# FUELS AND FIRE REGIMES IN CREOSOTEBUSH, BLACKBRUSH, AND INTERIOR CHAPARRAL SHRUBLANDS

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## Introduction

The vegetation, fire regime, and condition class descriptions in this paper apply broadly to the Mojave Desert, Colorado Plateau, and southern Great Basin of western North America. More detail, including estimated percentages within each condition class, is provided for the Mojave-Colorado Plateau ecotone within southern Nevada, the Arizona Strip northwest of the Grand Canyon, and southern Utah, including the area within the boundaries of the Southern Utah Fuel Management Demonstration Project (www.firelab.org/fep/research/sufm/home.htm).

The three shrubland vegetation types that we review are creosotebush scrub, blackbrush, and interior chaparral, which are typically situated along an increasing elevation gradient where they co-occur. The interior chaparral vegetation type is sometimes considered to include both Arizona chaparral, which occurs mostly in Arizona and New Mexico, and mountain brush or Petran chaparral, which occurs primarily in Utah and Colorado. We focus on Arizona chaparral in this paper, while mountain brush is covered elsewhere in this volume. Two vegetation types dominated by big sagebrush (*Artemisia tridentata*) and pinyon-juniper (*Pinus edulis, Pinus monophylla*, and *Juniperus* spp.) often intergrade between blackbrush and interior chaparral in the alluvial soils of broad valleys and foothill toe-slopes, but these types will also be reviewed elsewhere in this volume.

## Creosotebush Scrub

Creosotebush scrub is characterized by low cover (5 - 30%) of woody shrubs of various heights (0.5 - 1.5m) (Vasek and Barbour 1995). It is wide-ranging across the warm deserts of western North America, and is the most common plant assemblage in the Mojave Desert (MacMahon 2000). Creosotebush scrub is typically found below 1,500m on well-drained alluvial flats and slopes, below the blackbrush zone and above the saltbush zone that often occur within valley basins (Vasek and Barbour 1995). It phases into shrub-steppe in regions with higher summer rainfall than is typical for the Mojave Desert.

Creosotebush scrub is dominated by the type-species *Larrea tridentata* (creosotebush), which has the highest cover and is the most wide-ranging plant species in the Mojave Desert (Rowlands and others 1982). It is most frequently associated with *Ambrosia dumosa* (white bur-sage), but a wide range of other plants co-occur with *Larrea tridentata* including *Acamptopappus* spp. (goldenhead) *Atriplex* spp. (saltbush), *Ephedra* spp. (Mormon tea), *Ericameria* spp. (goldenbush), *Eriogonum fasciculatum* (wild buckwheat), *Krameria* spp. (ratany), *Krascheninnikovia lanata* (winterfat), *Lycium* spp. (boxthorn), *Psorothamnus* spp. (indigo bush), *Achnatherum* spp. (desert needlegrasses and Indian ricegrass), *Pleuraphis* spp. (galleta grass), *Opuntia* spp. (cholla and prickly pear cacti), and *Yucca* spp. (Joshua tree, Mojave yucca, and others). Dominant alien species include *Bromus rubens* (red brome), *Schismus* spp. (Mediterranean split-grass), and *Erodium cicutarium* (red-stemmed filaree).

Within the Mojave-Colorado plateau ecotone, creosotebush scrub reaches its northeast limit in southwestern Utah near the entrance to Zion National Park and follows the Virgin River Valley all the way to Lake Mead in Nevada, occurring in most of the lands of that river drainage below 1,250m elevation. The areal distribution broadens below the Hurricane Fault in Utah, spreading northward as far as Browse along Interstate15 and then follows the base of the red cliffs throughout the Dixie Valley north of Washington, St. George, and Gunlock. There is a large stand south of St. George in the Blake Lambing Grounds and throughout the Virgin River Gorge. Below the Gorge, the distribution spreads from the foot of the Beaver Dam Mountains and around Utah Hill, up the Beaver Dam Wash northward to Jackson Wash almost meeting with the creosotebush scrub community west of the town of Gunlock. From Littlefield, Arizona, there is continuous creosotebush scrub all the way to Lake Mead and Las Vegas with only minor interruptions in very rocky areas.

Creosotebush and associated plants provide much of the microhabitat diversity and vertical habitat structure in the Mojave Desert. Branches provide perches and nesting opportunities for songbirds, while desert tortoises (*Gopherus agasizii*) incorporate the root structure into their burrows. Shrubs also provide concealment and escape cover from predators and shade from the sun.

Many Mojave Desert shrubs are not fire-tolerant, because their drought-tolerant features (thin bark, shallow root system, small leaves) and high dead-to-live woody material ratio make them vulnerable to fire. Some species resprout after fire, but native plants are generally slow to recover or re-establish after fire and recurrent fire can prevent their re-establishment (O’Leary and Minnich 1981, Brown and Minnich 1986). The loss of native plants can be followed by invasion of alien annual grasses. The post-fire vegetation has typically lower species diversity and plant structural diversity than the native community, which can negatively affect the desert tortoise (Brooks and Esque 2002, Esque and others 2003).

*Historical Conditions*

We do not know the pre-settlement fire conditions in warm desert plant communities such as creosotebush scrub, because there are no species of single-trunked trees with strong seasonal responses for use in dendrochronology (Esque and Schwalbe 2002). It is generally thought that fires in creosotebush scrub were an infrequent event in pre-settlement desert habitats, because fine fuels from winter annual plants were probably sparse, only occurring in large amounts during exceptionally wet winters (Humphrey 1974, O’Leary and Minnich 1981, Brown and Minnich 1986, Esque and Schwalbe 2002, Brooks and Esque 2002, Salo 2003). Fires were more frequent in adjacent shrub-steppe areas, where perennial grasses provided fuel to carry fire. It appears that wildfire was not historically a landscape dominating influence in creosotebush scrub habitat, except possibly where it intergraded with shrub-steppe.

Creosotebush scrub fuels are comprised primarily of woody shrubs, but it is the fine fuels from annuals and perennial grasses that facilitate the ignition and spread of fires. Native annual plants break down rapidly during the summer after they are produced, and do not create a long-lived fuelbed (Brooks 1999a). As a result, the historical annual plant fuelbed, prior to the invasion by alien species, was probably transient, only lasting for one summer fire season after winters of exceptional high rainfall. Perennial grasses may have been more prevalent in creosotebush scrub before the introduction of livestock grazing, and provided another source of fine fuels that could have carried fire. However, stands of perennial bunchgrasses were probably patchy, reflecting localized soil conditions, and the discrete clumps of fine fuels created by individual bunchgrasses did not likely create a continuous fuelbed.

Since settlement in the 1860's, creosotebush scrub has been used for livestock operations along the Mojave Desert-Colorado plateau ecotone and elsewhere throughout its range. Over the past two centuries there has been widespread cattle and sheep use of this habitat. Widespread livestock grazing probably promoted the invasion of the annual grasses *Bromus rubens*, *Bromus tectorum*, and *Schismus* spp. (Brooks and Pyke 2001), creating more continuous fine fuelbeds that can persist for years (Brooks 1999a). Although these alien annual grasses were probably present for over 100 years (Brooks 2000a,b, Esque and Schwalbe 2002), wildfire in creosotebush scrub has only been prevalent in this region since the 1970s (Jerry Empey – BLM Color Country South Zone dispatch, personal communication). The recent increase in fire frequency was coincident with the end of the mid-century drought, and the beginning of a 20-year period of high rainfall in the late 1970s (Brooks and Esque 2002).

*Current Conditions*

Fine fuels from alien annual grasses currently represent the most important fuelbed component in creosotebush scrub. Alien annual grasses can comprise 66-97% of the total annual plant biomass in creosotebush scrub (Brooks 1999b). Annual plants were monitored as livestock/wildlife forage in unburned areas near St. George, Utah, from 1980 through 1995 and ranged from 0 to 700 kg/ha (BLM and T. Esque unpublished data). In unburned areas near Littlefield, Arizona, the aboveground production of annual plants in unburned areas was over 1,000 kg/ha in 1993, and was comprised mostly of alien annual grasses and forbs (Esque 1994). Aboveground production of annual plants in a recurrently burned area of the Pakoon Basin of the Arizona Strip was measured at >2,000 kg/ha in 2001, and was mostly comprised of *Bromus spp.* (T. Esque unpublished data).

During the 1980s and early 1990s, fire frequency increased substantially within the Mojave Desert (Brooks and Esque 2002), and most of these fires occurred in creosotebush scrub. In the Opal Mountain and Stoddard Mountain regions of California, alien annual grasses fueled recurrent fires, and some areas burned as many as three times in 10 years (M. Brooks and T. Esque, unpublished data). This increase in fire frequency is attributed to high rainfall in 1983 and 1992, which produced prodigious amounts of fine fuels, especially of *Bromus rubens*. Winter rainfall was positively correlated with fire frequency and fire size between 1980 and 2001 in the area dominated by creosotebush scrub below 1,280m (4,200ft) (M. Brooks, T. Esque, and J. Matchett unpublished data). Above 1,280m, fire frequency and size were not strongly correlated with winter rainfall, probably because fuel load and continuity of native perennials in blackbrush, interior chaparral, sagebrush, and pinyon/juniper communities are often high enough to carry fire without the help of ephemeral fine fuels.

There was one particularly wet period that produced large quantities of fine fuels in Mojave Desert-Colorado plateau ecotone during 1991 (303 kg/ha, ±78SE), 1992 (306 kg/ha ± 85SE), and 1994 (426 kg/ha ±110SE), which fueled a spate of fires in creosotebush scrub habitat. That year there was a substantial fire on the Beaver Dam Slope of Utah and another just north of St. George, Utah. Other very large fires (>30,000 ac) raged south of St. George in the Pakoon Basin of northwest Arizona fueled almost entirely on *Bromus rubens*. Since then, there have not been nearly as many large fires (>1,000ac) in creosotebush scrub. The current fire return interval in this region is still unknown, but is expected to be increasing due to the abundance of alien invasive grasses after particularly wet years.

*Fire Regime Condition Class Descriptions and Management Recommendations*

Condition Class 1

*Description* – Condition Class 1 is characterized by vegetation and fire regime attributes within the historical range of variation. The risk of losing key ecosystem components such as habitat diversity and cover sites for the desert tortoise is low. This is the historical condition where invasive annual grasses are absent, thus precluding the fine fuel buildup usually required to carry fire. Fire return intervals are virtually non-existent except for areas near the base of mountains experiencing locally higher rainfall and fine fuel buildup from native annuals, or where creosotebush scrub intergrades with shrub-steppe. There is currently 0% of the creosotebush scrub in Condition Class 1 at the Mojave Desert-Colorado plateau ecotone in southern Utah, southern Nevada, and northwestern Arizona, because invasive alien annual grasses have infested the entire area. However, the hyperarid regions of the Mojave Desert may classify as Condition Class 1.

*Recommendations* – It is unlikely that this condition class can ever be restored due to the widespread distribution of alien annual grasses, but the size of their impact may be mitigated through appropriate land management policies. We recommend suppression of all wildfires, because most native vegetation in this community responds poorly to fires, and minimization of surface disturbances that promote the dominance of alien annual grasses. Prescribed fires should not be conducted except for research burns designed to evaluate fire behavior, fire effects, and fire management techniques and treatments. We also recommend a program of early detection, evaluation, and eradication for new invasive plants before they become established. Many new plant species are in the process of invasion, and some pose potential fire threats due to their ability to produce large amounts of continuous fine fuels. Of particular concern are mustards (e.g. *Brassica tournefortii* and *Hirschfeldia incana*) and perennial grasses (e.g. *Pennisetum setaceum* and *Cenchrus ciliare*)(Brooks and Esque 2002).

Condition Class 2

*Description* – Condition Class 2 is characterized by vegetation and fire regime attributes that have been moderately altered from their historical range. The risk of losing key ecosystem components such as habitat diversity and cover sites for the desert tortoise is moderate. Patchy fires of limited extent are possible in more mesic regions during any year. Risk of larger more continuous fires is high during 10-20% of all years, when rainfall is exceptionally high. Fire risk can be exceptionally high when successive years of above average rainfall promote the accumulation of alien annual grass fuels (i.e. production values in excess of 300kg/ha in 2 or more successive years). An example of this dynamic occurred in the Dixie Valley north of St. George, Utah, and on the Beaver Dam Slope north of Littlefield, Arizona (T. Esque unpublished data). Approximately 95% of the creosotebush scrub at the Mojave Desert-Colorado plateau ecotone is in this condition class.

*Recommendations* – Suppress all wildfires, and prescribed fires should not be conducted except for research burns. Livestock grazing may reduce fine fuel loads temporarily, and may be effective for managing fuels in small defined areas, such as at the wildland urban interface. However, regular grazing will be required to maintain these managed fuel zones, except during years of very low rainfall, and regular grazing may reduce dominance of late seral native plants, and increase the dominance of alien and early seral plants that are often more flammable.

Condition Class 3

*Description* – Condition Class 3 is characterized by vegetation and fire regime attributes that have been significantly altered from their historical range. The risk of losing key ecosystem components such as habitat diversity and cover sites for the desert tortoise is high. Wildfires are frequent and widespread. An example of Condition Class 3 exists in the Pakoon Basin of northern Arizona, and the Opal Mountain and Stoddard Valley areas of California. Return intervals in this condition class may be as short as 5 years, and certainly there are fires every year at least within the Pakoon Basin. Fuel loads for areas in Condition Class 3 may exceed 2,000 kg/ha during peak years (T. Esque, unpublished data). The grass/fire cycle characterized by this condition class creates a feedback loop of decreasing habitat quality for wildlife and livestock. Native seedbanks may be depleted, lengthening the recovery times for native plants. Approximately 5% of the creosotebush scrub at the Mojave Desert-Colorado plateau ecotone is in this condition class.

*Recommendations* – We recommend research designed for the restoration of these sites. Suppress all wildfires, and prescribed fires should not be conducted except for research burns. Livestock grazing to reduce fuel loads may be counterproductive in the long run if it also hinders the re-establishment of late seral native plants.

## Blackbrush

The blackbrush vegetation type is characterized by relatively high cover (50%) of low statured (50cm tall) evergreen woody shrubs. It occurs at the bioregional transition between the Mojave and Great Basin deserts, from California through Nevada, Arizona, and Utah (Bowns 1973). Blackbrush is typically found in the elevational zone from 1,220 to 1,520m, above the creosotebush zone and below the interior chaparral or big sagebrush/pinyon-juniper zones (Bradley and Deacon 1967, Randall 1972, Beatley 1976).

Blackbrush is dominated by the type-species, *Coleogyne ramosissima* (blackbrush), which can comprise 90 to 95% of the total plant cover (Shreve 1942). Cover of *Coleogyne ramosissima* is highest in late seral stands on shallow, sandy soils with strong pretrocalcic (caliche) horizons, where it is the primary dominant plant species. Cover of *Coleogyne ramosissima* is lowest in deeper, silty soils, or at its upper or lower ecotones, where it is co-dominant with other native species such as *Larrea tridentata*, *Juniperus* spp. (juniper), *Prunus fasciculata* (desert almond), *Lycium andersonii* (Anderson wolfberry), *Yucca brevifolia*, *Salazaria mexicana* (bladder sage), *Achnatherum* spp., and *Pleuraphis* spp. Dominant alien species include the annuals *Bromus rubens*, *Bromus tectorum* (cheatgrass), and *Erodium cicutarium*.

Within the Mojave-Colorado plateau ecotone, blackbrush is found on dry slopes and benches above the river canyons of southern Utah and northern Arizona (Turner 1994). It is also found mid-slope on mountain ranges throughout this ecotone.

Blackbrush is used as winter forage by deer and bighorn sheep (Bowns and West 1976), and provides cover for nongame birds and small mammals (Brown and Smith 2000). It also protects soil from water and wind erosion, and promotes soil fertility (Bowns 1973). These ecosystem benefits are lost when blackbrush cover is removed following fire, because blackbrush is almost always killed by fire and may take >100 years to re-establish (literature reviewed in Brooks and Matchett 2003).

### *Historical Conditions*

*Coleogyne ramosissima* is considered a poor livestock forage species, and ranchers noted that during the late 1930s and early 1940s wildfires increased production of livestock forage in blackbrush rangeland of southern Nevada and northwestern Arizona (Anonymous 1945). In an attempt to further increase forage production, ranchers and the Bureau of Land Management began a program of prescribed burning in the 1940s, during which time approximately 20% of the 400,000 acres of blackbrush were burned by prescribed fire or wildfire in southern Nevada (BLM, Las Vegas, Nevada, grazing district 5) (Croft 1950). Many blackbrush fires also occurred in northwestern Arizona during this time (BLM, Arizona Strip, Arizona, grazing district 2). Additional blackbrush burning likely occurred at least through the 1960s, because a policy review during that time by the Range and Forestry Officer of the Bureau of Land Management in Nevada recommended that blackbrush burning be continued to increase livestock forage (Dimock 1960). Before 1940, fires in these regions were relatively uncommon (Croft 1950). The long-term effects of these mid-century range burns are currently being evaluated using repeat photography of historical photos originally taken 5-10 years postfire and analyses of field reports, memos, and vegetation plot data collected during the late 1940s through the early 1960s by range conservationists and foresters from the Bureau of Land Management and the United States Forest Service, Intermountain Forest and Range Experiment Station (M. Brooks, unpublished data).

Prior to European contact, late seral blackbrush stands were probably more extensive than they are today. The vast expanses of blackbrush rangeland that were burned to improve livestock production during the mid-1900s are still dominated by early seral species and have been re-colonized only sporadically by *Coleogyne ramosissima* (M. Brooks, unpublished data). Blackbrush within the Desert Wildlife Range and Nevada Test Site in southern Nevada that has not been managed for livestock production since the 1930s, and likely was not burned for rangeland improvement, does not currently contain evidence of widespread historical burning (M. Brooks and T. Esque personal observations). It therefore appears that extensive burning to remove blackbrush must have created many of the vegetation stands where *Coleogyne ramosissima* is either absent or a sub-dominant species today.

The historical fuel complex in late seral blackbrush stands was probably similar to that observed in relatively undisturbed sites today, except for the current prevalence of *Bromus* spp. and *Erodium cicutarium* in many stands. Vegetation characteristics of these stands were characteristic of blackbrush Condition Class 1 described below. Shrub cover was likely comprised primarily of *Coleogyne ramosissima* at 30-50% total cover, and interspaces were probably mostly bare, even during years of high rainfall, due to root competition from *Coleogyne ramosissima*. Other species such as perennial grasses and early seral shrubs probably occurred sporadically, as they do today, along wash stringers and on steep hillslopes where cover of *Coleogyne ramosissima* is typically low.

Low amounts of fine fuels in interspaces probably limited fire spread to only extreme fire conditions, during which high winds, low relative humidity, and low fuel moisture led to high intensity stand-replacing crown fires. Historical fire return intervals appear to have been on the order of centuries (Webb and others 1987), allowing late seral blackbrush stands to re-establish.

*Current Conditions*

Blackbrush is considered to be one of the most flammable native plant assemblages in the Mojave Desert. Many large fires have occurred in this vegetation type since the 1980s in the Spring Mountains and Mormon Mountains in Nevada, the Beaver Dam Mountains in Utah, the Black Mountains and Virgin Mountains in Arizona, and at Joshua Tree National Park in California (Brooks and Esque 2002). Although fire is generally no longer advocated as a tool for range improvement, ignitions from lightning and accidental ignitions along roads have been sufficient to burn significant acreage of blackbrush during the past few decades.

At Joshua Tree National Park in California, blackbrush was burned during the early 1990s to reduce woody fuel loads at the wildland-urban interface between Joshua Tree and the town of Yucca Valley. During the first few postfire years the landscape was dominated by native annual wildflowers, but by the fourth postfire year the alien annual grasses *Bromus rubens* and *Bromus tectorum* became the dominant annual plants, and remained as such into the 2000s. The appearance of this new flashy fuelbed resulted in a change in fire management at Joshua Tree, putting a stop to the use of fire as a management tool until prescriptions could be identified that would not create continuous fuelbeds of alien annual grasses. At the current rate of wildfire in blackbrush burning during 1980s and 1990s, managers estimate that all the blackbrush at Joshua Tree will burn within the next 15-20 years (Hank McCutchen, Chief of Resources, personal communication). This is a significant concern because the blackbrush stands at Joshua Tree are disjunct from the rest of the blackbrush range, and if all the stands were to burn it is very likely that *Coleogyne ramosissima* would not be able to re-establish.

The fuel complex in blackbrush appears to be more conducive to burning now than in the past. Alien annual grasses currently occur in most blackbrush stands, facilitating the spread of fire after years of high rainfall. Postfire landscapes are even more dominated by these alien grasses, raising concerns that they will promote recurrent fire and prevent the re-establishment of *Coleogyne ramosissima*. Interestingly, reports from the mid-1900s also acknowledge the role that alien annual grasses, especially *Bromus rubens*, play in facilitating the spread of fire in blackbrush (Dimrock 1960, Holmgren 1960, Jensen and others 1960), although there was disagreement as to whether the burned landscapes were more or less susceptible than unburned landscapes to reburning. Jensen et al (1960) thought the chances of reburning were low because they observed low fine fuel levels in postfire landscapes, but their observations were made during the mid-century drought when fine fuel loads were on the low end of their possible range. In contrast, Holmgren (1960), who accompanied Jensen and others on the same field visits, thought that the danger of accidental fire in blackbrush would be higher in areas that previously burned than in unburned areas, if high winter rainfall had produced more *Bromus rubens* biomass and other fine fuels. Prior to the invasion of *Bromus rubens* and *Bromus tectorum* during the late 1800s to early 1900s (Brooks 2000, Young 2000), fine fuel loads were likely not as great in either burned or unburned blackbrush stands, resulting in fewer fires, and fewer reburns.

*Fire Regime Condition Class Descriptions and Management Recommendations*

Condition Class 1

*Description* – Condition Class 1 is characterized by vegetation and fire regime attributes within the historical range of variation. The risk of losing key ecosystem components such as high *Coleogyne ramosissima* cover and associated protection from soil erosion is low. Mature blackbrush stands fall into this condition class. These stands are typically late seral with occasional early seral patches created by infrequent stand-replacing fires.

The fire regime for this condition class is active crown fire carried primarily by *Coleogyne ramosissima*, and perennial grasses (*Achnatherum* spp. and *Pleuraphis* spp.) on deep silty soils, burns are complete and stand-replacing, fire intensity is high, and fire return intervals are >100 years. Long fire return intervals allow for the typically slow process of blackbrush re-establishment. Approximately 20% of the blackbrush at the Mojave Desert-Colorado plateau ecotone in southern Utah, southern Nevada, and northwestern Arizona is in this condition class.

*Recommendations* – Suppress human-caused fires, but consider allowing lightning-caused wildfires to burn, unless significant populations of *Bromus rubens* or *Bromus tectorum* are present, or there are other reasons for suppression. Prescribed fires should not be conducted except for research burns designed to evaluate fire behavior, fire effects, and fire management techniques and treatments. Only apply fuel management treatments at the wildland urban interface to reduce fire hazard, or in wildland areas where fuel breaks are deemed necessary to achieve management goals. Realize that regular maintenance may be required to maintain these managed fuel zones, because fuel treatments that involve replacement of late seral woody fuels with early seral fine fuels will reduce fire intensity, but may increase susceptibility to ignition and rates of fire spread.

Condition Class 2

*Description* – Condition Class 2 is characterized by vegetation and fire regime attributes that have been moderately altered from their historical range. The risk of losing key ecosystem components such as high *Coleogyne ramosissima* cover and associated protection from soil erosion is moderate. Blackbrush stands with an intermix of late seral unburned patches and early seral burned patches are in this condition class. Blackbrush stands with patches that have been degraded by overgrazing, prescribed burning in the mid-1900s, or other forms of surface disturbance, also fall into this condition class. These disturbances reduce cover of *Coleogyne ramosissima*, and increase cover of early seral shrubs such as *Chrysothamnus* spp., *Gutierrezia* spp., and *Eriogonum fasciculatum*, early seral herbaceous perennials such as *Sphaeralcea ambigua* and *Astragalus* spp., and alien annual plants such as *Bromus rubens*, *Bromus tectorum*, and *Erodium cicutarum*. Burned stands without livestock over-grazing, and situated on deep silty soils, can also have a large perennial grass component (*Achnatherum* spp. and *Pleuraphis* spp.).

Fires in late seral patches are active crown fires carried by *Coleogyne ramosissima*, perennial grasses (*Achnatherum* spp. and *Pleuraphis* spp.), and alien annual grasses (*Bromus* spp.), burns are complete, and fire intensity is high. Fires within early seral patches are passive crown fires or ground fires, carried by perennial grasses and alien annual grasses between the sparse cover of early seral shrubs, burns are patchy, and fire intensity is low to moderate.

Fire return intervals in Condition Class 2 stands are approximately 50-100 years. This shorter fire return interval, and over-grazing pressure from livestock, helps to maintain dominance by early seral species and may prevent re-establishment by *Coleogyne ramosissima*. Approximately 75% of the blackbrush at the Mojave Desert-Colorado plateau ecotone is in this condition class.

*Recommendations* – Suppress all wildfires, and prescribed fires should not be conducted except for research burns. Minimize livestock grazing and other surface disturbances on early seral stands, or where early seral and late seral stands are intermixed. Do not apply fuel management treatments on late seral stands, except possibly at the wildland urban interface to reduce fire hazards or in wildland areas where fuel breaks are deemed necessary to achieve management goals. Realize that regular maintenance may be required to maintain these managed fuel zones, because fuel treatments that involve replacement of late seral woody fuels with early seral fine fuels will reduce fire intensity, but may increase susceptibility to ignition, fire spread rates, and fire frequency. Fuel treatments on early seral stands dominated by alien annual plants may include the use of grass-specific herbicides. Livestock grazing may reduce fine fuel loads temporarily, but may hinder the re-establishment of *Coleogyne ramosissima* and other late seral species, and thus may be counterproductive in the long-term.

Condition Class 3

*Description* – Condition Class 3 is characterized by vegetation and fire regime attributes that have been significantly altered from their historical range. The risk of losing key ecosystem components such as high *Coleogyne ramosissima* cover and associated protection from soil erosion is high. Blackbrush stands that burned during the 1900s, and have reburned at least once, fall into this condition class. These stands are typically dominated by alien annuals and early seral perennials. Recurrently burned stands without livestock over-grazing can also have a large perennial grass component (*Achnatherum* spp. and *Pleuraphis* spp.).

The fire regime for this condition class is typically surface fire carried primarily by alien annual plants, burns are patchy, fire intensity is low, and fire return intervals are <50 years. Re-establishment by *Coleogyne ramosissima* is unlikely under this fire regime. Approximately 5% of the blackbrush at the Mojave Desert-Colorado plateau ecotone is in this condition class, but this percentage could increase if ignition rates increase with burgeoning human populations and if fine fuel continuity increases with increased dominance of alien annual grasses that could occur if atmospheric $CO_2$ and rainfall levels increase (Brooks and Pyke 2001).

*Recommendations* – Suppress all wildfires, and prescribed fires should not be conducted except for research burns. Extreme measures may be required in these stands. Revegetation with *Coleogyne ramosissima* and other late seral shrubs and perennial grasses, and exclusion of livestock grazing and other surface disturbances, may be necessary. Control of alien annual grasses using herbicides or early season prescribed fire implemented immediately before revegetation treatments may improve initial establishment rates of revegetated plants.

## Interior Chaparral

Interior chaparral (Arizona chaparral) is characterized by moderate cover, ranging from 40% at dry sites to 80% at wetter sites, of moderately tall statured (1 - 2.5m tall) evergreen woody shrubs with dense crowns (Carmichael and others 1978). It is best represented in the foothills and mountain slopes and canyons in the sub-Mogollan region of central Arizona (Pase and Brown 1994). Disjunct stands also occur in the mountains of Washington County of southwestern Utah, in northwestern and southeastern Arizona, southern New Mexico, southwest Texas, and northern Mexico. It generally occurs between 1,000 and 2,000m elevation, above the desert grassland/shrub-steppe zone and below and pinyon-juniper/ponderosa pine zone (Keeley 2000).

Within the Mojave-Colorado Plateau ecotone, interior chaparral is best represented in the Pine Valley Mountains, Bull Valley Mountains, and Zion National Park in Washington County (Utah), in the Virgin Mountains of Mojave County (Arizona), and in the Spring Mountains and Gold Butte regions of Clark County (Nevada). In this region is it is characterized by *Quercus turbinella* (turbinella live oak), *Ceanothus greggii* (buckbrush), *Arctostaphylos pungens* (pointleaf manzanita), *Garrya wrightii (Wright silktassel)*, and *Eriodictyon angustifolium* (narrowleaf yerba-santa).  Understory grass species such as *Bouteloua* spp. (grama) and *Aristida* spp. (three-awn) occur throughout the range of interior chaparral.

Interior chaparral is an important vegetation community for wildlife. Game animals such as javelina, deer, and bighorn sheep use several plant species as forage and others as cover. Distinct from the communities above and below it, interior chaparral provides a significant amount of wildlife habitat diversity.

Most chaparral species are adapted to a fire-prone system, but methods of response vary. *Quercus turbinella* is well adapted to survive fire, typically resprouting vigorously from the root crown and rhizomes in response to fire or other disturbance (Pase 1969), while *Ceanothus greggii* and *Arctostaphylos pungens* regenerate from long-lived seeds that accumulate in the soil and germinate prolifically following fire. Areas dominated by non-sprouting chaparral species, including *Arctostaphylos pungens*, may develop a persistent cover of herbaceous species following fire, especially where *Bromus* spp. are present. Interior chaparral dominated by *Quercus turbinella*, have fire return intervals from 74 to 100 years. At least 20 years may be required before these sites can reburn (Cable 1975).

### *Historical Conditions*

In some areas prior to the 1900s interior chaparral was considered good livestock range, but overgrazing has removed much of the perennial grass component since then (Nichol 1937). Most people now view interior chaparral as a nuisance or obstacle to human activity. Ranchers have routinely attempted to get rid of the brush that competed with forage grass and made travel difficult. Livestock grazing and fire suppression have at least partly caused shrub encroachment into grassland and woodland/forest encroachment into shrublands during the 1900s in the southwestern United States (Leopold 1924, Hastings and Turner 1965, Miller and Rose 1999).

Many lower elevation interior chaparral sites have been managed for livestock grazing since the 1880s (Pase and Brown 1994). Where fire was used to maintain grass forage, interior chaparral probably did not encroach into lower elevation grasslands. However, where fire was not used, and the removal of fine fuels by livestock grazing and fire suppression further decreased the frequency of wildfire, interior chaparral very likely did encroach into lower elevation grasslands. Large areas near the early settlements of Prescott and Globe were reported to be grasslands in the 1860s and became dense stands of interior chaparral by 1936 (Cable 1975). Aldo Leopold (1924) reported a substantial increase in "brush" cover at the expense of herbaceous plant cover after 40 years of livestock grazing since the 1880s.

Aldo Leopold made additional observations at the interior chaparral – grassland ecotone in southern Arizona, which shed some light on the pre-settlement fire regime of this region. He noted during the early 1920s that there were multiple fire scars on ancient juniper stumps embedded in even-aged chaparral stands consisting of shrubs <40 years old, suggesting that the fire scars were created during low intensity grassland fires that pre-dated the current chaparral stands (Leopold 1924). Based on observations such as these, Leopold concluded that there had been no widespread fires in the chaparral – grassland ecotone in southern Arizona between the early 1880s and early 1920s. He further hypothesized that previous grassland fires at these same sites occurred at intervals of approximately once every 10 years before the advent of widespread livestock grazing.

Higher elevation interior chaparral sites likely did not receive as much grazing pressure, but fire suppression, especially at the interface with ponderosa pine forests, may have resulted in forest encroachment into chaparral shrublands. For example, where old chaparral stands intergrade with woodlands or forests at higher elevations, chaparral species such as *Arctostaphylos pringlei* (Pringle manzanita) and *Ceanothus fendleri* (Fendler ceanothus) may be replaced by *Pinus ponderosa* (ponderosa pine), *Quercus emoryi* (emory oak), or *Quercus arizonica* (Arizona oak) after long fire-free intervals (Pase and Brown 1994).

Historical fire return intervals in interior chaparral were likely 50-100 years (Cable 1975), although this is an average over its entire range.

*Current Conditions*

Interior chaparral presents a more complex management challenge than the forests above or the deserts below, facing some of the challenges of both. Like the ponderosa pine forests, chaparral communities are fire-dependant. Exclusion of fire from interior chaparral can lead to encroachments by woodland species. Like the creosotebush scrub and blackbrush desert shrublands, alien annual grasses can increase fire frequency to the point where even the fire-adapted interior chaparral cannot recover. Thus, interior chaparral requires fire, but not too much fire.

Conventional wisdom in the fire suppression community is that chaparral either does not burn, but when it does burn, it burns hot. Due to threats to humans and their property, as well as to other high value resources, full suppression remains the primary response to wildfires that occur under the hot, dry conditions of summer in the southwest.

*Fire Regime Condition Class Descriptions and Management Recommendations*

Condition Class 1

*Description* – Condition Class 1 is characterized by vegetation and fire regime attributes within the historical range of variation. The risk of losing key ecosystem components such as cover for wildlife is low. These stands are typically late seral with occasional early seral patches created by infrequent stand-replacing fires. The fire regime for this condition class is active crown fire carried primarily by *Quercus turbinella*, *Ceanothus greggii*, and *Arctostaphylos* spp., burns are complete and stand-replacing, fire intensity is high, and fire return intervals are between 50 and 100 years.

Long fire return intervals allow for the re-establishment of seed banks and the development of the fuel loads (and spatial continuity) necessary for fire to occur. Approximately 40% of the interior chaparral at the Mojave Desert-Colorado plateau ecotone in southern Utah, southern Nevada, and northwestern Arizona is in this condition class.

*Recommendations* – Suppress human-caused fires. Consider allowing lightning-caused fires to burn, unless significant populations of *Bromus* spp. are present, especially near stands of non-sprouting chaparral species, or there are other reasons for suppression. Prescribed fires should not be conducted except for research burns designed to evaluate fire behavior, fire effects, and fire management techniques and treatments. Apply fuel management treatments at the wildland urban interface to reduce fire hazard and in wildland areas where fuel breaks are deemed necessary to achieve management goals. Where possible, use indirect fire suppression tactics that provide a reasonable containment strategy to protect human life, property, and other valuable resources, while allowing some acres to burn during the high-intensity summer fire season.

Since this is a fire-dependent ecosystem, counter the effects of fire suppression by implementing burn treatments, unless a significant threat of conversion to a *Bromus*-dominated system is present. The goal of these treatments would be to replicate normal patch size/mosaic patterns in order to provide diversity and to reduce the potential size of wildfires. Treatment frequency should not occur more often than 20 years at any site. Treatment areas should not be reseeded with herbaceous vegetation unless necessary to compete with alien annual grasses. Treatments on sites dominated by seed propagators (e.g. pointleaf manzanita) may need to be seeded with chaparral species.

Realize that regular maintenance may be required to maintain these managed fuel zones, because fuel treatments that involve replacement of late seral woody fuels with early seral fine fuels will reduce fire intensity, but may increase susceptibility to ignition and rates of fire spread.

Condition Class 2

*Description* – Condition Class 2 is characterized by vegetation and fire regime attributes that have been moderately altered from their historical range. The risk of losing key ecosystem components such as cover for wildlife is moderate. There are two types of chaparral within Condition Class 2: 1) sites where the fire return intervals are greater than the natural range of variation (>100 years) and sites where encroachment of interior chaparral by conifer woodlands has occurred (10% of the Mojave Desert-Colorado plateau ecotone region), and 2) sites where fire return intervals, or other landscape-scale disturbances, are within or slightly less than the natural range of variation (≤50-100 years) and the post-disturbance community contains a significant intermix of late seral unburned patches and early seral burned patches dominated by alien grasses (20% of the Mojave Desert-Colorado plateau ecotone region). These sites typically retain significant amounts of area with late seral interior chaparral characteristics, but the trend is toward Condition Class 3.

*Recommendations* – Treat sites that have had fire excluded and are being encroached by conifer woodlands in a manner similar to Condition Class 1, except where alien grasses are a significant threat (i.e., suppress human-caused fires, but consider allowing lightning-caused fires to burn, unless significant populations of *Bromus* spp. are present, or there are other reasons for suppression. Prescribed fires should not be conducted except for research burns. Apply fuel management treatments at the wildland urban interface to reduce fire hazard and in wildland areas where fuel breaks are deemed necessary to achieve management goals. Where possible, use indirect fire suppression tactics that provide a reasonable containment strategy to protect human life, property, and other valuable resources, while allowing some acres to burn during the high-intensity summer fire season.

Treat sites where disturbances have occurred, but the post-disturbance community has changed to one with a significant intermix of late seral unburned patches and early seral burned patches with alien grasses, in a manner similar to Condition Class 3 (i.e., suppress all fires; revegetate with live oak, buckbrush, manzanita, and other late seral shrubs and perennial grasses; exclude livestock grazing and other surface disturbing activities at least until plants become established; control alien annual grasses using herbicides).

Condition Class 3

*Description* – Condition Class 3 is characterized by vegetation and fire regime attributes that have been significantly altered from their historical range. The risk of losing key ecosystem components such as cover for wildlife is high. Chaparral stands that have burned repeatedly and lost most of the shrub cover, have lost the shrub seed bank, and have significant amounts of *Bromus* spp. or other alien grasses fall into this condition class. Alien annuals and early seral perennials typically dominate these stands.

The fire regime for this condition class is typically ground fire carried primarily by alien annual plants, burns are patchy, fire intensity is low, and fire return intervals are <20 years. Re-establishment by native interior chaparral shrub species is diminished under this fire regime, and becomes less likely as native chaparral seed banks disappear.

Approximately 30% of the interior chaparral at the Mojave Desert-Colorado plateau ecotone is in this condition class, but this percentage could increase if ignition rates increase with burgeoning human populations and if fine fuel continuity increases with increased dominance of alien annual grasses that could occur if atmospheric $CO_2$ and rainfall levels increase.

*Recommendations* – Suppress all wildfires, and prescribed fires should not be conducted except for research burns. Revegetation may be necessary using *Quercus turbinella, Ceanothus* spp., and *Arctostaphylos* spp. and other late seral shrubs and perennial grasses, along with exclusion of livestock grazing and other surface disturbances. Control of alien annual grasses using herbicides immediately before revegetation treatments may improve initial establishment rates of revegetated plants.

We recommend research designed for the restoration of these sites. The grass/fire cycle creates a feedback loop of decreasing habitat quality for wildlife and livestock. Livestock grazing to reduce fuel loads may be counterproductive in the long run if it also hinders the re-establishment of late seral native plants.

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**Literature Cited**

Anonymous. 1945. Artificial Revegetation Study Plan for Study B-108 Near Elgin, Nevada, September, 27, 1945. United States Department of the Interior, Grazing Service, Nevada, Searchlight District, 9/27/1945. 8pp.

Beatley, J.C. 1976. Vascular Plants of the Nevada Test Site and Central-Southern Nevada: Ecological and Geographic Distributions. Energy Research and Development Administration TID-26881. Technical Information Center, Office of Technical Information, Springfield Virginia. 308 pp.

Bowns, J.E. 1973. An autecological study of blackbrush (*Coleogyne ramosissima* Torr.) in southwestern Utah. Doctoral dissertation, Utah State University, Logan. 115 pp.

Bowns, J.E. and N.E. West. 1976. Blackbrush (*Coleogyne ramosissima* Torr.) on southwestern Utah rangelands. Research Report 27. Logan, UT: Utah State University, Utah Agricultural Experiment Station. 27 p.

Bradley, W.G. and J.E. Deacon. 1967. The biotic communities of southern Nevada. Nevada State Museum Anthropological Papers, 13:202–295.

Brooks, M.L. 1999a. Alien annual grasses and fire in the Mojave Desert. Madroño 46:13-19.

Brooks, M.L 1999b. Habitat invasibility and dominance by alien annual plants in the western Mojave Desert. Biological Invasions 1:325-337.

Brooks, M.L. 2000a. *Bromus madritensis* subsp. *rubens* (L.) Husnot. Pp. 72-76. In: C. Bossard, M. Hoshovsky, and J. Randall (eds.). Invasive Plants of California's Wildlands. University of California Press. Berkeley, CA.

Brooks, M.L. 2000b. *Schismus arabicus* Nees, *Schismus barbatus* (L.) Thell. p. 287-291. In: C. Bossard, M. Hoshovsky, and J. Randall (eds.), Invasive Plants of California's Wildlands. University of California Press. Berkeley, CA.

Brooks, M.L., and T.C. Esque. 2002. Alien annual plants and wildfire in desert tortoise habitat: status, ecological effects, and management. Chelonian Conservation and Biology. In press.

Brooks, M.L. and J.R. Matchett. 2003. Plant community patterns in unburned and burned blackbrush (*Coleogyne ramosissima*) shrublands in the Mojave Desert. Western North American Naturalist. In press.

Brooks, M.L. and D. Pyke. 2001. Invasive plants and fire in the deserts of North America. p. 1-14 In: K. Galley and T. Wilson (eds.), Proceedings of the Invasive Species Workshop: The Role of Fire In the Control and Spread of Invasive Species. Fire Conference 2000: The First National Congress on Fire, Ecology, Prevention and Management. Miscellaneous Publications No. 11, Tall Timbers Research Station, Tallahassee, Florida, USA.

Brown, J.K., S. Kapler Smith, eds. 2000. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech Rep. RMRS-GRT-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Brown, D.E. and Minnich, R.A. 1986. Fire and creosote bush scrub of the western Sonoran Desert, California. American Midland Naturalist 116:411-422.

Cable, Dwight R. 1975. Range management in the chaparral type and its ecological basis: the status of our knowledge. Res. Pap. RM-155. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 30 p.

Carmichael, R. S.; Knipe, O. D.; Pase, C. P.; Brady, W. W. 1978. Arizona chaparral: plant associations and ecology. Res. Pap. RM-202. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 16 p.

Croft, A.R. 1950. Inspection of black brush burn, May 12, 1950. Memorandum to the Unpublished report, Bureau of Land Management, Bureau of Land Management, State Supervisor for Nevada, 6 pp. plus photographs.

Dimock, D.E. 1960. Report on Blackbrush Burn Observations, April 18-20, 1960. Memorandum to the Bureau of Land Management, State Supervisor for Nevada. 6p.

Esque, T.C. 1994. Diet and diet selection of the desert tortoise (*Gopherus agassizii*) in the northeast Mojave Desert. Masters Thesis, Colorado State University, 243 p.

Esque, T.C., and C.R. Schwalbe. 2002. Alien annual plants and their relationships to fire and biotic change in Sonoran Desertscrub. In: Tellman, B. (Ed.). Invasive exotic species in the Sonoran region. Tucson, Arizona: Arizona-Sonora Desert Museum and The University of Arizona Press. p. 165-194.

Esque, T.C., C.R. Schwalbe, L.A. DeFalco, T.J. Hughes and R.B. Duncan. 2003. Effects of wildfire on small desert vertebrates, especially desert tortoises (*Gopherus agassizii*). The Southwestern Naturalist. In press.

Hastings, J.R. and R.M. Turner. 1965. The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semi-Arid Region. University of Arizona Press, Tucson, AZ. 317pp.

Holmgren, R.C. 1960. Inspection tour of old blackbrush burns in BLM District N-5, southern Nevada. Unpublished report, US Forest Service, Intermountain Forest and Range Experiment Station, Reno Research Center, Reno, NV. 8 pp.

Humphrey, R.R. 1974. Fire in the deserts and desert grassland of North America. In: T. T. Kozlowski and C.E. Ahlgren (eds.) Fire and Ecosystems. New York: Academic Press, pp. 365-400.

Jenson, D.E., M.E. Buzan, D.E. Dimock, and R. Holmgren. 1960. Report on field examinations, blackbrush burns, Las Vegas Grazing District (Nev. 5), April 1960. Unpublished report, Bureau of Land Management, Nevada State Office. 10 pp.

Keeley, J. E. 2000. Chaparral. p. 203-253 In: M.G. Barbour and W.D. Billings (eds.) North American Terrestrial Vegetation, 2nd edition. Cambridge University Press, Cambridge, UK.

Leopold, A.S. 1924. Grass, brush, timber, and fire in southern Arizona. Journal of Forestry 22:1-10.

MacMahon, J. A. 2000. Warm Deserts. p. 285-322 In: M.G. Barbour and W.D. Billings (eds.) North American Terrestrial Vegetation, 2nd edition. Cambridge University Press, Cambridge, UK.

Miller, R.F. and J.A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. Journal of Range Management 52:550-559.

Nichol, A.A. 1937. The natural vegetation of Arizona. University of Arizona, College of Agriculture, Agricultural Experiment Station. Technical Bulletin No. 68.

O'Leary, J. F., and Minnich, R.A. 1981. Postfire recovery of creosote bush scrub vegetation in the Western Colorado Desert. Madroño 28:61-66.

Pase, C. P. 1969. Survival of *Quercus turbinella* and *Q. emoryi* seedlings in an Arizona chaparral community. The Southwestern Naturalist. 14(2): 149-156.

Pase, C.P. and D.E. Brown. 1994. Interior Chaparral. p. 95-99 In: D.E. Brown (ed.) Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City, UT.

Randall, D.C. 1972. An analysis of some desert shrub vegetation of Saline Valley, California. PhD dissertation, University of California, Davis. 186 pp.

Rowlands, P.G., Johnson, H.B., Ritter, E., and Endo, A. 1982. The Mojave Desert. In: Bender, G.L. (Ed.). Reference Handbook of North American Deserts. Connecticut: Greenwood Press, pp. 103-159.

Salo, L.F. 2003. Ecology and biogeography of red brome (*Bromus madritensis* subspecies *rubens*) in western North America. Dissertation. University of Arizona.

Shreve, F. 1942. The desert vegetation of North America. Botanical Review 8:195–246.

Turner, R.M. 1994. Great Basin desertscrub. p. 145-155 In: D.E. Brown (ed.) Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City, UT.

Vasek, F.C. and M.G. Barbour. 1995. Mojave desert scrub vegetation. p. 835-868 in M.G. Barbour and J. Major (eds.) Terrestrial Vegetation of California. California Native Plant Society. Special Publication: No. 9.

Webb R.H., J.W. Steiger, and R.M. Turner. 1987. Dynamics of Mojave Desert assemblages in the Panamint Mountains, California. Ecology 68:478-490.

Young, J.A. 2000. *Bromus tectorum* (L.). Pp. 76-80. In: C. Bossard, M. Hoshovsky, and J. Randall (eds.). Invasive Plants of California's Wildlands. University of California Press. Berkeley, CA.