- or off-site seed sources)

Fire Adaptations and Plant Response to Fire

Mature western junipers develop bark thick enough to protect them from at least low-severity surface fire [131,168,201]. Fire scars have been observed on western junipers in fuel-limited low sagebrush communities that lacked perennial grasses [37,231].

Western juniper does not sprout after fire [37,168]; it establishes only from seed. Surviving and off-site parent trees are seed sources for western juniper establishment on burns [134]. Gravity, water runoff, and cone-eating birds and mammals disperse western juniper seeds onto burned sites from both on- and off-site seed sources [51]. Postfire recovery time (time required to regain prefire or unburned cover) depends on prefire stand maturity, the size and severity of the fire, location of seed source, species and number of animal dispersers, and postfire weather [37]. Large fires, drought, long distances from seed sources, and absence of nurse shrubs slow recovery times [35,145].

Western juniper colonizes burns slowly, as its seeds disperse onto the burn and its seedlings establish and grow [37,53]. Pace of postfire seed dispersal can be slow. On four burns in southwestern Idaho, gravity and water dispersal of western juniper seeds averaged 10 feet (3 m)/year [37]. Shrubs are important for postfire establishment. They provide perching-dispersal sites for birds that eat the cones [145], and shrubs act as nurse plants that facilitate establishment of western juniper seedlings [37,145,151] (see Regeneration Processes). When fire removes much or all of the shrub layer, there may be a lag time between fire and postfire establishment of western juniper [37,60,145]. Thirty to 50 postfire years are required before western juniper begins overtopping shrubs on a burned site [31,105,145]. It takes about 70 to 90 years to approach stand closure on cool, moist sites and 120 to 170 years on warm, dry sites [105,145] (see Successional Status).

Time-since-fire for big sagebrush recovery varies with site and subspecies. Mountain big sagebrush may reach 20% to 30% cover within 16 [163] to 35 postfire years [147,149], but recovery may take >70 years [163]. Analyses by Innes (2018, 2019) found mountain big sagebrush sites tended toward full recovery (≥28% canopy cover) 26 to 30 years after fire; however, not all burns >25 years old were fully recovered [99]. For Wyoming big sagebrush sites, full recovery did not occur within 66 years since fire [100].

Soil moisture availability is critical to postfire establishment of big sagebrush [24,25,147]. Wyoming big sagebrush generally occurs on warmer, drier sites than mountain big sagebrush, and cheatgrass is a more effective competitor for early-season soil moisture on Wyoming big sagebrush sites than on the cooler, moister mountain big sagebrush sites [147]. Thus, postfire recovery of Wyoming big sagebrush can be very slow to nearly nonexistent [98,147,183]. Postfire recovery of mountain big sagebrush and Wyoming big sagebrush is discussed in detail in the FEIS Species Reviews.

FUELS AND FIRE REGIMES

- **Fuels**
- **Fire Regimes**

Fuels: Western juniper is highly flammable; its foliage is more resinous than that of most conifers [168,222]. Ash and heat content of western juniper fuels in California are shown in table 3 [222].

Table 3—Mean ash and heat content of western juniper fuels [222].

Variable	Foliage	Litter	Cones	Woody fuel
Ash content (%)	4.26	5.31	3.42	1.35-2.80
Heat content with ash (mJ/kg)	23.64	22.53	23.68	20.04-20.27
Heat content without ash (mJ/kg)	24.70	23.79	24.51	20.31-20.66

Several authors have developed regressions estimating western juniper leaf area, leaf biomass, and total standing crop using tree basal and sapwood areas [79,148]. Field guides [203,215] for estimating fuel loads in sagebrush steppe and western juniper woodlands are also available.

Low productivity limits fuel accumulation in old-growth stands [145], and surface fire does not carry well in open stands of mature western juniper with sparse understories [31,38] (e.g., on rimrock or sand dunes [2]), although these communities may carry crown fire with high winds. Shrub and herbaceous fuels decrease as succession advances in woodland transitional communities, making surface fires less likely.

Western juniper communities are susceptible to invasion by nonnative annual herbs in all stages of succession, particularly in phase IV [145]. Annual grasses such as cheatgrass and medusahead often dominate postfire plant communities (fig. 8), and once established, they greatly increase surface fuel continuity and hence, the potential for and recurrence of wildfires [6,11,40,150,172,186,231]. Soil moisture availability can affect cheatgrass productivity and thus affect surface fuels on a site. Drought years may reduce the dominance of cheatgrass in both recently burned and unburned areas, thus decreasing fuel loads and the chance of fire [40,112,147]. Nonnative annual mustards [216] such as herb sophia and tall tumblemustard may also provide fine fuels [217], and their litter may aid in establishment of cheatgrass [63,64]. Tall tumblemustard in particular often occurs with cheatgrass; it is one of the most widespread, invasive nonnative forbs in the Great Basin [181,234].

Figure 9—On this site in east-central Oregon, past fire has removed most mountain big sagebrush and all western juniper from the hillslope in the foreground. Cheatgrass established in the postfire environment, and the hillslope is covered with fine, continuous cheatgrass fuels. Forest Service image by Janet Fryer.

Fire Regimes: Presettlement fires were ignited by lightning and American Indians [81,82]. Fires generally burned in mid- to late summer, after herbaceous species had cured (review by [35]). Fire of all types—including surface; patchy, mixed-severity [88,172]; and stand-replacement crown fires [110,135]—occurred in presettlement juniper woodlands and savannas. Limited data and LANDFIRE [119] models suggest fires were infrequent in many pure juniper stands, occurring at intervals of ~100 [119] to ≥150 years [149,158]. Fire severity was probably historically low to moderate in old-growth stands on rocky, shallow soils [147]. Most fires in western juniper woodlands and savannas were probably small due to dissected terrain and sparse fuels [33,158]. In western juniper woodlands of the San Bernardino Mountains of California, infrequent canopy fires have resulted in a mosaic of fairly small, scattered patches of uniformly-sized western junipers [225]. Low-severity fires were apparently frequent in some ponderosa pine-western juniper woodlands, with fire intervals ranging from around 7 to 17 years [134,157].

Altered fuel loads and stand structure due to successional advancement, climate change, and invasive, nonnative annual grasses have altered fire regimes in many western juniper and adjacent steppe communities [36,37,138,145,152,182]. In adjacent mountain big sagebrush communities, fire intervals of 26 to 30 years [101] historically helped restrict western juniper to mostly rocky, shallow soils with sparse fuels [2,37,145]. Burkhart and Tisdale [37] stated that 30- to 40-year return intervals are sufficient to keep western juniper from persisting in sagebrush-steppe communities.

The nonnative annual grasses cheatgrass [6,11,112,147,166,172,186] and medusahead [74,112,126,166,206] have altered fire regimes in western juniper communities by increasing continuity of surface fuels, resulting in shorter fire intervals and longer fire seasons than what occurred historically [6,11,40,150,172,186,231]. Cheatgrass fires tend to burn fast and cover large areas, with a fire season 1 to 3 months longer than that of native rangelands [6,11,150,172,186]. Frequent fire gives cheatgrass and medusahead a competitive advantage in western juniper-sagebrush ecosystems. The grass/fire cycle is self-promoting because it reduces the ability of many perennial grasses and shrubs to reestablish and furthers the dominance of annual grasses [11,28,47,175,177].

In general, warm, dry sites are more vulnerable to cheatgrass invasion than cooler, moister sites, and south-facing slopes and shallow soils more vulnerable than north-facing slopes and deep, loamy soils supporting bunchgrasses [127]. Cool-moist, high-elevation sites, such as Jeffrey pine-western juniper sites on the east slope of the Sierra Nevada, are apparently more resistant to invasion by nonnative annual grasses than warmer, low-elevation sites [147]. Postfire cover of cheatgrass tends to remain low on cool, mesic sites if its prefire cover was low [13,127,147].

The following FEIS publications provide further information on historical and altered fire regimes of western juniper communities:

- Fire regimes of juniper communities in the Columbia and Great basins (Fire Regime Synthesis)
- Fire regimes of California pinyon-juniper communities (Fire Regime Report)

FIRE MANAGEMENT CONSIDERATIONS

Although fire exclusion, overgrazing, and climate variability have led to an expansion of western juniper into adjacent shrubland and grassland steppes [36,37,138,145,152,182] (see Successional Status and Fire Regimes), management of this native tree focuses on setting back succession, not eradicating it from a site [16,102,145]. Prescribed fire can reduce western juniper cover in steppe vegetation and easily covers large areas [43,133]. However, it can also be unpredictable, hard to control, may burn nontarget species, and often results in greater risk of establishment and spread of nonnative invasive annuals after treatment [39,111,146]. Prescribed fire is not recommended in areas where cheatgrass or other nonnative plants are present and likely to spread or become dominant after fire [78,114,128]. Mechanical removal of junipers may be more appropriate than prescribed fire [39,111] (see Conifer Expansion).

When prescribed fire is used to reduce juniper abundance on sagebrush sites, it is most effective when used in successional phases I or II [127,145]. Thirty- to 50-year-old western juniper stands with an understory and a canopy under 10 feet (3.1 m) tall are fairly easy to burn. Western juniper communities in late succession (phase III) can be hard to burn because understory fuels are sparse [16,32,38,145]. As the canopy of a western juniper woodland expands over time, herbaceous production generally declines due to the combined effects of shading, litter accumulation, and reduced soil moisture availability [2]. Sites with less than 535 lbs/acre (600 kg/ha) of fine fuels may not carry fire [32]. By shading out the understory, trees on sites with few annual grasses create their own fine fuel break, rendering stands virtually "fireproof" except under the "most severe burning conditions" [2,231]. Where canopy cover is >30%, the understory may be so sparse that high winds and air temperatures and low relative humidity are needed to carry fire [9,138]: conditions under which managers are generally unwilling to burn [131].

Many western juniper woodlands have advanced successionally to the point that prescribed fire is no longer a viable management option without fuel enhancement [32,145]. Mechanical treatments are sometimes used to reduce density of western juniper [145]. If live western junipers are cut to enhance fuels, cut trees and other vegetation need to form a fairly continuous fuelbed, with cut trees still retaining their needles. Sites can be burned when fine fuels average 400 to 700 lbs/acre (450-480 kg/ha) and slash fuels 0.2 to >3 inches (0.6 to >8 cm) in diameter total at least 4 tons/acre (9 t/ha) [125]. Fuel enhancement using cut western junipers resulted in successful burns on two sites in southwestern Idaho. Study sites were in western snowberry-mountain big sagebrush/Idaho fescue-Columbia needlegrass and mountain big sagebrush/Letterman's needlegrass-bluebunch wheatgrass communities dominated by postsettlement western junipers <100 years old. Twenty-five percent of the western junipers were cut and allowed to dry for 1 year. The sites were broadcast burned the next October. The dry, dead western junipers provided surface and ladders fuels, and the fires killed 100% of remaining live western junipers [196].

These management guides provide information on using prescribed fire and/or cutting to reduce cover and density of western juniper:

- A field guide for rapid assessment of post-wildfire recovery potential in sagebrush and piñon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses and predicting vegetation response (2015) [146]
- A field guide for selecting the most appropriate treatment in sagebrush and piñon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses, and predicting vegetation response (2014) [146]
- Piñon and juniper field guide: Asking the right questions to select appropriate management actions (2009) [208]
- Western juniper field guide: Asking the right questions to select appropriate management actions (2007) [143]
- Western juniper--Its impact and management in Oregon rangelands (1993) [16]

These Fire Studies provide information on responses of western juniper and associated plants species to prescribed fire:

- Effects of fall and spring prescribed burning in sagebrush steppe in central Oregon (FEIS Fire Research Summary)
- Factors affecting efficacy of prescribed fire for western juniper control (original paper, study conducted in southwestern Idaho)

MANAGEMENT CONSIDERATIONS

SPECIES: Juniperus occidentalis

FEDERAL LEGAL STATUS
None

OTHER STATUS
Western juniper has no special protection status. Information on state- and province-level protection status of plants in the United States and Canada is available at NatureServe.

IMPORTANCE TO WILDLIFE AND LIVESTOCK
Western juniper communities are important wildlife habitat [145], providing food and cover for a variety of bird and mammal species [218]. In woodland transitional communities, value to most wildlife species decreases as shrub and herbaceous layers decline with succession [145,167].

Elk, mule deer, North American porcupine, black-tailed jackrabbit, and mountain cottontail browse western juniper [136], and so do domestic goats [68]. In parts of California, mule deer eat small amounts of western juniper in winter and early spring [19,121]. However, western juniper browse is primarily an emergency food for big game species and most classes of livestock [171]. It is a critical food source for mule deer in severe winters, when they may consume the browse in large quantities [121]. Western juniper is an important winter food for pronghorn in central and eastern Oregon [198].

The berry-like female cones are an important winter food for frugivorous birds including the American robin, [55,57,126], California scrub-jay, [59], dusky grouse [45], Lewis' woodpecker, Steller's jay [59], and Townsend's solitaire [55,57,126].

The female cones are also a food source for a number of mammals. Elk, mule deer, coyote, and mountain cottontail consume the cones [126,136,195], as do frugivorous and seed-eating rodents including the dusky-footed woodrat, golden-mantled ground squirrel, North American deermouse, and yellow-pine chipmunk [126,136]. On some sites, the female cones are the primary food source of the dusky-footed woodrat [136].

Palatability and Nutritional Value: Overall palatability of western juniper browse for wildlife [189] and livestock [37] is rated as low. Palatability of western juniper varies by individual tree [201], so some trees are browsed more than others.

Western juniper seed cones are palatable to wintering birds such as the American robin and Townsend's solitaire [57].

Western juniper browse has been rated as "fairly nutritious" for mule deer and other large mammals, but it is not highly digestible [122]. Protein content of western juniper is provided in table 4 [19].

Table 4—Mean crude protein content of western juniper foliage in California, by month [19].

Month	Crude protein content (%)
January	6.9
February	5.6
March	7.2
April	7.0
May	8.3
August	7.5
October	7.8
November	8.5
December	7.0

Nutritional value of western juniper browse varies by season and plant part. Protein and ash content of western juniper in southeastern Oregon is shown in table 5 [68].

Table 5—Nutritional content of western juniper foliage in Oregon [68].

Plant part	Crude protein (%)	Ash (%)
green foliage	8.1	3.9
cured foliage	7.6	4.2
bark	3.2	7.1

Cover Value: Western juniper provides perching and nesting sites for at least 27 species of birds, as well as cover and hibernation sites for small mammals [136]. Decadent trees provide nesting cavities for the Lewis' woodpecker, northern flicker [115,209], mountain chickadee, and mountain bluebird. The bole and branches provide hibernation sites for several species of bats [136].

Western junipers provide hiding and thermal cover for mule deer [123,124] and pronghorn [229], and thermal cover for domestic livestock [49].

Wildlife diversity may decline with canopy closure in woodland transitional communities. In particular, populations of sagebrush obligates such as greater sage-grouse, sagebrush sparrow, and pronghorn decline as understory sagebrush and herbaceous species decline [145,167,209]. Greater sage-grouse avoid sagebrush steppes where western juniper has established [8,127]. Surveys on the Bureau of Land Management's Prineville District in Oregon found 146 wildlife species occupied midsuccessional western juniper communities; these communities had big sagebrush, antelope bitterbrush, and a "strong" component of forbs and perennial grasses. Only 71 wildlife species were found in late-successional western juniper communities; these communities had no shrubs or forbs, and perennial bunchgrasses were sparse [16].

VALUE FOR RESTORATION OF DISTURBED SITES

Western juniper can be propagated from cuttings or by layering [49,201]; however, it is not usually planted on burns or other disturbed soils. Cut trees have been used as riprap for stabilizing streambanks [49].

At least 3 years of rest from grazing is suggested after seeding with forage species in western juniper stands [189].

OTHER USES

The market for western juniper wood is expanding [169,207]. The wood is used for paneling, interior studs, particleboard, veneer, plywood, and other lumber products. It is extremely durable and resistant to rot [171]. The boles are short with a rapid taper [86]. Most logs are limby, and bark inclusions extend deep into the wood. Western juniper wood requires slow kiln drying to prevent warping [86], and it is difficult to plane [49]. Specialty items made from western juniper wood include toys, sporting goods, jewelry boxes, suitcase and closet liners, inlay products, clocks, decorative items, and pencils [86,171]. Pipe bowls are made from the roots, and pet bedding from the shavings [86]. Juniper boughs are used for Christmas wreaths and other decorations [171]. The essential oils of western juniper are used for flavoring or scenting agents in medicines, beverages, condiments, aerosols, soaps, cosmetics, and insecticides [86].

Western juniper wood was historically—and still is—used for fuel, poles, fenceposts, and making charcoal [49]. It splits easily, burns clean, and produces little ash [49,86]. Western juniper woodlands can produce 8 to 11 cords of firewood/acre (72-98 m^3/ha) [30].American Indians traditionally used western juniper wood as fuel and for making bows [228].

Western juniper has been cultivated as an ornamental since 1840 [103].

The seed cones of western juniper are edible and taste best when dried [96]. They are used to make gin [10].

OTHER MANAGEMENT CONSIDERATIONS

Western juniper is relatively resistant to pests and diseases [120], although it gets attacked by a few insects and infected with dense mistletoe and juniper mistletoe. Miller et al. [145] review pests that afflict western juniper.

Conifer Expansion:

In the late 19th and 20th centuries, expansion rate of western juniper into adjacent communities was greater than any other period during the Holocene [155,156]. In woodland transitional communities, management goals generally target setting back succession [16,102,145]. Various means of mechanical treatments have been described for removing western juniper [46,143,145,230,233]. Management guides are also available. Gentilcore [78] and Miller et al. [146] review the advantages and disadvantages of conifer removal methods.

Loss of steppe communities to western juniper woodland transitional communities can have negative impacts on ecosystem function [59,145,233]. These changes are not well understood or researched but may include changes in fire regimes [37,82,152,157,231]; hydrologic function, loss of soil organic matter and nutrients [127,145];

increased erosion due to loss of understory vegetation [16,127,145,179]; and reduced productivity, forage availability, and diversity of rangelands [15,17,141,226].

Figure 10—Western juniper beginning to expand into a mesic, productive rangeland in north-central Oregon. Forest Service image by Janet Fryer.

Limited evidence suggests water loss accelerates and growing season decreases by 4 to 6 weeks as sagebrush communities succeed to woodland transitional communities [145]. However, Miller et al. [145] caution that effects of western juniper expansion have not been studied at watershed levels; only anecdotal evidence exists for streams, springs, and meadows drying up with increases in western juniper. Studies in Oregon found erosion sediment loads were higher in late-successional western juniper than in adjacent communities, while infiltration rates were lower [16].

Juniper density and cover have not changed or have declined in some juniper and pinyon-juniper communities in the West (e.g., [7,27,129,187]. Romme et al. [75419] cautioned that "one cannot necessarily assume that pinyon and juniper are increasing in density in any particular portion of their range without local data".

Potential for interception of precipitation is greater in western juniper woodlands than in shrub steppes [59], and the amount of snow trapped and stored on the landscape may be less in western juniper-dominated than in shrub-steppe communities [145]. However, research on this was lacking as of 2019.

Distinguishing between juniper woodlands and shrub steppe sites undergoing western juniper expansion is necessary to determine what level of tree removal, if any, is warranted [143]. Western juniper woodlands and savannas have some old growth (trees >150 years old); scattered snags, downed woody debris, and often, stumps; and often have claypan or shallow, rocky soils. Shrub steppes undergoing expansion have few or no old junipers; few or no snags, woody debris, or stumps; and often have deep, productive soils. Thinning of infill may be appropriate in woodlands [18,127], while removal of most or all trees may be appropriate in shrub steppes [127].

Populations of nonnative herbaceous species, particularly cheatgrass and medusahead, may increase after mechanical treatments and/or fire. Posttreatment responses of nonnative invasive species is site-specific and depends on what species were present before treatment. Intense or frequent disturbances can result in a type conversion to annual grassland [145] (see Fire Regimes and figure 9).

APPENDICES

- **APPENDIX A1: PLANT AND ANIMAL SPECIES**
- **APPENDIX A2: PLANT COMMUNITY CLASSIFICATIONS**

APPENDIX A1: PLANT AND ANIMAL SPECIES

- Plants
- Animals

Table A1—Plant species mentioned in this Species Review. Links go to other FEIS Species Reviews.

Common name	**Scientific name**
Forbs	
arrowleaf balsamroot	*Balsamorhiza sagittata*
basalt milkvetch	*Astragalus filipes*
common yarrow	*Achillea millefolium*
herb sophia	*Descurainia sophia*
tall tumblemustard	*Sisymbrium altissimum*
Graminoids	
basin wildrye	*Leymus cinereus*
bluebunch wheatgrass	*Pseudoroegneria spicata*
cheatgrass	*Bromus tectorum*
Columbia needlegrass	*Achnatherum nelsonii*
crested wheatgrass	*Agropyron cristatum*
Idaho fescue	*Festuca idahoensis*
Letterman's needlegrass	*Achnatherum lettermanii*
littleseed ricegrass	*Piptatheropsis micrantha*
prairie Junegrass	*Koeleria macrantha*
medusahead	*Taeniatherum caput-medusae*
needle and thread	*Hesperostipa comata*
Sandberg bluegrass	*Poa secunda*
squirreltail	*Elymus elymoides*
Thurber's needlegrass	*Achnatherum thurberianum*
Shrubs	
antelope bitterbrush	*Purshia tridentata*

big sagebrush basin big sagebrush mountain big sagebrush Wyoming big sagebrush	*Artemisia tridentata* *Artemisia tridentata* var. *tridentata* *Artemisia tridentata* var. *vaseyana* *Artemisia tridentata* var. *wyomingensis*
curlleaf mountain-mahogany	*Cercocarpus ledifolius*
dense mistletoe	*Phoradendron densum*
juniper mistletoe	*Phoradendron juniperinum*
low sagebrush	*Artemisia arbuscula*
mountain snowberry	*Symphoricarpos oreophilus*
rubber rabbitbrush	*Ericameria nauseosa*
sagebrush	*Artemisia* spp.
scabland sagebrush	*Artemisia rigida*
spineless horsebrush	*Tetradymia canescens*
spiny hopsage	*Grayia spinosa*
wax currant	*Ribes cereum*
western snowberry	*Symphoricarpos occidentalis*
yellow rabbitbrush	*Chrysothamnus viscidiflorus*
Trees	
Douglas-fir Rocky Mountain Douglas-fir	*Pseudotsuga menziesii* *Pseudotsuga menziesii* var. *glauca*
Jeffrey pine	*Pinus jeffreyi*
juniper	*Juniperus* spp.
pinyon	*Pinus* spp., section Cembroides
ponderosa pine Pacific ponderosa pine Columbia ponderosa pine	*Pinus ponderosa* *Pinus ponderosa* var. *benthamiana* *Pinus ponderosa* var. *ponderosa*
lodgepole pine Rocky Mountain lodgepole pine Sierra lodgepole pine	*Pinus contorta* *Pinus contorta* var. *latifolia* *Pinus contorta* var. *murrayana*
quaking aspen	*Populus tremuloides*
Rocky Mountain juniper	*Juniperus scopulorum*
Sierra juniper	*Juniperus grandis*
singleleaf pinyon	*Pinus monophylla*
Utah juniper	*Juniperus osteosperma*
western juniper	*Juniperus occidentalis*, this review

Table A2—Animal species mentioned in this Species Review. Links go to FEIS Species Reviews.

Common name	**Scientific name**
Birds	
greater sage-grouse	*Centrocercus urophasianus*
mountain bluebird	*Sialia currucoides*

Mammals	
black-tailed jackrabbit	*Lepus californicus*
coyote	*Canis latrans*
elk	*Cervus elaphus*
North American deer mouse	*Peromyscus maniculatus*
mule deer	*Odocoileus hemionus*
pronghorn	*Antilocapra americana*

APPENDIX A2: PLANT COMMUNITY CLASSIFICATIONS

Western juniper occurs in the following plant communities:

- **Ecosystems**
- **Kuchler Plant Associations**
- **SAF Cover Types**
- **SRM (Rangeland) Cover Types**

Ecosystems: [76]
FRES21 Ponderosa pine
FRES29 Sagebrush
FRES35 Pinyon-juniper

Kuchler Plant Associations: [118]
K011 Western ponderosa forest
K023 Juniper-pinyon woodland
K024 Juniper steppe woodland

SAF Cover Types: [67]
218 Interior Douglas-fir
237 Interior ponderosa pine
238 Western juniper
247 Jeffrey pine

SRM (Rangeland) Cover Types: [197]
107 Western juniper/big sagebrush/bluebunch wheatgrass
109 Ponderosa pine shrubland
110 Ponderosa pine-grassland
210 Bitterbrush
212 Blackbush
322 Curlleaf mountain-mahogany-bluebunch wheatgrass
412 Juniper-pinyon woodland
415 Curlleaf mountain-mahogany

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