Parkinsonia microphylla, yellow paloverde

2022

Yellow paloverde growing among saguaro, Tucson Mountain Park, AZ. Photo by William Giles, used with permission.

Yellow paloverde in flower, Phoenix Desert Botanical Garden, AZ. Photo by Todd Wynia, used with permission.

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SUMMARY

This review summarizes information that was available in the scientific literature as of 2022 on the biology, ecology, and effects of fire on yellow paloverde in North America.

Yellow paloverde is a multi-stemmed shrub or small tree that often grows to 6 m tall. It has thin, photosynthetic bark and small, drought-deciduous leaves.

Yellow paloverde is native to the Sonoran Desert, where it occurs most often on bajadas, plains, and hillslopes. Although drought-tolerant, yellow paloverde typically requires winter and summer precipitation. Yellow paloverde is dominant in Sonoran desert scrub and is a nurse plant for several species including saguaro.

Yellow paloverde regenerates primarily from seeds. Flower and seed production may be prolific in wet years and diminished or absent after dry winters. Many of its seeds are eaten by insects and granivorous rodents. However, seed-caching rodents also disperse seeds in small clusters, and seed caches that are forgotten or abandoned may germinate. Yellow paloverde has both dormant and nondormant seeds and may form a small, short-term seed bank. Seedlings emerge in pulses after rain and warm temperatures trigger germination; however, seedling establishment and survival are generally low. Although yellow paloverde sometimes sprouts from the root crown after top-kill from fire and/or drought, and has been observed sprouting from roots, yellow paloverde does not typically reproduce vegetatively.

Yellow paloverde is easily damaged and often killed or top-killed by fire. Although yellow paloverde may resprout after top-kill or injury from fire, observations suggest that it is more likely to be killed. Postfire mortality rates often exceed 70% within the first few years. Because it is a weak sprouter, postfire recovery of yellow paloverde is largely dependent on establishment from seeds. Given that seed and seedling predation rates are high and seedling establishment and survival rates are low, yellow paloverde postfire seedling establishment is also likely to be low; however, information on its establishment after fire is limited and largely anecdotal.

Historically, plant communities dominated by yellow paloverde did not have enough fine fuel to carry fire in most years. Patches of vegetation were separated by large areas of bare ground, and cover of annual and perennial herbs was sparse and discontinuous, except after one or more relatively wet years. Fuel and fire regime characteristics in contemporary Sonoran desert scrub communities have likely shifted outside the range of historical variation, primarily due to the introduction and spread of nonnative invasive grasses. Annual and perennial nonnative grasses have fueled many wildfires in yellow paloverde communities over the last several decades. These fires may lead to a vegetation type conversion on frequently or severely burned sites.

Climate models suggest that the Sonoran Desert may become warmer and drier over the next century. Yellow paloverde may be highly vulnerable to regional effects of climate change, particularly in relation to summer moisture availability. Disruptions in the timing of moisture availability could result in a range shift. Climate variability and change may benefit invasive plant species that interfere with yellow paloverde establishment and persistence.

TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

FEIS Abreviation
PARMIC

Common Name
yellow paloverde
little-leaf paloverde
foothill paloverde

TAXONOMY
The scientific name for yellow paloverde is *Parkinsonia microphylla* Torr [59,79,80][59,79,80][59,79,80]. Fabaceae (Leguminosae) [12]. Common names are used throughout this review. For scientific names of plants and links to other FEIS Species Reviews, see table A1.

Hybrids: Yellow paloverde hybridizes with palo brea (i.e., Parkinsonia × sonorae [141]) in the southern part of yellow paloverde's range [33,56,141,180], and with blue paloverde in the northern part of yellow paloverde's range [34,78,180,182]. In the Tucson region, the "Desert Museum" hybrid used in landscaping is propagated from crossing yellow paloverde, blue paloverde, and Jerusalem thorn [56].

Synonyms
Cercidium microphyllum (Torr.) Rose & I.M. Johnst. [141,175].

LIFE FORM
Shrub-tree

DISTRIBUTION AND PLANT COMMUNITIES

GENERAL DISTRIBUTION
Yellow paloverde is native to the Sonoran Desert. It is common on bajadas, plains, and hillslopes in the Sonoran Desert regions of Arizona, southeastern California, the state of Sonora [89], and the Baja Peninsula (fig. 1) [144]. On the Baja peninsula, yellow paloverde occurs at low abundance on the gulf (east) side [157,180] and only very rarely on the Pacific (west) side [180]. Yellow paloverde also grows on many of the islands in the Gulf of California [144]. However, it does not extend to the extreme southern portions of the Sonoran Desert, either on the Mexican mainland or in Baja, California [157,177].

Yellow paloverde is generally restricted to the Sonoran Desert. However, isolated individuals occur beyond the desert's boundaries such as on a few south-facing slopes in southeastern Arizona [157], and in the transition zone between the Mojave and Sonoran Deserts where yellow paloverde trees may grow interspersed with Joshua trees [157].

Figure 1—Distribution of yellow paloverde in the United States and Mexico. Map from Little (1976) and digitized by Thompson et al. (1999) [88], Thompson et al. (1999) [176]

In Arizona, yellow paloverde occurs from the northwest to the south at around 1,220 m or lower [80]. From the lower San Pedro Valley (Pinal County), yellow paloverde extends westward across the foothills of the desert mountain ranges, gradually becoming less abundant until Ajo and Gila Bend, where it occurs only occasionally in steep mountain drainages. In its northern distribution, it is found in the lower Verde, Salt, Gila, and lower Hassayampa drainages [125].

In southeastern California, a few isolated populations occur in the Whipple Mountains near the Colorado River [70,80,157].

In Sonora, Mexico, yellow paloverde is common as far south as the Rio Sonora. It is uncommon on the sandy plains between the Rio Sonora and the Rio Yaqui, and in the interior desert valleys that extend into desert grassland. It has not been reported south of the Rio Yaqui [157,180].

States and Provinces

United States: Arizona, California [70,185]

Mexico: Sonora, Baja California, Baja California Sur [89,144,177,180]

SITE CHARACTERISTICS

Yellow paloverde grows in a warm, dry climate. Although drought-tolerant, yellow paloverde typically requires bimodal precipitation, with regular summer moisture [180]. In the Sonoran Desert, summers are very hot, and winters are relatively mild, with mean annual temperatures ranging from approximately 19 to 25°C [194]. Freezing temperatures occur occasionally in the north and at higher elevations, but much of this region remains frost free [157]. Across the Sonoran Desert, the mean annual precipitation is 206 mm, ranging from 75 to 560 mm. However, the driest areas average only 100 mm. Winter rainfall decreases from west to east, while summer rainfall decreases from east to west. Evaporation rates are high across the entire Sonoran Desert [194].

Yellow paloverde occurs at elevations ranging from 200 to 1,280 m. It can tolerate freezing temperatures as low as -9.5°C [76,152]. While the northern and upper elevational boundaries of its range appear to be temperature-limited, yellow paloverde's southern limits appear to correspond with the northern extent of palo brea [180].

Yellow paloverde communities are more common on coarse soils of plains, outwash slopes, and hills [157,177,193], than on the fine-textured soils of valley floors, which tend to be dominated by creosote bush-ragweed communities [198]. However, in some upland areas, and in the lower Colorado River valley where annual rainfall averages less than 75 mm, yellow paloverde often grows in narrow, dry washes [93,135,183,192].

PLANT COMMUNITIES

Yellow paloverde is dominant in three NatureServe Terrestrial Ecological Systems, all within the Sonoran Desert. The following descriptions are modified from NatureServe unless otherwise cited [123]. Associated LANDFIRE Biophysical Setting (BpS) models are provided in parentheses [87].

Sonoran Paloverde-Mixed Cacti Desert Scrub (11090)

> This system occurs on hillsides, mesas and upper bajadas in southern Arizona and extreme southeastern California. The vegetation is characterized by a diagnostic sparse, emergent layer of saguaro (3-16 m tall) and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs yellow paloverde and creosote bush, with species of mesquite, desert ironwood, and ocotillo less prominent. The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant. On slopes, plants are often distributed in patches around rock outcrops where suitable habitat exists.

Sonoran Brittlebush-Ironwood Desert Scrub

> This system is common in plains of Sonora, Mexico, between 100 and 800 m elevation, but may not occur in the United States. It consists of a sparse to moderately dense layer of short trees and xeromorphic, small-leaved and broad-leaved evergreen shrubs. Desert ironwood and brittlebush are dominant, and yellow paloverde and mesquites can also be common in the short-tree canopy. The understory is typically sparse but may include desert grasses and ephemerals.

Sonoran Granite Outcrop Desert Scrub (10900)

> This system occurs in foothills and mountains of Sonora, Mexico, and extends north into southern Arizona. It often occurs on low- to mid-elevation granitic outcrops, but may not be restricted to outcrops in Arizona. This system occurs upslope from Sonoran Paloverde-Mixed Cacti Desert Scrub and is dominated by sparse to clumped barbados nut and elephant trees. Other common species include elephant tree, Bigelow's nolina, yellow paloverde, and Kearney's sumac.

Commonly associated with saguaro cactus [14,47,74,113,132], yellow paloverde is critical to the pattern and structure of Sonoran desert scrub vegetation [60,102,134,180]. Yellow paloverde canopies create sheltered microhabitats for many plant species (fig. 2) [126,132], reducing incoming shortwave radiation by as much as 50% compared to open areas [92]. A single paloverde plant may provide shelter for multiple other plants [47,130,170] (fig. 2).

Figure 2—Three species of cactus grow within the shelter of a yellow paloverde canopy in Saguaro National Park. Photo by Cathy Mullen, used with permission.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

BOTANICAL DESCRIPTION

This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Identification keys are available (e.g., [80,175,180,193]).

Aboveground: Yellow paloverde is a multi-stemmed shrub or small tree that often grows to 6 m tall but occasionally may grow to 10 m [157,180]. The short trunk branches into two or three main stems at 10 to 25 cm from the ground, after which the crown branches prolifically, but not densely [157]. Stems are 15 to 20 cm in diameter [126]. The relatively thin bark (3-4 mm) is mostly smooth and green, covering all twigs and branches, except for occasional patches where scars have formed gray bark over wounds [157]. Gray bark also surrounds the base of the trunk. Stem tips end in spines [180].

Yellow paloverde leaves are between 2 cm [175] and 7 cm [56] long and are pinnately compound. Leaves have 2 to 8 pairs of leaflets that are 1 to 3.3 mm long [56] (fig. 3). Foliar biomass represents only about 0.5% of the total aboveground biomass [173,174]. Photosynthesis occurs in the leaves (~24%), stems (72%), and fruits and flowers (~4%) [173,180].

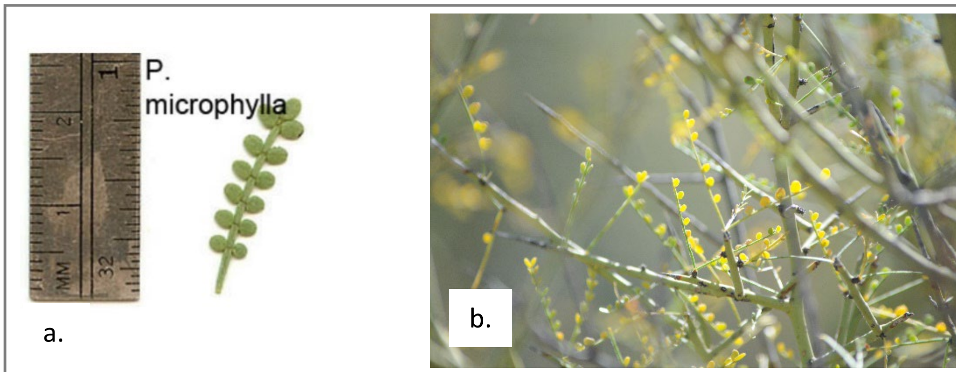

Figure 3—a) Bipinnate leaf structure of yellow paloverde. Photo by Sue Rutman, used with permission. b) Branches and stems showing sparseness of foliage. Photo by Andy Blackledge, used with permission.

Flowers are less than 10 mm long [80], with four yellow petals and one white [157] (fig. 4a). Seed pods are 3 to 13 cm long [152] and are somewhat constricted between each of the 1 to 5 seeds (fig. 4b) [193]. Seed pods end in a flat triangular or sword-shaped spine [80]. Seeds are 6 to 9 mm long, slightly flattened, and have a thick, waxy coat [157].

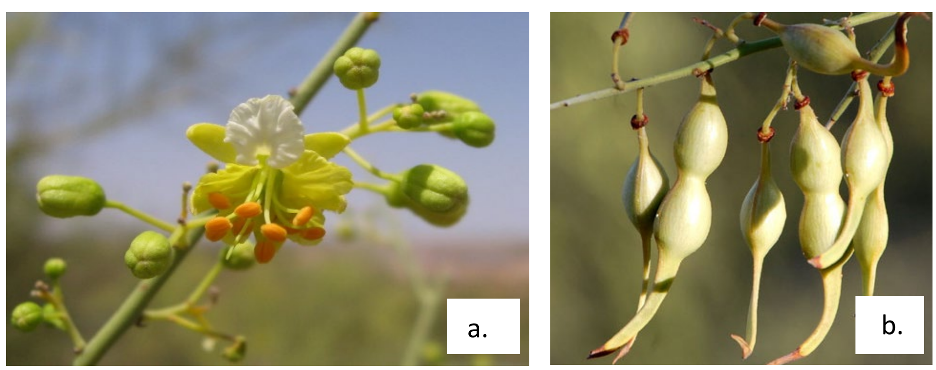

Figure 4—a) Yellow paloverde flower. Photo by Johnida Dockens, used with permission. b) Yellow paloverde seed pods. Photo by Michael Plagens, used with permission.

Belowground: Yellow paloverde roots are generally deep and wide spreading. On rocky slopes, roots follow pockets of soil and narrow fissures in rocks where moisture accumulates and is sheltered from evaporation [157]. Cannon (1911) described one yellow paloverde individual as having a taproot which extended down to the caliche soil layer, where it "terminated abruptly". Slender horizontal roots branched from the main root between 5 and 10 cm deep and extended horizontally, before growing downward "to a depth of 45 cm and even deeper where they penetrated the caliche" [31]. Plants occasionally produce shoots from horizontal roots [21,182].

Raunkiaer Life Form

Phanerophyte [143]

STAND STRUCTURE

Yellow paloverde density and cover vary with substrate and topography. Densities in rocky uplands tend to be higher than on adjacent, typically sandy, bajadas [103]. For example, at Tumamoc Hill (an outlier of the Tucson Mountains), yellow paloverde density was 308 trees/ha on basaltic andesite slopes and 8 trees/ha on coarse alluvium flats [21]. Along the boundary between the wetter Arizona Upland and drier Lower Colorado Valley subdivisions in Organ Pipe Cactus National Monument, cover of yellow paloverde ranged from around 9% on relatively coarse granitic substrates to around 3% on fine sandy alluvium [131].

SEASONAL DEVELOPMENT

Yellow paloverde branches and leaves can grow throughout the year, depending on moisture and temperature conditions [95,158,159,177]. However, branch radial growth is fastest during late summer months after the summer rain begins [94,177].

Yellow paloverde is drought deciduous. Trees generally produce two crops of leaves annually, following summer and winter rains [156,180]. Leaves generally persist for 6 to 10 weeks following the start of each rainy season [157]. Leaves are not produced when there is no rain, nor during cold winter months. However, if sufficient soil moisture is available, yellow paloverde may foliate in the spring, summer, or autumn. Under these conditions, yellow paloverde may produce and lose leaves several times in a year [183]. Leaflets turn yellow and fall from the rachis under dry conditions, and the rachis persists as a functional photosynthetic organ for a few weeks longer before it also falls [153,156,157].

Yellow paloverde flowers in late March [193] or April [157,175,180] until May [114,157,175,193] and occasionally after rains in August to November [41]. In very dry years, yellow paloverde might not flower at all [157,177,183]. However, after a wetter-than-usual rainy season, it may produce flowers in great abundance, inspiring another common name, fluvia de oro, or "fountain of gold" (see cover photo) [41]. Day length and temperature also contribute to the timing of flowering [20,180,183].

About 6 weeks after flowering, seeds ripen and seed pods drop [108], typically just before the summer rains [157,180,183].

REGENERATION PROCESSES

Yellow paloverde reproduces sexually and regenerates from seed. Although it can sprout from the root crown after top-kill from fire and/or drought [157,183], and has been observed sprouting from roots [21], yellow paloverde does not typically reproduce vegetatively.

Prolonged drought may reduce establishment [158,178]. However, yellow paloverde's long lifespan may buffer population reduction [158,180].

Pollination and Breeding System

Flowers are insect-pollinated, most commonly by bees [77]. Bees that pollinate yellow paloverde include European honeybees, pallid bees, centris-cuckoo bees, and megachilid bees. Yellow paloverde is also pollinated by painted lady butterflies [58]. Other related species, including palo brea, are bird-pollinated [8,13]. It is conceivable that birds may also pollinate yellow paloverde [58].

Yellow paloverde is protandrous and self-incompatible [77]. Flower timing may overlap extensively with that of blue paloverde. The two species occasionally co-occur, have flowers that are similar both in form and color, and are often pollinated by the same insect species. They can be artificially hybridized, producing offspring with pollen and seed fertility nearly equal to either parent. However, naturally occurring hybrids between these two species are uncommon [77]. Pollination studies suggest small differences in flowering period, flower color, and ultraviolet patterns may strengthen pollinator constancy and reduce hybridization incidence [34,77,180].

Seed Production and Predation

Yellow paloverde can flower copiously, especially in wet years [41]. However, more than 95% of flower buds may be lost prior to seed production due to limited plant resources and insect herbivory, particularly by gelechiid moth larvae [164]. Seed crops may be "very large" [157], with estimates of 1,958 seeds/30 cm of stem for a wet site (Filthy Five Park, Yavapai County, AZ), and 134 seeds/30 cm of stem for a dry site (Table Mesa Road, Yavapai County, AZ) [164]. However, seed crops may be poor or absent after unusually dry winters [19].

Yellow paloverde seeds are eaten by granivorous animals [105](see Importance to Wildlife). White-throated woodrats and round-tailed ground squirrels remove seeds from the plant [105]. Seeds that fall to the ground may be cached and eaten by kangaroo rats or other heteromyid rodents (e.g., pocket mice) [105,108,157]. Cached seeds are at increased risk of (re)discovery and consumption. While unconsumed seeds often germinate from caches (see Germination), emerging seedlings have olfactory cues that attract rodents [105,157]. Although he does not estimate the total number of seeds produced per plant, Shreve (1964) states that seed crops are often so large that many seeds remain, despite most being consumed by rodents [157].

Bruchid beetles are a common pre-dispersal seed predator but may occasionally scarify seeds for germination [105,180]. Bruchid beetles may destroy virtually all seeds that are retained in tree canopies. For example, McAuliffe (1990) reported that 44 of 45 seeds artificially suspended in a yellow paloverde canopy were destroyed outright, while the one remaining seed had more than ten bruchid eggs on its surface, and would have "undoubtedly" been later destroyed [105]. Pods and seeds that fall to the ground are generally avoided by bruchid beetles [105]. Early abscission of mature pods may help prevent pre-dispersal seed predation [105,165].

Seed Dispersal

Yellow paloverde seeds fall to the ground after the seed pods open. Within days of falling, almost all seeds are removed from beneath the parent canopy by seed predators. McAuliffe (1990) reports that on one site, 97% of seeds were removed within a week of falling, while on another, 99.5% of seeds were removed. Seed-caching heteromyid rodents, such as pocket mice, are likely the primary seed predators and de-facto dispersers. They cache seeds 2 to 3 cm deep in relatively small, dispersed clusters, often away from parent trees and under shrub canopy cover. Seedlings often germinate from forgotten or abandoned caches [105].

Yellow paloverde seeds dispersed by rodents to the bases of invasive grasses may limit yellow paloverde recruitment. In the field, rodents disproportionately cached seeds under dense canopies of invasive buffelgrass, rather than under canopies of native plants. Greenhouse experiments demonstrated buffelgrass reduced the early survival of yellow paloverde seedlings, but not their germination rates. This suggests that seedling establishment may be low when rodents cache seeds under buffelgrass in the field [166].

Seed Banking

Yellow paloverde has a small, at least short-term seed bank. Dormant seeds that are not removed by predators or destroyed by pathogens (see Seed Dispersal) likely remain in the soil for a year or more before germinating [18,19,105,180,183]. Observations at Tumamoc Hill suggest that seed crops comprise dormant and nondormant seeds (see Germination). Over two consecutive winters with severe drought and no seed production, yellow paloverde seeds germinated after rains during both summers, indicating that seeds germinated from the soil seed bank [19]. Some may remain viable for longer periods in rodent caches [105], although information is lacking. McAuliffe (1990) observed two seedlings emerge from a cache where seedlings emerged one to two years earlier [105], suggesting that seeds may germinate from a single cache over several years.

Seedlings emerge in pulses after rain and warm conditions which trigger germination (see Germination), but seed banks are not exhausted after these pulses [18]. A seed bank study in the Tucson Mountains, Arizona, estimated 141 yellow paloverde seeds/m^2 over 30 microplots prior to seedling emergence. After the first emergence pulse, 58% of viable seeds remained in the soil, and after the second pulse, 28% remained. The author speculated that multiple emergence pulses may reflect differing ages of seed cohorts, with older cohorts germinating earlier. Alternatively, seeds within a single age cohort may have different germination requirements [18].

Yellow paloverde was “important in the vegetation” but not detected in seed bank samples from 14 sites in Saguaro National Park, possibly because hard seed coats and/or seed dormancy prevented germination (see Germination), resulting in seeds going undetected by the emergence method [2].

Germination

Most yellow paloverde seeds are viable at maturity [19,140,157] and germinate under warm, moist conditions. Germination may occur soon after the first substantial summer rains [18,105,160], when soils are warm [158,160,183]. Over a 7-year period in the Tucson Mountains, germination was triggered after at least 17 mm of rain when temperatures were at least 20°C. Seeds mostly failed to germinate below these thresholds. Over this period, there were 13 pulses when high numbers of yellow paloverde seeds germinated and seedlings emerged [18].

Yellow paloverde produces both dormant and nondormant seeds. Several sources describe yellow paloverde’s hard seed coat and suggest that seeds require scarification to break dormancy and trigger germination (e.g., [51,160,182]); however, some seeds can germinate shortly after dispersal without scarification [19]. Field experiments repeated for 2 years indicated that 49% of ripe, unscarified seeds collected in mid-June and planted about 2.5 cm deep, germinated after August rains. Only 4%

germinated when the experiment was repeated the second year. Germination rates were 17.5% and 70% in the first and second year for scarified seeds planted under the same conditions. In the first year, seeds were scarified by rubbing seed coats with a metal file; in the second year, seeds were nicked with a razor blade. Poor germination of scarified seeds the first year was attributed to incomplete scarification. Most ungerminated seeds retained viability at the end of each experiment (i.e., after burial for 1 summer (~80 days)). After scarification, germination averaged 88% and 100% for previously unscarified and scarified seeds, respectively. Laboratory experiments suggest permeability of fresh (unscarified) seed is highest under warm temperatures with no more than one cycle of wetting and drying. Germination of unscarified seeds was twice as high at 40°C (51%) than at 25°C (26%). Wetting/drying experiments found that germination declined as the number of wetting/drying cycles increased [19].

For dormant seeds, scarification hastens germination and may occur when the seed coat is compromised by seed predators or through weathering processes in the soil. If seeds are not scarified before being buried, “months or years” may pass before the seed coat is weathered enough to allow water to penetrate and trigger germination [105]. Shreve (1917) speculated that seeds must “lie in the ground” for at least a year before they can germinate [160].

Seedling Establishment and Mortality

Yellow paloverde seedlings may have high emergence (e.g., [22,160]); however, survival and establishment are generally low. Four studies at Tumamoc Hill, near Tucson, found low establishment rates [22,158,160,161]. Over a 7-year period (1987-1993 inclusive), mean first year survivorship was 1.7%, with only 2 of 1,008 seedlings surviving longer than one year. Most seedlings germinated between July and October, then died before the following spring (April-June). Survivorship from germination to the following May averaged 5.2%, ranging from 0 to 18.8% [22]. An earlier study in the same area found similar results. Over a 6-year period (1910-1915 inclusive), mean first year survivorship was 0.9%. Between 1910 and 1917, 1,188 seedlings emerged, but only 19 survived to 1917. Six of the survivors were at least 8 years old (some seedlings had emerged before the study began) and 5 were only 1 year old [160]. By 1928, there was only one surviving seedling out of about 2,500 seedlings that emerged on this study site between 1910 and 1928 [161]. After the first year, yellow paloverde survival remains low overall. One study found that less than 3% of seedlings survive to the end of the third year [158]. At around 3 to 5 years old, seedlings may lose branches during extreme drought [158,160], which may increase their chance of survival. However, survival remains low during the first decade [157,160]. While Shreve (1917) found that only 0.37% (2/542) of the first cohort of seedlings in the 7-year study survived to 7 years [160], a later study in the same area reported that seedling survival to at least 7 years was 42% (n=12), although first-year seedlings were excluded from analysis [63].

Seedling establishment may be limited by moisture availability [158,160] and herbivory [22]. During the summer monsoon season (July-August), newly germinated seedlings can grow to 2 to 3 cm tall, with a root system 4 to 9 cm long [157]. Those with more extensive roots are more likely to survive dry periods [160]. Seedlings will die if the substrate is not porous enough for roots to penetrate and access pockets of moisture [160]. Early work on Tumamoc Hill, associated seedling mortality with dry periods. A one-year study found mortality rates of first-year seedlings were higher during the dry periods (after-summer and fore-summer) than the wetter periods (mid-summer and winter) [158,160]. Although the same seasonal attrition of seedlings (e.g., highest mortality rates during the dry after-summer and fore-summer) was found in a later study on the same site, there was no correlation between mean daily rain and lifespan of seedlings in two seedling cohorts analyzed over 2 years. Rather, the authors suggested that most seedling mortality was due to herbivory [22]. Similarly, on bajadas at Organ Pipe Cactus National Monument and at Punta Arenas, Sonora, Mexico, death due to water stress and desiccation was "uncommon" in marked seedlings, despite prolonged dry conditions. Rather, herbivory was very high. Around 92% of seedlings growing in open conditions were eaten and around 14% of seedlings growing under shrubs were eaten. The author suggested that herbivory may limit yellow paloverde establishment to refuges under the canopies of perennial plants (particularly triangle bur ragweed and burrobush) [103].

Yellow paloverde seedlings growing in open microsites are often browsed by lagomorphs and rodents, and they have minimal or no ability to resprout. Mortality rates due to herbivory can be as high as 100% [103]. Seedlings growing in sheltered habitat, such as rocky areas or under dense shrubs, are less likely to be discovered and eaten by herbivores than seedlings growing in the open [103,105,180]. Yellow paloverde seedlings often establish under the shelter of shrubs in the genus *Ambrosia* [29], and in some locations, do so almost exclusively [104]. However, seedlings that establish under buffelgrass may have low, short-term survival rates (see Seed Dispersal) [166]. When protected from herbivores, seedlings growing in the open may have "very high short-term survival rates" (McAuliffe, personal communication cited in [30]).

Plant Growth and Mortality

Yellow paloverde is slow-growing [94,177] and long-lived [77,158,177,180]. Shreve (1911) counted growth rings of yellow paloverde on Tumamoc Hill and estimated that plants lived up to 400 years old [158]. However, growth rings may not be reliable for determining age in yellow paloverde, because 1) it can be difficult to determine whether a single ring is the result of multiple years of growth [95], and 2) a plant may produce two rings in 1 year due to two periods of growth in a single year (See Seasonal Development) [22]. Bowers and Turner (2002) revisited Shreve's 1911 study site and developed an age-growth model based on basal stem circumference and historical photographs. They calculated that yellow paloverde maximum lifespan was likely less than 200 years, with most plants living less than 100 years. They suggested that Shreve (1911) mistook seasonal growth-rings for annual rings, which may account the for the doubled estimated lifespan [22].

Although few studies estimate yellow paloverde height growth, several publications describe yellow paloverde as being slow-growing (e.g., [16,94]). On Tumamoc Hill, Shreve (1917) estimated that 20-cm tall yellow paloverde plants may be between 20 and 40 years old [160]. However, cultivated and watered yellow paloverde seedlings grow faster than under natural conditions [16,110]. On quarry restoration sites in Sonora, Mexico, planted and watered seedlings averaged 2.67 m tall at 8 years old [110]. On Tumamoc Hill, basal stem circumference increased linearly with estimated age (R^2=0.95). Plants estimated to be 5 years old had a ~5 cm basal circumference, plants estimated to be 40 years old had a ~30 cm basal circumference, and plants estimated to be 90 years old had a ~60 cm basal circumference [22]. In the Tucson Mountains, mean radial growth (within 1 m of soil surface) of 5 "large" yellow paloverde over 2 years was estimated to be between 0.04 and 0.14 cm per year [177]. Compared with other paloverde species in cultivation, yellow paloverde is the slowest growing [152].

Barring drought conditions, adult survival rates can be very high [161]. However, periods of extreme drought, particularly following dry winters or summers, can cause widespread episodic mortality in large yellow paloverde [21,182]. Extreme drought may cause 100% mortality particularly on steep, south-facing slopes [21]. See Management Under a Changing Climate for more information. During drought periods, plants drop leaves, twigs, and branches [158]. If droughts are extended, large branches may die, which could reduce water loss and limit plant size [156]. Prolonged drought may top-kill individuals, although new growth may sprout from the root crown when moisture returns [157,182].

Like many other perennial desert plant species, yellow paloverde can withstand temperature extremes. Outer layers of yellow paloverde trunks can reach temperatures of 41°C [94], and plants can survive freezing temperatures as low as -9.5°C [76]. However, yellow paloverde is susceptible to catastrophic freezes—periods of time when the temperature drops low enough, for long enough—when many Sonoran Desert plant species are injured or killed [17].

Yellow paloverde trees may grow in close association with saguaro for many years, serving as a nurse plant with no apparent ill effects to either species. However, the saguaro's presence may eventually become detrimental, or even lethal for the paloverde [97,188]. Mortality rates are higher among yellow paloverde that have large saguaro beneath their canopies than those without [67,178], and dead yellow paloverde plants are often found with saguaro growing among their skeletal branches [102,183]. The shallower-rooted saguaro may be more efficient at extracting moisture from the soil than yellow paloverde [31,102,168,183].

Vegetative Reproduction and Regeneration

Yellow paloverde can die-back entirely in response to drought, then resprout from the base [157,183]. It can also sprout from roots within several meters of the trunk. It is unclear whether the root sprouts are independent of the parent plant and can persist after the parent plant dies [21,182]. Information was not available indicating what conditions trigger root sprouting and if it is related to disturbance (e.g., fire).

SUCCESSIONAL STATUS

Disturbances that initiate secondary succession were historically rare to infrequent in most desert ecosystems. Based on fuel characteristics and lack of fire adaptations in dominant vegetation, small or patchy fires were thought to be infrequent, and replacement fires were thought to be rare to absent in yellow paloverde communities (see Fire Regimes). Prolonged drought or freezing temperatures lasting longer than 24 hours likely thinned dominant overstory plants and, in rare cases, led to stand replacement [86,87]. Episodic mortality may be caused by factors such as freezing [17,170] and drought [21,182]. Variation in severity and duration of drought conditions in the Southwest likely contributed to vegetation changes, including fluctuations in yellow paloverde populations [21,182].

Secondary succession proceeds slowly in deserts, with changes occurring over a longer period than in more mesic environments and more temperate regions (reviewed in [1]). Native plant communities may require decades to centuries to reach predisturbance plant cover, community structure, and species diversity and composition. For example, in Sonoran Paloverde-Mixed Cacti Desert Scrub where yellow paloverde typically codominates with saguaro, saguaro depends on the alignment of multiple factors for successful recruitment of new individuals into the population, which can prolong recovery (see the FEIS saguaro Species Review). Because disturbances were historically rare and succession slow, the dynamics and underlying mechanisms of succession in desert systems are not well described [104]. However, one chronosequence study conducted on abandoned agricultural fields in La Costa de Hermosillo desert region, Mexico, found a pattern of species replacement that had not previously been documented in the Sonoran Desert. Species replacement and establishment of late successional species was relatively fast (occurring after 4-10 years), at which time, most pioneer species were absent. Yellow paloverde established 4 years after abandonment, with shrubs and trees dominating after 18 years [36].

Presence of nonnative invasive plants and increased fire occurrence can influence contemporary patterns of succession in yellow paloverde communities. Nonnative grasses (especially red brome and buffelgrass, but also lovegrasses, crimson fountaingrass and Mediterranean grass) are increasing in abundance in yellow paloverde habitat [61,91,129,138]. Buffelgrass resprouts after fire more readily than native plants; sometimes within a few days after fire [111]. Grasses can increase fine fuel loads and continuity on invaded sites, which increases the likelihood of fire ignition and spread and can create a feedback loop resulting in an invasive grass/fire cycle [37,44,111,122]. This can result in a plant community type conversion—from desert shrubland to nonnative grassland—which would likely persist as an alternative stable state [24,25]. The presence of nonnative, invasive plants and changing climatic conditions may make recovery to predisturbance community structure and composition impossible after stand-replacing disturbances [1]. See Fuel Characteristics and Fire Regimes for more information.

Even in the absence of fire, yellow paloverde cover is lower when buffelgrass is present, and negatively correlated with time since buffelgrass invasion, both initial and secondary invasion [129]. Buffelgrass may interfere with yellow paloverde establishment and growth (e.g., [119,166]) by competing for water [50]. Where the two species co-occur, buffelgrass often grows abundantly under yellow paloverde canopies [45].

As a dominant in Sonoran Paloverde-Mixed Cacti Desert Scrub, yellow paloverde plants provide cover for seedlings and plants of multiple species. For example, yellow paloverde are nurse plants for saguaro [74,127,170,179,188]. The likelihood of a yellow paloverde harboring at least one saguaro increases with age, as does the average number of saguaros associated with each yellow paloverde canopy [104]. Yellow paloverde plants that shelter saguaro are eventually outcompeted by the shallower-rooted cactus for moisture [102]. Yellow paloverde canopies buffer maximum and minimum temperatures by limiting incoming radiation during the day and outgoing radiation at night [49,60,92,162]. Under the moderate shade of yellow paloverde's open canopy, shallow-rooted annuals are more abundant than in open areas with coarser soils [98].

FIRE ECOLOGY AND MANAGEMENT

IMMEDIATE FIRE EFFECTS

Yellow paloverde is easily damaged by fire [53,55,184] and is often killed or top-killed [5,15,27,55,101,111,117,129,186]. Yellow paloverde has relatively thin, photosynthetic bark (3-4 mm thick), which makes it susceptible to damage and death from high fire temperatures [101]. According to McAuliffe (1995), fire "does not have to be particularly intense to kill a palo verde", and the "heat of even small fires sears and kills the green bark and underlying cambium, causing death of the tree" [101]. Estimates of postfire mortality reported within the first year after wildfire range from 35%, 1 month after the 1994 Mother's Day Fire [54], to 100% immediately after the 1980 Bulldog Canyon Wildfire [37]. However, yellow paloverde postfire mortality may be delayed, and mortality rates may increase with time since fire (see Postfire Mortality, below).

Immediate effects of fire on yellow paloverde include charring, scorching, and consumption [55,149,184]. Biomass often remains intact immediately after fire [90], and individuals are seldom consumed by fire [195]; however, they are often top-killed, or completely killed by girdling or scorching. While observations indicate that yellow paloverde can sometimes survive with severe fire damage (e.g., [137]), it is unclear what degree of damage is likely to be lethal. Within 2 years after the King Valley Fire at the Kofa National Wildlife Refuge, for example, 90% of yellow and blue paloverdes with more than 10% char (i.e., blackened by incineration and showing damage to deep tissue on branches, trunks, and/or roots) were top-killed, as were about 50% of individuals with severe (>50%) scorching (i.e., singed and discolored leaves and small twigs) (Esque unpublished data, 2008 cited in [184]). Only one of these top-killed paloverdes survived and resprouted [55]. Resprouting may have been inhibited by low postfire rainfall [184]. Some injured or top-killed plants can resprout from branches or from the root crown [38,117,149,184,195,196]; however, resprouting is not common, and information about drivers of postfire resprouting is lacking (see Plant Response to Fire).

Plants that are surrounded by high fuel densities are likely to sustain greater fire damage [101], including deeper charring [184], than those on fuel-limited sites. Nonnative grasses—especially perennial grasses such as buffelgrass—increase fuel load and continuity on invaded desert scrub sites and may increase yellow paloverde mortality by increasing flame lengths, rate of spread, and fire temperatures compared to uninvaded sites [52,112]. For example, paloverde mortality rate (yellow and blue paloverde combined) was greater in semi-desert grassland (80%) than in fuel-limited Sonoran desert scrub (68%) after the 2020 Bighorn Fire outside of Tucson, Arizona, although paloverde was far less common in grassland. In addition, observations suggest that mortality and damage of paloverdes was greater in areas of Sonoran desert scrub where crimson fountaingrass and buffelgrass were present and contributed to higher fuel loads than in areas where only winter annual grasses were present [195].

Yellow paloverde seeds may survive fire in the soil seed bank, although seed bank densities may be low and seed banks short-lived (see Seed Banking). Yellow paloverde seeds have a thick seed coat, which may protect them from heat damage during fire, especially when buried in soil, as has been observed in laboratory studies of seeds from other Sonoran leguminous shrubs [43]. A flush of paloverde seedlings a few weeks after a severe fire in the Harcuvar Mountains of Arizona suggests that seeds in the soil seed bank were not killed by fire [53].

Postfire Mortality

Mortality of fire damaged plants may be delayed for many months or possibly years after fire [37,38,137,184]. Therefore, observations within the first 1 to 2 years after fire may not be indicative of total postfire mortality [184]. On the Tonto National Forest, 26% of yellow paloverde plants died immediately after a 1981 prescribed fire. Nine months later, 73% were dead. Before the fire, yellow paloverde stand density averaged 203 trees/ha and 8% cover. Immediately after the fire, density averaged 155 trees/ha and 3.5% cover, and 9 months later, density averaged 55 trees/ha and 0.5% cover [38]. Similarly, yellow paloverde mortality rate was estimated at about 35%, 1 month after the 1994 Mother's Day Fire in Saguaro National Park, and this increased to around 72% 3 and 6 years after fire [54]. After the 2005 King Valley Fire in the Kofa National Wildlife Refuge in southwestern Arizona, yellow paloverde and blue paloverde crowns that were alive but fire-damaged 9 months after fire were dead 16 months after fire. Rainfall during the intervening winter was "well below average", which may have reduced postfire survival [184]. Paloverde cover averaged 7.02% on unburned xeroriparian plots and 1.66% on burned xeroriparian plots 6 to 21 months after the fire [55].

POSTFIRE REGENERATION STRATEGY

Tree with adventitious buds, a sprouting root crown, sobols, and/or root sprouts
Tall shrub, adventitious buds and/or a sprouting root crown
Secondary colonizer (on- or off-site seed sources) [171]

FIRE ADAPTATIONS

Yellow paloverde is not fire-adapted. It is sensitive to fire [184,186], and is often killed [101,117,149]; however, it sometimes resprouts from stems and root crowns after fire (e.g., [15,38,55,117,149,184,195,196] (see Immediate Fire Effects and Plant Response to Fire). Given that fire is thought to have been historically rare in Sonoran desert scrub communities, resprouting may have developed as a response to stress damage from drought, rather than in response to damage from fire [195].

Yellow paloverde seeds have a short-term soil seed bank, but information about seed survival and germination after fire is limited (see Immediate Fire Effects and Plant Response to Fire).

PLANT RESPONSE TO FIRE

Although yellow paloverde may resprout after top-kill or injury from fire [15,38,55,90,101,117,149,184,195,196], observations suggest that it is more likely to be killed. Postfire mortality rates often exceed 70% within the first few years (e.g., [37,54,55,101,149]) (see Immediate Fire Effects). Because it is a weak sprouter, postfire recovery of yellow paloverde is largely dependent on establishment from seeds. Yellow paloverde populations are slow to recover after fire, and recovery depends on the availability of propagules, postfire weather, and site characteristics that affect moisture availability, and incidence and severity of subsequent disturbances, including repeated fires.

Resprouting

Very little information is available on rates of postfire resprouting in yellow paloverde. Reported rates of resprouting from top-killed or injured plants range from 0 to about 32% when observed anywhere from 4 months to 4 years after fire (e.g., [55,101,117,195]). It is unclear what variables most affect rates of postfire mortality and survival via resprouting. However, suggested drivers of postfire resprouting in yellow paloverde include severity of fire injury (i.e., amount of charring and scorching, which is related to fuel and fire characteristics) [55,90,184], postfire moisture availability [55,75,184,195], and occurrence of subsequent disturbances (including repeated fires) [52].

Although yellow paloverde can be killed by even low-intensity fire (see Immediate Fire Effects), postfire mortality rates are likely to increase and resprouting rates are likely to decrease when fire injury (charring and scorching) is more severe, which is more likely to occur when fuel loads are high and continuous and fire weather is severe. Loftin (1987) notes that yellow paloverde "will resprout if their rootstocks are not killed" [90]. Eight yellow paloverde plants with 78% of their photosynthetic surface scorched or consumed by fire had resprouted 4 years after the June 1974 Dead Man Wash Fire [149], and Esque and others (2013) suggested that "some of the plants with no visible live material may resprout after 100% top-kill", although they indicated that this was rare [55].

Postfire sprouting is likely to be reduced when postfire water availability is limited; however, data are lacking. After prescribed fires in Sonora, Mexico, sprouting of all shrubs, including yellow paloverde, was "limited due to low rainfall" the following summer [75]. After the 2020 Big Horn Fire, near Tucson, "sprouting and growth of live plants was greatly reduced" due to "extremely low summer monsoon precipitation" [195]. For 2 years after the 2005 King Valley Fire rainfall was "well below average" [184] and, although 18% of yellow paloverde plants resprouted, the authors suggested that "the short time between the fire and our samplings, coupled with one very dry year, was insufficient to promote extensive resprouting" [55].

Yellow paloverde abundance is likely to be substantially reduced by a single fire, and it is likely to be extirpated from areas with repeated or frequent fire [52], in part because postfire sprouting is likely to be reduced by repeated fires [90,195]; however, data are lacking. Wilder et al. (2021) suggest that "the degree of resilience offered by resprouting capacity is unclear and likely not robust after repeated burns" [195].

Postfire Seedling Establishment

Given that seed and seedling predation rates are high and seedling establishment and survival rates are low (see Seedling Establishment and Mortality), yellow paloverde postfire seedling establishment is also likely to be low; however, information on yellow paloverde postfire seedling establishment is limited and largely anecdotal. Postfire establishment of yellow paloverde seedlings is described for only two burned areas [53,149], whereas postfire surveys on 4 other burned sites found no yellow paloverde seedlings [38,117,149]. In Arizona's Harcuvar Mountains, "multitudes" of yellow paloverde seedlings were observed a few weeks after a severe fire in 1999, which was described as "intense", having "left only ash as ground cover" (Esque personal observation, 1999 cited in [53]). The authors suggested that seeds survived fire in the soil, although they did not identify any environmental factors that may have contributed to this flush of seedlings. They did speculate that most of these seedlings would not likely survive their first year, lacking cover (e.g., nurse plants) from herbivores [53].

Other postfire observations found few or no yellow paloverde seedlings. Three years after the 1974 Saguaro Fire, 50 km east of Phoenix, five yellow paloverde seedlings were found in a 900-m^2 burned plot, and none were found in a 600-m^2 burned plot 4 years after the 1974 Dead Man Wash fire, 45 km north of Phoenix [149]. No yellow paloverde seedlings were found 19 months after the 1979 Granite Fire, 20 km southeast of Florence, Arizona [117], and none were found immediately or 9 months after a prescribed fire in Bulldog Canyon on the Tonto National Forest, or 14 and 26 months after the 1980 Bulldog Canyon Wildfire [38].

Precipitation both before and after fire is likely an important driver of yellow paloverde seed production and postfire seedling establishment; however, data and observations are lacking. Despite above-average precipitation for two winters prior to the Granite Fire, and an expectation of a large number of seeds added to the soil, no yellow paloverde seedlings were found 19 months after fire [117]. Similarly, although "substantial rainfall occurred in January and February" of the year following the Bulldog Canyon fires that "result[ed] in good germination and growth conditions for most desert species", no yellow paloverde seedlings were present on burned sites 14 or 26 months after fire [38].

Postfire Recovery

Yellow paloverde density and cover typically decrease substantially after fire and are slow to recover. For example, on the Tonto National Forest, yellow paloverde was "noticeably removed" or absent from burned plots 5 years after the 1995 River Fire, 7 years after the 1993 Vista View Fire, 17 years after the 1983 Massacre Fire, and 6 years after the last of several repeated fires near the Bush Highway. A small but significant increase in yellow paloverde density 21 years after the 1979 Siphon Fire suggests that yellow paloverde recovery may have begun on those sites [5]. In contrast, a study in Sonoran desert scrub communities in Saguaro National Park spanning more than 40 years after the cessation of livestock grazing shows little to no recovery after more than 20 years since fire. It also seems to show a decrease in density and/or cover of yellow paloverde over time across all sample plots, regardless of plot fire history, although plots with no known fire history seemed to show less of a decline over time (table 1). Analyses suggested that mean yellow paloverde cover and density were negatively correlated with fire recency (i.e., yellow paloverde abundance tended to be lower on plots with shortest time since fire). However, data from individual plots do not seem to reflect this pattern (table 1). Cover and density of all trees decreased over time, regardless of time-since-fire and, although this trend was not significant, the authors note that sites had transitioned from Sonoran desert scrub to dominance by perennial bunchgrass over the 40-year study period. The authors also stated that climate was a better predictor for postfire community structure than time since fire, and that other fire data, such as fire duration, intensity, and seasonality might improve our understanding of the effects of fire in this system [172].

Table 1—Total cover and density of yellow paloverde on 7 sample plots with different fire histories in Saguaro National Park, Arizona, on 3 sample dates spanning >40 years [172].

Plot # (Fire Year)	Sample Year	Time Since Fire (years)	Cover (m)	Density (plants/100 m^2)
3 (N/A)	1976	unknown	19.6	8
	2007	>31	3.2	8
	2018	>43	1.8	8
7 (N/A)	1976	unknown	48.9	65
	2007	>31	17.1	24
	2018	>43	21.7	24
4 (1989)	1976	unknown	25.1	14
	2007	18	9.3	5
	2018	29	1.2	1
5 (1989)	1976	unknown	0	14
	2007	18	0	0
	2018	29	0	0
8 (1989)	1976	unknown	51.5	40
	2007	18	1.4	5
	2018	29	5.8	6
1 (1994)	1976	unknown	15.5	16
	2007	13	0.6	1
	2018	24	0.5	2
2 (1999)	1976	unknown	45.5	25
	2007	13	7.4	5
	2018	24	2.8	7

While a single fire can substantially reduce yellow paloverde abundance for decades or more, repeated fires are likely to further reduce abundance and may eliminate the species from a site. However, information on the effects of repeated fires on yellow paloverde is lacking. The Bush Highway Fire site that burned four times in 24 years showed a significant decrease in abundance of dominant native species such as yellow paloverde and saguaro [5]. Yellow paloverde abundance varied in burned (n = 4) and unburned (*n* = 1) plots in Sonoran desert scrub communities on the Tonto National Monument. Burned plots had a history of 1, 2, or 5 fires. Density of yellow paloverde was greatest (7 trees/plot = 233 trees/ha) on the plot with no known history of fire, where its relative cover was ~23%. On the two plots with a history of one fire, yellow paloverde relative cover was ~27% and density 4 trees/plot (133 trees/ha) 26 years after fire, and relative cover was ~16% and density 3 trees/plot (100 trees/ha) 14 years after fire. On these plots the author noted 2 and 3 fire-damaged yellow paloverde trees, respectively, that were still living. The plot that had burned twice (26 years and 14 years prior) had no yellow paloverde trees, while the plot that had burned five times prior to sampling (43, 26, 20, 14 and 10 years prior), had 1 yellow paloverde tree (~33 trees/ha) [137].

FUEL CHARACTERISTICS

Although they are susceptible to charring and scorching, yellow paloverde plants are rarely entirely consumed by fire [149], and biomass may be left largely intact [90]. Living yellow paloverde plants often have dead branches and twigs, representing 5% to 10% of medium-sized branches, and >30% of the twigs, depending on the season [156]. However, in living tissue, xylem water potentials are high relative to other Sonoran Desert plants [68], suggesting that yellow paloverde stems may be more hydrated than other plants during drought conditions [38]. Consequently, litter and other fuels (mostly annual forbs and grasses) growing beneath yellow paloverde canopies are more likely to burn than yellow paloverde canopies. During an experimental fire in Bulldog Canyon on the Tonto National Forest, mean maximum temperatures under yellow paloverdes were 299 °C at 1 cm above the soil surface (compared to 88°C in interspaces and 405°C within triangle bur ragweeds) and 167°C at 30 cm above the soil surface (compared to 76°C in interspaces and 210°C within triangle bur ragweeds) [133].

Because it is commonly associated with, and a nurse plant to, saguaro (e.g., [102,181]), yellow paloverde can also contribute to saguaro injury or death by providing fuel for fire [197].

In most years, fuels in Sonoran desert scrub communities are sparse and discontinuous and insufficient to carry fire. However, after one or more years of above-average precipitation, native annual plants may establish in sufficient density to carry fire [6,26,64,87,155]. Although data from yellow paloverde communities are limited, nonnative invasive grasses, especially buffelgrass and red brome, may alter fuel characteristics on invaded sites by adding a novel source of fine fuel that is more abundant, continuous, and persistent than native herbaceous fuels [52,54,64,112,150]. Nonnative annual grasses are the most abundant plants over large areas of the northern Sonoran Desert, and red brome is the most abundant nonnative annual grass in most yellow paloverde communities. Red brome has fueled several wildfires in Sonoran desert scrub habitat, including Saguaro National Park [53]. Buffelgrass is of particular concern because it is rapidly spreading in saguaro scrub communities [52,129], it produces biomass that can be orders of magnitude greater than that of red brome [52,54], and it creates a persistent, year-to-year fire hazard that can burn in any month [52,112]. Fires fueled by buffelgrass are likely to have longer flame lengths, more rapid spread rates, higher temperatures, and to cause greater mortality to native flora and fauna than fires fueled by nonnative annual grasses or native annual plants [54,112]. Other nonnative species of concern include annual Mediterranean grass and perennials crimson fountaingrass and lovegrasses. Altered fuel characteristics from annual or perennial nonnative grass invasions have the potential to increase fire frequency, size, and severity, and thus lead to an invasive grass/fire cycle and plant community type conversion (see Fire Regimes, below).

See the FEIS Synthesis on fire regimes in Sonoran desert scrub communities for more information about historical and contemporary fuel characteristics in communities where yellow paloverde dominates.

FIRE REGIMES

Yellow paloverde occurs in desert scrub ecosystems where fire is thought to have been rare to infrequent, based on a lack of fuels to carry fire in most years and a lack of fire adaptations in dominant species. Yellow paloverde is likely to be extirpated from areas with frequent fires [5,137]. Projections estimate that paloverde populations would trend towards extinction when fire frequency is 50 years or less [147].

Although ignition from lightning storms may have been common during summer monsoons, based on fuel characteristics, lack of fire adaptations in dominant plants [5,9,142], slow growth rates, and slow postfire recovery rates of dominant plant species [149,163,184], fire is considered to have been rare to absent in presettlement Sonoran desert scrub communities [117,148]. Mean historical fire intervals derived from LANDFIRE succession modeling are estimated to exceed 1,000 years [86]. Large fires are considered historically rare and were likely driven by accumulations of annuals following unusually wet years (see Fuel Characteristics). Long-lived desert perennials, including yellow paloverde and the commercially important saguaro with which yellow paloverde is associated, lack fire adaptations (see Plant Response to Fire).

Fuel and fire regime characteristics in contemporary Sonoran desert scrub communities have likely shifted outside the range of historical variation, due to both increases in human populations and human-caused ignitions, and to the introduction and spread of nonnative invasive grasses. These grasses can increase fine fuel loads and continuity on invaded sites, which may alter fire regime characteristics and create a feedback loop that results in an invasive grass/fire cycle [37,44,111,122]. This can result in a plant community type conversion (i.e., from native desert scrub to nonnative grassland [24,25]). Changes in fire regime and plant community characteristics such as these have been observed in other arid systems where buffelgrass [10,27,28,62], red brome, and Mediterranean grasses [62,83] are invasive.

Table 2—Modeled fire regime characteristics for LANDFIRE Biophysical Settings where yellow paloverde is dominant in the United States. Table created from data in LANDFIRE (2020) [87].

Biophysical Setting Name (BpS Code_Map Zone)	Fire interval (years)	Replacement severity fire (%)	Mixed severity fire (%)	Low severity fire (%)	Fire regime group
Sonoran Paloverde-Mixed Cacti Desert Scrub (11090_14)	1,056	1,056	NA	NA	V-B
Sonoran Paloverde-Mixed Cacti Desert Scrub (11090_15)	1,049	1,049	NA	NA	V-B
Sonoran Granite Outcrop Desert Scrub (10900_14)	513	513	NA	NA	V-B

See these FEIS publications for information on historical fire regimes in plant communities in which yellow paloverde is most common or dominant:

- Fire regimes of Sonoran desert scrub communities
- Fire regimes of desert riparian communities

FIRE MANAGEMENT CONSIDERATIONS

Fire is generally considered harmful to Sonoran desert scrub communities where yellow paloverde dominates. Yellow paloverde is easily damaged and often killed by fire, and evidence suggests that postfire regeneration is limited, and postfire recovery is slow – on the scale of decades or centuries (see Plant Response to Fire).

Fire management considerations to maintain yellow paloverde communities should be focused on excluding fire and facilitating postfire recovery. Excluding fires from Sonoran desert scrub is challenging because of increased human-caused ignitions and nonnative invasive grass fuels [184].

Invasion of nonnative grasses, such as buffelgrass, may be contributing to increased fire frequency [52,62,195], which though not yet linked explicitly to the decline of yellow paloverde, could more generally facilitate transitions from desert scrub communities to grassy mesquite and acacia savannas [52,187]. Over the last several decades, nonnative invasive grasses have fueled wildfires that burned many hectares of yellow paloverde habitat [196]. Buffelgrass is of primary concern because it produces large, continuous, and persistent fuel loads that burn at high temperatures, and it is rapidly spreading and increasing in abundance in some areas [52,54,129]. This fire-adapted, perennial bunchgrass displaces native desert vegetation [27] and forms dense infestations that can carry fires across the landscape [139]. See the FEIS review on buffelgrass for more information.

While prescribed fire is not used to manage native Sonoran desert scrub communities, nonnative pastures are often burned to kill yellow paloverde and other woody plants and to keep them from establishing and spreading [75,196]. Loss of yellow paloverde to fire may slow saguaro recolonization in burned areas [111,196].

OTHER MANAGEMENT CONSIDERATIONS

Federal status

None

Other status

None

IMPORTANCE TO WILDLIFE AND LIVESTOCK

Yellow paloverde provides habitat and forage to many wildlife species. Many species of birds use yellow paloverde as habitat. Birds observed perching or roosting in yellow paloverde include Ferruginous pygmy-owls [35], white-winged doves [124], and rufous-winged sparrows [96]. Yellow paloverde snags are also used by birds. One study lists 14 species of birds perching on a yellow paloverde snag; the most frequent visitors were mourning doves, house finches, and starlings [81]. Small mammals associated with yellow paloverde include Arizona pocket mice [100] and rock pocket mice [145].

Yellow paloverde is browsed by mule deer [84], bighorn sheep [80,116], and feral burros [69]. Livestock browse yellow paloverde leaves, seeds, immature pods, and flowers. Even leafless branches may provide important forage during drought conditions [67,75,80,107,170,180].

Yellow paloverde seeds are eaten by a variety of mammals, including collared peccaries, round-tailed ground squirrels, Harris's antelope ground squirrels, rock squirrels, several species of pocket mice, and Merriam's kangaroo rats [73,103,105], personal observation cited in [22].

A study on insect herbivore diversity found 22 species of insect herbivores using yellow paloverde flowers and stems. These included suckers and chewers, but not miners or gallers [99]. Desert leaf-cutting ants collect yellow paloverde leaves for cultivation of fungus gardens [191]. *Centris spp.*-cuckoo bees use the nectar and pollen from yellow paloverde flowers to provision nests [4]. Honey bees visit flowers [115].

Palatability and Nutritional Value

Seeds yield 4,971 calories per gram [146], and have a high oil content [32,153], making them preferred among many small mammal species. No information was available about palatability and nutritional value of yellow paloverde leaves or stems.

Cover Value

Yellow paloverde provides thermal cover for many lagomorphs and bird species [92]. Winter overnight low temperatures under yellow paloverde canopies can be as much as 4°C warmer than the open interspaces between woody and shrubby vegetation [48]. Energy budget models suggest that in cold temperatures, small mammals and birds (<200 g) could function for only short time periods without yellow paloverde moderating temperatures [92].

VALUE FOR RESTORATION OF DISTURBED SITES

Yellow paloverde is a nurse plant to saguaro and other plant species [71,179], can enhance soil fertility [29], and has successfully established in many restoration projects. It is relatively easy to germinate and grow from seeds [110] and has shown moderate to high short-term survival after outplanting [3,151], although survival rates vary among studies. Yellow paloverde survival and growth appears to be greater when planted under protective shelters or surrounded with herbivore-resistant cages [15,167]. When planted in conjunction with other species (e.g., giant cardon cactus), yellow paloverde presence may enhance survival and growth of the associated species, while reducing its own survival rates [120].

Although yellow paloverde appears to be a good candidate for revegetation and restoration efforts [3,23,110,128], it may not establish under all conditions. For example, yellow paloverde established on abandoned agricultural fields in La Costa de Hermosillo, Mexico, but failed to establish on nearby salinated fields [36]. Information on yellow paloverde establishment and survival on degraded mined sites are available for copper mines [128], and uranium mines [190].

Under experimental conditions, unspecified paloverde species have been propagated by air layering as well as by arial and basal cuttings [65,66].

OTHER USES

Yellow paloverde seeds are edible and are a traditional food of indigenous peoples of the Southwest [118,152]. Flowers provide nectar that yields high-quality honey [80,85,152].

Until the 1940s, yellow paloverde was heavily harvested for use as fuel [67,106]. Now it is commonly planted as an ornamental, in xeriscaping, and in urban forests [16,56,82,152,180].

In Baja, Mexico, yellow paloverde is often used to make wooden fences. This practice may be degrading community composition and threatening the survival of yellow paloverde in areas with limited distribution [136].

ADDITIONAL MANAGEMENT CONSIDERATIONS

Woodcutting and urbanization can cause yellow paloverde to decline on a regional scale [21].

Nonnative invasive grasses may alter fuel characteristics on invaded sites by adding fine fuels that are more abundant, continuous, and persistent than native herbaceous fuels. This may lead to increased fire frequency, which though not yet linked explicitly to the decline of yellow paloverde, could more generally facilitate transitions from desert scrub communities to grassy mesquite and acacia savannas (see Succession, Fuel Characteristics, Fire Regimes, and Fire Management Considerations for more information).

Yellow paloverde is parasitized by a variety of plants and insects. It is parasitized by mesquite mistletoe [11,21] and ratany [31], a plant that attaches to the roots [31]. Insects that parasitize paloverdes include paloverde root borers and paloverde webber moths [152]. Witches' broom causes a proliferation of dense twig growth and is associated with mites [152].

Management Under a Changing Climate

The climate of the Sonoran Desert has been warming over the past century [72,189], and climate models predict that this area will get hotter and drier through the remainder of the 21st century [39]. Yellow paloverde may be highly vulnerable to regional effects of climate change, particularly in relation to summer moisture availability. Disruptions in the timing of moisture availability could result in a range shift for the species because of its requirement for summer rain [40]. For instance, a drought that began in the latter part of the 1990s and persisted for several years in western North America [42] likely contributed to widespread mortality of yellow paloverde across the northern part of its range [21].

Yellow paloverde undergoes periodic dieback and episodic mortality that is exacerbated by severe or prolonged drought [21,57,182]. A study of past and current dieback on Tumamoc Hill found that of the >1,000 living and dead yellow paloverde plants sampled, 7.7% had died during the 5 to 7 years prior to 1999, and 12.8% had died in the more distant past. Diebacks tended to occur during severe annual, and especially summer, rain deficits. More than half of the dead plants were large (> 50 cm basal circumference). While cause of death could not be unambiguously attributed to the variables considered (e.g., distance to saguaro, presence of saguaro underneath or within the canopy, mesquite mistletoe infection, climate), the authors suggested that "it seems likely that severe drought interacted with natural senescence of an aging population, weakening large, old trees and hastening their deaths". Steep, south-facing slopes had the highest mortality rates (up to 100%) [21]. This relationship between yellow paloverde mortality and drought may reduce or shift yellow paloverde populations under a warming and drying climate.

Predicted warming, drying, and changes in timing of precipitation in the regional climate [7,109,154] may present novel threats to Sonoran Desert plant communities, including favoring production of nonnative annuals and grasses that create conditions conducive for wildfires [44,46,129]. Declines in yellow paloverde populations due to changes in climate [121] could have detrimental effects on other members of the Sonoran Desert community, including saguaro [169].

APPENDIX

Table A1—Common and scientific names of plant species mentioned in this review. Links go to FEIS Species Reviews.

Common name	Scientific name
Cacti	
giant cardon cactus	*Pachycereus pringlei*
saguaro	*Carnegiea gigantea*
Shrubs	
Bigelow's nolina	*Nolina bigelovii*
blue paloverde	*Parkinsonia florida*
brittlebush	*Encelia farinosa*
burrobush	*Ambrosia dumosa*
creosote bush	*Larrea tridentata*
desert ironwood	*Olneya tesota*
Jerusalem thorn	*Parkinsonia aculeata*
Joshua tree	*Yucca brevifolia*
Kearney's sumac	*Rhus kearneyi*
mesquite mistletoe	*Phoradendron californicum*
ocotillo	*Fouquieria splendens*
palo brea	*Parkinsonia praecox*
ratany	*Krameria spp.*
triangle bur ragweed	*Ambrosia deltoidea*
Trees	
Acacia	*Acacia spp.*
Barbados nut	*Jatropha curcas*
elephant tree	*Bursera microphylla*
mesquite	*Prosopis spp.*
Graminoids	
buffelgrass*	*Pennisetum ciliare*
crimson fountaingrass*	*Pennisetum setaceum*
lovegrasses*	*Eragrostis spp.*
Mediterranean grasses*	*Schismus spp.*
red brome*	*Bromus rubens*

Table A2— Common and scientific names of animal species mentioned in this review. Links go to FEIS Species Reviews.

Common Name	Scientific name
Arthropods	
Bruchid beetle	*Bruchus spp.*
Centris-cuckoo bee	*Ericrocis arizonenesis*
desert leaf-cutter ant	*Acromyrmex versicolor*
Gelechiid moth	Gelechioidea
European honey bee*	*Apis mellifera*
leafcutter bee	*Megachile spp.*
painted lady butterfly	*Venessa cardui*
pallid bee	*Centris pallida*
paloverde root borer	*Derobrachus hovorei*
paloverde webber moth	*Faculta inaequalis*
Birds	
European starling	*Sturnus vulgaris*
ferruginous pygmy-owl	*Glaucidium brasilianum*
house finch	*Haemorhous mexicanus*
mourning dove	*Zenaida macroura*
rufous-winged sparrow	*Peucaea carpalis*
white-winged dove	*Zenaida asiatica*
Mammals	
Arizona pocket mouse	*Perognathus amplus*
bighorn sheep	*Ovis canadensis*
collared peccary	*Pecari tajacu*
Harris's antelope ground squirrel	*Ammospermophilus harrisii*
kangaroo rat	*Dipodomys spp.*
Merriam's kangaroo rat	*Dipodomys merriami*
mule deer	*Odocoileus hemionus*
rock pocket mouse	*Chaetodipus intermedius*
rock squirrel	*Otospermophilus variegatus*
round-tailed ground squirrel	*Xerospermophilus tereticaudus*
white-throated woodrat	*Neotoma albigula*

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