SPECIES: Arctostaphylos glandulosa

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Eastwood's manzanita over Hot Springs Canyon in the Santa Ana Mountains of southern California. Creative Commons image by Laura Camp.

SUMMARY

SPECIES: Arctostaphylos glandulosa

This review summarizes information on fire effects and related ecology of Eastwood's manzanita that was available in the scientific literature as of 2020.

Eastwood's manzanita is native to Oregon, California, and southern Mexico. It grows in nutrient-poor soils at a wide range of elevations. It grows primarily in chaparral but also in annual grasslands, oak scrub, oak and pine woodlands, and coniferous forests.

Eastwood manzanita is morphologically highly variable and has many accepted infrataxa. Some of these have protection status. Eastwood's manzanita regenerates by sprouting from the basal burl and from seed; sprouting is more common. Its seeds are dormant in the soil-stored seed bank; they require intense heat shock or chemicals leached from charred wood to germinate. Eastwood's manzanita occurs in all stages of chaparral succession.

Fire top-kills Eastwood's manzanita. It recovers from fire by sprouting and by establishing from seed. Fire can break dormancy of Eastwood's manzanita seeds. Eastwood's manzanita foliage and branches are highly flammable. Chaparral fires are stand-replacing, in part, due to the high flammability of Eastwood's manzanita and other chaparral species and the horizontal and vertical continuity of fuels.

Although Eastwood's manzanita foliage is unpalatable, its fruits provide food for many wildlife species. Its dense stands provide cover for small birds and mammals. Eastwood's manzanita provides watershed protection, particularly after fire, when it is among the first species to sprout.

INTRODUCTORY

SPECIES: Arctostaphylos glandulosa

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Most research on the fire and general ecology of Eastwood's manzanita has been conducted in southern California, and virtually none in Oregon. In this Species Review, "historical" refers to the time before Spanish settlement (prior to 1770). This Species Review cites several reviews: [11,25,54,72,77,93,110].

Common names are used throughout this Species Review. See table A1 for a complete list of plant species mentioned in this review.

FEIS abbreviation:

ARCGLA

Common names:

Eastwood's manzanita
Adams' manzanita
Del Mar manzanita
Transverse Range manzanita
Zaca manzanita

TAXONOMY

The scientific name of Eastwood's manzanita is *Arctostaphylos glandulosa* Eastw. (Ericaceae) [3,16,23,27,60,78,138,142]. Eastwood's manzanita has wide morphological variation and is classified into many infrataxa. They are as follows:

- *Arctostaphylos glandulosa* subsp. *adamsii* (Munz) Munz, Adams' manzanita [3,16,27,60,78,138,142]
- *Arctostaphylos glandulosa* subsp. *atumescens* J.T. Keeley, M.C. Vasey & V.T. Parker, Eastwood's manzanita [14,78]
- *Arctostaphylos glandulosa* subsp. *crassifolia* (Jeps.) P.V. Wells, Del Mar manzanita [3,14,16,27,60,78,138,142,150]
- *Arctostaphylos glandulosa* subsp. *erecta* J.T. Keeley, M.C. Vasey & V.T. Parker, Eastwood's manzanita [3,78]
- *Arctostaphylos glandulosa* subsp. *glandulosa*, Eastwood's manzanita (typical subspecies) [14,16,27,78,138,142]
- *Arctostaphylos glandulosa* subsp. *glaucomollis* P.V. Wells, Eastwood's manzanita [138,142]
- *Arctostaphylos glandulosa* subsp. *leucophylla* J.T. Keeley, M.C. Vasey & V.T. Parker, Eastwood's manzanita [3,16,27,60,78,138]
- *Arctostaphylos glandulosa* subsp. *mollis* (J.E. Adams) P.V. Wells, Transverse Range manzanita [3,16,27,60,78,138,142,150]
- *Arctostaphylos glandulosa* subsp. *zacaensis* (Eastw.) P.V. Wells, Zaca manzanita [138,142,150]

San Gabriel manzanita is recognized as a distinct species [138,142], although some authorities recognize it as subspecies of Eastwood's manzanita (*Arctostaphylos glandulosa* subsp. *gabrielensis* J.T. Keeley, M.C. Vasey & V.T. Parker) [3,16,27,60,78].

Hybrids: Campbell's manzanita is a hybrid of Eastwood's manzanita and woolyleaf manzanita [142]. Putative hybrids of Eastwood's manzanita are reported from Mendocino County. These hybrids are apparently various combinations of the typical subspecies (*Arctostaphylos glandulosa* subsp. *glandulosa*), common manzanita, hoary manzanita, Roof's manzanita, and Stanford's manzanita [17].

SYNONYMS

For ***Arctostaphylos glandulosa* subsp. *adamsii***:

- *Arctostaphylos glandulosa* var. *adamsii* Munz [102]

For ***Arctostaphylos glandulosa* subsp. *crassifolia***:

- *Arctostaphylos glandulosa* var. *crassifolia* Jeps. [102]

For ***Arctostaphylos glandulosa* subsp. *glandulosa***:

- *Arctostaphylos glandulosa* subsp. *cushingiana* (Eastw.) Keeley, Vasey & Parker [3,16,27,60,78,138]
- *Arctostaphylos glandulosa* var. *cushingiana* (Eastw.) J.E. Adams ex McMinn [102]
- *Arctostaphylos glandulosa* subsp. *glandulosa* forma *cushingiana* (Eastw.) P. V. Wells [150,151]
- *Arctostaphylos intricata* Howell (documented in [142])

For ***Arctostaphylos glandulosa* subsp. *mollis***:

- *Arctostaphylos glandulosa* var. *mollis* J.E. Adams [102]

For ***Arctostaphylos glandulosa* subsp. *zacaensis***:

- *Arctostaphylos glandulosa* subsp. *howellii* (Eastw.) P.V. Wells [3,16,27,60,138,150]
- *Arctostaphylos glandulosa* var. *howellii* (Eastw.) J.E. Adams ex McMinn [102]
- *Arctostaphylos glandulosa* subsp. *zacaensis* forma *howellii* (Eastw.) Wells [151]

- *Arctostaphylos glandulosa* var. *zacaensis* (Eastw.) J.E. Adams ex McMinn [102]

LIFE FORM
Shrub

DISTRIBUTION AND OCCURRENCE

SPECIES: Arctostaphylos glandulosa

GENERAL DISTRIBUTION

Eastwood's manzanita is one of the widest-ranging manzanita species in North America. It is distributed from west-central Oregon south to Baja California Norte, Mexico [78] (fig. 1).

Figure 1—Distribution of Eastwood's manzanita in the United States. Map courtesy of the U.S. Department of Agriculture, Natural Resources Conservation Service. [2020, June 11] [142]. See Plants Database for distributions of infrataxa.

States:
United States: CA, OR [142] (fig. 1)
Mexico: BCN [78]

SITE CHARACTERISTICS AND PLANT COMMUNITIES

Site Characteristics: Eastwood's manzanita occurs in areas of mild climate, over a wide range of elevations and soil types.

The climate within the distribution of Eastwood's manzanita is mediterranean, with mild winters and summer drought. Over 60% of California chaparral is in areas receiving between 10 to 30 inches (250-750 mm) of annual precipitation and where mean January daily temperature falls between 32 °F and 59 °F (0°C and 15 °C) [72].

Topography: Eastwood's manzanita has a wide elevational range [91]. It occurs from 160 to 7,200 feet (50-2,200 m) [3,20], depending on location and infrataxon (see Baldwin et al. (2012) [3] for elevational ranges of infrataxa). It grows on slopes that range from flat to extremely steep and rugged [11], on all exposures. In the North Coast Ranges, it is most common on north-facing slopes [136]. In southern California, it is most common on south- and west-facing slopes, above 3,200 feet (975 m) [147]. However, in mixed chaparral on the Cleveland National Forest, Eastwood's manzanita is dominant on north-, west- and south-facing slopes. Its occurrence is positively associated with increasing elevation ($P < 0.1$) but not with aspect [42]. It also grows on ridgetops and crests. Pure stands occur mostly on gentle slopes and flats [147]. In the Santa Monica Mountains, Eastwood's manzanita grows in sandstone-derived soils on north-facing slopes, while birchleaf mountain-mahogany grows in andesite-derived soils on south-facing slopes [108].

Soils: Chaparral soils are generally shallow, rocky, and nutrient poor [11,72,141]. Eastwood's manzanita tolerates dry soils and drought [44,50,52,53,117]. Parent materials of soils supporting Eastwood's manzanita include sandstone, shale, granite, and volcanics [11,72]. Eastwood's manzanita also occurs on serpentine [17,60] and other ultramafic soils [2,17,72]. In the Pine Hills Ecological Preserve in El Dorado County, California, it grows in gabbro soils that are extremely acidic to very strongly acidic (pH 4-5) [2]. Soil textures in which Eastwood's manzanita grows include clay and sand [46,158]. In maritime chaparral, Eastwood's manzanita grows in weathered sands in the fog belt [46].

Del Mar manzanita grows on sandstone-derived terraces near the sea [14].

Plant Communities: Eastwood's manzanita grows primarily in chaparral but also in annual grasslands [139], oak scrub, oak and pine woodlands, and coniferous forests [12,20,40,139]. It occurs in several types of chaparral including chamise, mixed, manzanita, and ceanothus chaparral. Chaparral vegetation is typically dense and has little to no understory except during the first year or two after fire [11].

Chamise chaparral and mixed chaparral: Chamise chaparral often occurs on south-facing slopes, while mixed chaparral with Eastwood's manzanita often occurs on north-facing slopes [85]. Eastwood's manzanita frequently codominates with chamise [17,22,30,37,128]. In chamise chaparral on the San Bernardino National Forest, Eastwood's manzanita averaged about 17% less density and 12% less cover than that of chamise (mean density = 484 plants/acre (1,196/ha) versus 2,800 plants/acre (6,919/ha) and mean cover = 4.8% versus 39.4%, respectively) [118].

Eastwood's manzanita often dominates mixed chaparral above the chamise zone [37,91,128,146]: around 4,500 to 5,000 feet (1,400-1,500 m) elevation in southern California [91]. Mixed chaparral in the Coast Ranges is composed of chamise, Eastwood's manzanita, bigberry manzanita, chaparral whitethorn, California scrub oak or coastal sage scrub oak, hoaryleaf ceanothus, and/or interior live oak [93]. On the Cleveland and Los Padres National Forests, Eastwood's manzanita grows in and often dominates mixed chaparral, growing in association with chamise, coastal sage scrub oak, birchleaf mountain-mahogany, cupleaf ceanothus, California buckwheat, and chaparral yucca [17,35,42]. In the Sierra San Pedro Mártir of Baja California, Mexico, Eastwood's manzanita occurs in mixed chaparral with composition similar to that of mixed chaparral in southern California. Commonly associated species not previously mentioned include pointleaf manzanita, and sugar sumac [98].

Manzanita chaparral: Eastwood's manzanita dominates some manzanita chaparral [22,41,158]. On the San Bernardino National Forest, it codominates summit slopes with pinkbracted manzanita [17]. In the Santa Ana Mountains on the Cleveland National Forest, nearly pure stands of Eastwood's manzanita occur above chamise-Eastwood's manzanita chaparral, starting around 3,200 feet (1,000 m) elevation. Density in the nearly pure Eastwood's manzanita stands averaged 3,736 stems/acre (9,232/ha). These stands are most common on gentle (10-30°), north-facing slopes on fine-textured shale-derived or clay soils. Chamise-Eastwood's manzanita communities occur mostly on south-facing slopes on granitic soils, and oak scrub is most common on steep (30-40°), north- and east-facing slopes [158].

Southern maritime chaparral: Eastwood's manzanita grows in and often dominates southern maritime chaparral [14,46]. Chamise is frequently codominant with Eastwood's manzanita in maritime chaparral [46]. Del Mar manzanita is considered an indicator species of southern maritime chaparral [14] and dominates southern maritime chaparral in San Diego County [72]. Associates of Eastwood's manzanita in maritime chaparral include barranca brush, California scrub oak, Encinitis false willow [41] and Torrey pine [41,46]. Maritime chaparral is usually <6 feet (2 m) tall. It is the rarest chaparral type due to urban development [41].

Montane chaparral: Eastwood's manzanita grows in and may dominate montane chaparral [17,43]. Montane chaparral often occurs on seral sites succeeding to conifer forests. On harsh sites, this may take many decades. Associated shrub species include birchleaf mountain-mahogany, bush chinquapin, and other manzanitas (e.g., Parry manzanita and pointleaf manzanita) [43].

Other chaparral types: Eastwood's manzanita associates in ceanothus-dominated stands with bigpod ceanothus, hairy ceanothus, woolyleaf ceanothus, chaparral whitethorn, and/or deerbrush, [42,95,124]. Eastwood's manzanita also occurs in redshank chaparral in southern California and in desert chaparral [30] in the Transverse Ranges, where it is associated with birchleaf mountain-mahogany, chaparral whitethorn, desert ceanothus, eastern Mojave buckwheat, and Sonoran scrub oak [42,95].

Oak scrub and oak woodlands: Eastwood's manzanita is a component of oak scrub and oak woodland communities. In oak scrub, it occurs in canyon live oak [17,43,48], California scrub oak, coastal sage scrub oak, and interior live oak communities [17,43,48,154]. Oak scrub sites are more mesic than chamise chaparral sites; typically, they occupy north-facing slopes or canyon bottoms [43,48]. On the San Bernardino National Forest, oak scrub with Eastwood's manzanita is most common on steep (30-40°), north- and east-facing slopes. California scrub oak-interior live oak/Eastwood's manzanita oak scrub communities occur in the Santa Ana Mountains [158]. In oak woodlands, Eastwood's manzanita is an understory species in blue oak [139], canyon live oak [17,48], California black oak [17], and occasionally valley oak woodlands [139].

Conifer woodlands and mixed-conifer forests: In conifer belts, Eastwood's manzanita occurs in woodlands and mixed-conifer forests [11,72]. It is a component of the vegetation in Coulter pine [95,139], knobcone pine [48,139], Tecate cypress [4], bigcone Douglas-fir-canyon live oak [17], bristlecone fir [17], Jeffrey pine, ponderosa pine, and mixed-conifer woodlands and forests [20]. On the San Bernardino National Forest, Coulter pine/Eastwood's manzanita communities are common on north- and northeast-facing slopes [158]. Eastwood's manzanita also grows in Bishop pine-Bolander beach pine dwarf forests in Mendocino County [153]. In the Siskiyou Mountains of southern Oregon, Eastwood's manzanita is an understory species in coast Douglas-fir/bigleaf maple forests [122].

Other communities: Eastwood's manzanita may finger into annual grassland, coastal sage scrub, and desert chaparral communities. Annual grassland borders low-elevation chaparral in northern California, while coastal sage scrub borders low-elevation chaparral on coastal exposures in southern California [42]. Eastwood's manzanita dominates some coastal sage scrub-chaparral transition communities [30]. Desert chaparral borders chaparral to the east. Desert chaparral has no homolog in northern California [42].

See table A2 for a representative list of plant classifications in which Eastwood's manzanita occurs.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

GENERAL BOTANICAL CHARACTERISTICS

Botanical Description: This description covers characteristics that may be relevant to fire ecology of Eastwood's manzanita and is not meant for identification. See Baldwin et. al (2012) for an identification key [3]. For identifying Eastwood's manzanita infrataxa, see these publications: [3,78,111].

Eastwood's manzanita is an erect or mound-forming evergreen shrub, growing 3 to 10 feet (1-3 m) tall [20,27]. It has multiple stems arising from the basal burl [1]. Sometimes the multiple stems are genetically distinct, resulting from grafting of seedlings that emerged from a fused seed propagule or a common animal horde [81]. The stems and branches are crooked and rigid [121,141] and often bear ribbons of dead wood [58] (fig. 4). The bark is thin and shreddy [58,121,141].

All infrataxa of Eastwood's manzanita except *Arctostaphylos glandulosa* subsp. *atumescens* [78] form a large basal burl or lignotuber at the stem base [20,27,78]. In the San Gabriel Mountains, Eastwood's manzanita had basal burls that that were 3 to 6 feet (1-2 m) across [42]. Jepson (1916) found basal burls of coastal populations in the Bay Area were completely buried. Basal burl diameters increased with each successive fire. Eventually, some were 10 feet (3 m) across, with highly irregular circular or crescent shapes [57].

The stems, leaves, inflorescences, and fruits of Eastwood's manzanita are sticky [1,23,58]. Leaves are alternate and sclerophyllous [20,121,141]. The inflorescence is a panicle [27] (fig. 2). The fruit is a mealy drupe [3,159] bearing stone seeds. For a single drupe, the stones may be free and separate or fused, depending on the infrataxon [3,27]. Fused stones form a single propagule [74].

Figure 2—Eastwood's manzanita flowers. Image courtesy of Charles

Webber ©California Academy of Sciences, used with permission.

Eastwood's manzanita is a deep-rooted species. On sites with deep soil profiles, roots may extend >17 feet (5 m) down [45,54]. In the San Gabriel and San Bernardino mountains, lateral roots of Eastwood's manzanita were well branched and grew 3.0 inches (7.5 cm) or more in diameter and more than 17 feet deep. The lateral roots penetrated rock cracks that were apparently too tight for the roots of associated chamise to penetrate. Eastwood's manzanita had adventitious roots near the soil surface [45].

Eastwood's manzanita is long-lived for a chaparral species [42,95]: its maximum lifespan is estimated at >100 years [134]. Growth rings can be used to age Eastwood's manzanita stands. This technique reveals stem age, not the age of the basal burl and roots, which are older [69]. Hanes (1971) considered stands >50 years old "mature", and stands >60 years old "senescent" [42]. On Mt. Tamalpais in Marin County, individuals in an Eastwood's manzanita population ranged from about 5 to 65 years old [68].

Pure Eastwood's manzanita stands tend to be dense and uniform in height, and ≥5.0 feet (1.5 m) tall when mature [147]. In the Santa Ana Mountains, pure stands that had not burned for at least 25 years formed a dense, interwoven canopy of branches. The tallest individuals were 10 to 12 feet (3-4 m) tall. There were almost no woody seedlings or herbs in the understory [158]. Above 3,000 feet (900 m) on the Cleveland National Forest, Eastwood's manzanita occurred in dense stands of mixed chaparral composed of mostly sprouting species. Stands older than ~40 years averaged about 8.0 feet (2.4 m) tall [42]. In a study in the San Raphael Mountains, Zaca manzanita stands were nearly pure, with 50% to 100% canopy cover. In intershrub spaces, the soil surfaces were mostly bare, lacking seedlings of either Zaca manzanita or other plant species [19].

Raunkiaer Life Form:
Phanerophyte
Geophyte [116]

SEASONAL DEVELOPMENT

Eastwood's manzanita plants are dormant for 4 to 6 months prior to flowering [3]. Manzanitas flower on old growth from buds produced the previous growing season; this likely contributes to them being the earliest shrubs to flower [72]. Eastwood's manzanita flowers in winter at low elevations and in spring at high elevations [60,159], from approximately February to late May [20]. Fruits ripen from early summer to fall, depending on location [159]. Seeds germinate in spring [42]. Sprouting may occur a few weeks after a top-killing disturbance, regardless of the time of year [54].

REGENERATION PROCESSES

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

Vegetative Regeneration: Sprouting is the primary mode of regeneration for Eastwood's manzanita; it is considered a facultative seeder (or facultative sprouter) because it also establishes from seeds. Chaparral shrubs that do not sprout and establish only from seeds, such as bigberry manzanita, are considered obligate seeders [62,146]. Eastwood's manzanita sprouts from its basal burl after top-kill by fire (e.g., [11,20,22,23,53,57,78,141]) or mechanical injury, including mastication [13,115]. Sprouts are more common than seedlings after top-killing disturbances [64,146]. Multiple stems arise from the basal burl after top-kill [57].

Pollination and Breeding System: Eastwood's manzanita requires cross-pollination. Solitary bees and syrphid flies are among the pollinators. In the San Jacinto Mountains, Eastwood's manzanita produced fewer, smaller flowers and less sugary nectar than Pringle manzanita, an obligate seeder; hence, it attracted fewer pollinators [31].

Seed Production: Seed production in Eastwood's manzanita depends on the number of flower buds initiated the previous year [62]. Drought may lower flower and seed set [62]. Most sprouting chaparral species begin to set seed 3 to 5 years after fire or other top-killing events [11]. Fruit and seed production of Eastwood's manzanita and other sprouting species are generally less than that of obligate seeders [62,75]. Over time, obligate seeders such as bigberry manzanita usually deposit more seeds in the community seed bank than sprouters such as Eastwood's manzanita [75]. However, on a 23-year-old mixed-chaparral burn in Marin County, seed production and vegetative growth were similar for Eastwood's manzanita and bigberry manzanita [112].

Eastwood's manzanita can produce many flowers and seeds in favorable years. For a population in San Diego County, production averaged 5.6 seeds/fruit [62]. Maximum mean seed production was 2,778 seeds/plant. Seed production was positively correlated with above-average precipitation the year prior ($r_s = 0.97$, $P < 0.05$) [62]. Not all seeds within a propagule may remain viable. For example, in three Eastwood's manzanita populations in coastal northern California, seed set of Eastwood's manzanita propagules was 50% to 62% of the propagules' ovule production. Diploid plants had higher rates of seed set than tetraploid plants [82].

Seed Dispersal: Most Eastwood's manzanita seeds disperse beneath or near the parent plant. Frugivorous animals [66,72,79,134], particularly coyotes and American black bears, disperse Eastwood's manzanita seeds longer distances [66,72,79].

Seed Banking: Eastwood's manzanita has a persistent, soil-stored seed bank. The seeds can remain viable in the soil for decades, so Eastwood's manzanita may establish from the soil seed bank on burned sites where it had not been a component of aboveground vegetation before fire [11]. Its seed bank densities differ between sites and times-since-fire [110]. A review reported Eastwood's manzanita seed bank densities of 8,422 (SE 1,575) seeds/m² in northern California, and from 3,038 (SE 731) seeds/m² to 4,116 (SE 982) seeds/m² in southern California [110]. Over 10 years in San Diego County, Eastwood's manzanita contributed about 89.9 x 10^6 seeds/ha to the soil seedbed of an Eastwood's manzanita-bigberry manzanita community. Over that time, there was no significant change in the number of seeds in the soil seedbank of Eastwood's manzanita despite this high seed output [65]. Rodents commonly deplete the seed bank of Eastwood's manzanita [62,81], and this likely hindered buildup of its seed bank on that site [62]. Rates of seed predation were as high as 80% within 10 days of placement onto the soil surface [74]. On Mt. Tamalpais, depletion due to seed predation was estimated at 14% over 11 months [81].

Although germination rates of soil-stored Eastwood's manzanita appear low compared to other chaparral species, seed production and seed bank numbers are high enough that this does not seem to limit Eastwood's manzanita establishment [64,81]. In a 2-year study on Mt. Tamalpais, Eastwood's manzanita seed bank numbers averaged 392.4 viable seeds/m^2 the first year and 709.0 viable seeds/m^2 the next [81].

Germination: Eastwood's manzanita seeds are dormant at ripening, having both a hard seed coat that requires scarification and embryo dormancy [64,159]. Fire [66,77,141,159], mechanical scarification, acid treatment [159], and/or exposure to charate leachate [64,66] break dormancy. Animal digestion results in scarification [159]. Eastwood's manzanita seeds are considered refractory because in the field, intense heat shock or chemicals leached from charred wood induces germination [66]. Keeley (1987) stated that germination of Eastwood's manzanita requires "a chemical cue from charred wood" [64] or intense heat [66], with most seeds remaining dormant until a fire breaks dormancy [64]. Following scarification by fire and exposure to wet charate, overwinter stratification breaks embryo dormancy [159].

Soil-stored Eastwood's manzanita seeds show low viability in laboratory and field studies. In the laboratory, exposure to charate alone resulted in <5% germination [55]. A combination of heat, light or dark treatments, and

application of charate leachate to soil resulted in limited Eastwood's manzanita germination (2%-18%), while a combination of heat (180-212 °F (70-100 °C)), light or dark treatments, and application of distilled water resulted in 0% germination ($P < 0.001$). For a population in San Diego County, the percentage of filled (viable) seed in the soil ranged from 7% to 9% [62]. On Mt. Tamalpais, viability of seeds in the soil seed bank averaged 7% [81].

Seedling Establishment and Plant Growth: Eastwood's manzanita requires open mineral soil to establish [67]. In 12 chaparral sites across California, Eastwood's manzanita seedlings occurred on new burns, but few seedlings were present in chaparral 56 to 120 years old. Chaparral communities of other ages were not examined [67,68]. Fused seeds within a propagule may germinate together but over time, one seedling often becomes dominant while the others die [62]. Seedling mortality can be high [5,146] (see Plant response to fire). Drought results in considerable mortality of Eastwood's manzanita seedlings, particularly for seedlings in desert chaparral [42].

Germinants and seedlings usually fail to establish in mature and old chaparral. In the Santa Ana Mountains, no Eastwood's manzanita seedlings were detected in chaparral that had not experienced fire for at least 40 years, although mature plants were present. Mortality of mature individuals was high in the stand, with dead Eastwood's manzanita plants averaging 297 plants/acre (734/ha) and live plants averaging 231 plants/acre (570/ha) [61].

Eastwood's manzanita sprouts grow quickly. On the Cleveland National Forest, Eastwood's manzanita sprouts on fuelbreaks averaged 2.0 feet (0. 6 m) tall 5 years after cutting [35]. Wakimoto (1978) provides a model for predicting growth of Eastwood's manzanita based on age and current height. It was developed using data collected in chamise-redshanks-Eastwood's manzanita stands on the Cleveland National Forest [147].

Basal burls of manzanitas also develop quickly in young plants. Although basal burls grow larger with successive fires, fire is not required for their development [72].

Eastwood's manzanita continues to produce new stems as it matures, and one study suggests that growth rates are similar in mature and old stands. On 12 mature to old chaparral stands (56-120 years old) across California, Eastwood's manzanita plants continued to produce new sprouts from their aging basal burls [68]. A study in 28-year-old and 90-year old mixed chaparral stands in San Diego County found growth of Eastwood's manzanita vegetative tissues was similar for the two stands (87.0 and 86.8 g oven dry weight/m^2 of cover for the two stands, respectively). Fruit production slowed, but not substantially (62.6 and 55.8 oven dry weight/m^2 of cover for the two stands, respectively) [75].

SUCCESSIONAL STATUS:

Subshrubs and herbaceous plants often have greatest cover in the first few years after a stand-replacing event such as fire or logging, with once-dominant shrubs such as Eastwood's manzanita having lower coverage. In chaparral, transition to the mid- to late-seral stages happens quickly (8-15 years). By then, shrubs that were dominant prior to the event occupy most of the available growing space (>80% canopy cover), with herbaceous species and subshrubs restricted to openings [25].

Within the chaparral belt, chaparral vegetation does not usually succeed to other vegetation types [72], likely because fires are too frequent for conifer establishment [158]. Biswell (1974) noted that "chaparral is largely a fire-induced type with a remarkable capacity to persist with recurring fires" [11]. However, montane chaparral often succeeds to pine woodland or forest [25]. Initially, chaparral and montane chaparral have similar successional trajectories after a stand-replacing event. The early-seral stage of montane chaparral can have 0% to 70% shrub cover, with limited conifer seedling cover. However, the shrubs often become nurse plants for conifer regeneration [25]. In mixed-conifer forests on the Blodgett Forest Research Station, Eastwood and other manzanita species developed dense canopies following stand-replacing fire or clearcutting [56]. If fires reoccur within ~30 years, the montane chaparral might not succeed to conifer forest. This may occur on southerly slopes with shallow soils and on ridgetops, where fire behavior is often severe [25].

Eastwood's manzanita occurs in all stages of chaparral succession [11,42]. Fire has little effect on composition of chaparral dominated by species that both sprout and seed after fire, such as Eastwood's manzanita and chamise [11,29,79,147]: Sprouting shrubs usually dominate after fire if they dominated before [147]. After 10 to 15 years growth, shrub foliar cover approaches prefire values and the canopy thins [108,123]. Within a few decades, Eastwood's manzanita and other chaparral shrubs recover their prefire height and density [147].

Over an approximately 70-year period, shrubs—including Eastwood Manzanita—remained dominant on sites with both frequent (≥2 fires in 91 years) and infrequent (0 or 1 fire in 91 years) fire in mixed chaparral in San Diego County. Repeat surveys in the 1930s and 2001 showed that neither trees nor annual grasses became dominant on the chaparral sites, even with infrequent fire. Cover and frequency of Eastwood's manzanita averaged 5% and 13%, respectively, in the 1930s and 7.5% and 17%, respectively, in 2001. On sites with infrequent fire, mean cover of sprouting shrubs, including Eastwood's manzanita, increased from 72% to 91%. On sites with frequent fire, it decreased from 87% to 80% [29].

Herbaceous species usually have greatest cover in chaparral in postfire years 1 or 2, then decrease in successive postfire years [28,80,146]. This may be true for nonnative invasive herbs as well as native herbs. In the Santa Monica Mountains, species richness of native and nonnative herbs increased during the first 2 years after fire, then gradually declined [40].

Chaparral may convert to annual grassland with very frequent fire (fire intervals of <10-15 years), especially if annual grasses were present in the prefire plant community [21,72,77]. Litter of Eastwood's manzanita is allelopathic to annual grasses and other herbaceous species. In the absence of fire, compounds in Eastwood's manzanita litter apparently inhibit germination and establishment of groundlayer herbs beneath the Eastwood's manzanita canopy [18] (see Fire Management Considerations). However, fire intervals of <6 years may substantially reduce presence of Eastwood's manzanita and other sprouting shrubs [77].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Arctostaphylos glandulosa

FIRE EFFECTS

Immediate Fire Effects on Plant: Fire top-kills Eastwood's manzanita [11,38,79,88,147], reducing its cover and density to near zero in the short term [88,89]. Biswell (1974) reported that while fire may kill 25% to 30% of chamise plants in a mixed stand, it rarely kills any Eastwood's manzanita plants: they are only top-killed, and the basal burls and roots survive [11]. Intense fire may kill some Eastwood's manzanita plants [38,97]. For example, although Eastwood's manzanita usually sprouts soon after fire, even in late fall [54], Griffin (1978) observed some Eastwood's manzanita basal burls that had still not sprouted 3 months after the 1977 Marble Cone Fire. He speculated that intense heat from the fire killed those plants. On some chaparral sites, the Marble Cone Fire was intense enough to melt glass bottles and cans [38].

Soil-stored Eastwood's manzanita seeds usually survive fire [11,62], although fire kills some Eastwood's manzanita seed stored in the seed bank [62]. In particular, seeds in heavy duff may not survive [11].

Postfire Regeneration Strategy:
Small to tall shrub, adventitious buds and/or a sprouting root crown
Geophyte, growing points in soil
Ground residual colonizer (on site, initial community)
Initial off-site colonizer (off site, initial community)
Secondary colonizer (on- or off-site seed sources) [133]

Fire Adaptations and Plant Response to Fire: Eastwood's manzanita sprouts from the basal burl and establishes from seed after fire. Sprouts grow quickly, while seedling mortality is high.

- Fire adaptations
- Plant response to fire

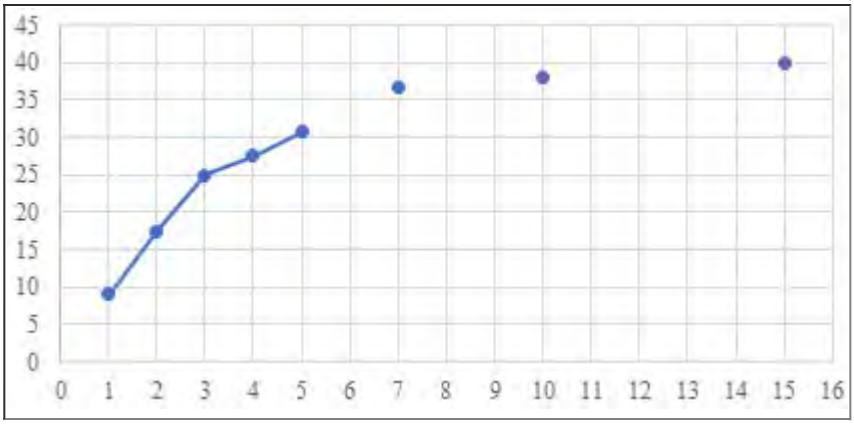
Fire adaptations: Buds on the basal burls of Eastwood's manzanita plants are protected from fire because they are buried in soil [57,78]. Seeds are protected by their hard seed coat; they are further protected when buried in the soil [64,159].

Figure 3—Eastwood's manzanita sprouting after fire in the Santa Ana Mountains. Photo ©2018 Ron Vanderhoff, used with permission.

Plant response to fire: Eastwood's manzanita sprouts from its basal burl (lignotuber) after top-kill by fire (e.g., [11,22,23,42,53,57,72,77,79,141,144]) (fig. 3). The large basal burl and deep roots of this species favor sprouting compared to shallow-rooted species with small root crowns, which are usually nonsprouting [54]. Eastwood's manzanita plants with small burls (i.e., young plants) or that lack burls (*Arctostaphylos glandulosa* subsp. *atumescens*) may not sprout after fire [54,79]. Sprouts emerge in postfire year 1 [47], soon after fire [54], and grow rapidly for the first 1 to 3 postfire years. Growth usually slows after that [54]. However, in the San Bernardino Mountains, Eastwood's manzanita showed rapid growth for at least 15 postfire years [47].

In the San Gabriel Mountains, Eastwood's manzanita plants that had been repeatedly top-killed by fire had basal burls spreading 3 to 6 feet (1-2 m) across [42]. After the Fern Canyon Fire in the San Bernardino Mountains, Eastwood's manzanita grew rapidly in the first 3 postfire years, with growth continuing more slowly for at least 15 postfire years (fig. 4). Sprout density of Eastwood's manzanita remained stable, averaging one plant/0.001 acre (0.2 plant/m^2) over 15 years. Seedlings emerged at a density of 2 plants/0.001 acre (0.5 plant/m^2)in postfire year 1, but they were not present on plots in postfire year 2 [47].

Figure 4—Eastwood's manzanita sprout height after the 1987 Fern Canyon Fire. Adapted from [47].



Jepson (1916) reported this response of Eastwood's manzanita [57]:

> "After the Mt. Tamalpais chaparral fire of early July, 1913, sprouts began to appear within four weeks, and in two months made an abundant showing. Two of my students, Wieslander and Herbert, counted forty-eight sprouts in a square inch from the crown of an individual of this species" [57].

Although sprouting is more common [64,146], Eastwood's manzanita also establishes from seed after fire [53,64,72,159], including pile burning [159]. Eastwood's manzanita is deemed a postfire "facultative seeder" because unlike most manzanitas, it establishes from both seeds and sprouts after fire [41,72,77]. Fire cracks the hard seed coat [159], and leachate provides chemical cues that break seed dormancy [64] (see Germination). On one 4-year-old burn in southern California, 11% of Eastwood's manzanita plants were of seed origin and the rest were sprouts; on another 4-year-old burn, all Eastwood's manzanita plants were sprouts [76]. Colonization can occur from off-site seed dispersed by parent plants adjacent to the burn [72] or from seed in the feces of frugivorous animals [66,72,79,134]. In a burned Tecate cypress community in San Diego County, Zedler (1977) noted both sprouting and postfire seedling establishment of Eastwood's manzanita. Although seed production and seed bank replenishment occurred in young and old stands, seedling establishment occurred only on new burns, in the first few postfire years. He attributed this to favorable nutrient and moisture conditions and sites available for germination and growth in early postfire environments [160].

Although Eastwood's manzanita seedlings may occur in large numbers after fire, seedling mortality is high [42,79,146], while sprout mortality is very low [146]. In San Diego County, mortality of Eastwood's manzanita seedlings averaged 55% on a 1-year-old burn [79]. On 1- and 2-year-old burns in the San Jacinto Mountains, researchers tallied large numbers of Eastwood's manzanita sprouts and seedlings, but they noted that "seedlings are suspected of seldom contributing to mature chaparral cover" due to high rates of mortality. Seedling density was 7.5% lower on the 2-year old burn compared to the 1-year-old burn (table 1). Eastwood's manzanita seedlings were most numerous on gentle slopes and level sites with a deep ash layer. Eastwood's manzanita

sprouts averaged 4.9 feet (1.5 m) tall in postfire year 2. Eastwood's manzanita was the dominant shrub in postfire succession, averaging 8.0% cover on the 1-year-old burn and 25.3% cover on the 2-year-old burn [146].

Table 1—Mean density (stems/acre) of Eastwood's manzanita sprouts and seedlings after two wildfires in Eastwood's manzanita-chamise chaparral in the San Jacinto Mountains. The control site had not burned for at least 42 years. Data were collected on 25 one-fiftieth acre (0.008 ha) quadrats [146].

Regeneration type	1-year-old burn	2-year-old burn	Unburned control
Seedlings	3,524	3,258	1,990
Sprouts	1,868	3,724	

Postfire recovery of Eastwood's manzanita is typically rapid [48,72]. On the Laguna-Morena Demonstration Area in San Diego County, rates of Eastwood's manzanita photosynthesis and water conductance—processes that lead to biomass accumulation and growth—were greater on burned plots than on hand-cleared or control plots, and were greater on hand-cleared plots than on control plots [109]. Chaparral shrubs generally reach prefire height by postfire year 20, although regaining prefire cover and density takes longer. When new burns were compared to mature chaparral (>40 years old) in the Laguna Mountains of southern California, 85% of mature shrub cover was reached by postfire year 10. By postfire years 30 to 40, shrub cover was similar to that of mature chaparral [96]. In chamise-Eastwood's manzanita chaparral on the Mt. Hamilton Range, Santa Clara County, cover of Eastwood's manzanita and chamise on burned sites was similar to that on adjacent unburned sites by postfire year 3 [158]. After the September, 1970 Laguna Fire in San Diego County, a comparison of burned mixed chaparral to adjacent unburned mixed chaparral found early relative dominance of the burn by sprouting Eastwood's manzanita and chamise (table 2). Mortality of Eastwood's manzanita sprouts was very low; estimated at 7% and 10% on 1-year-old burned and unburned sites. In contrast, mortality of chamise was estimated at 38% to 50%, respectively (table 2). Individuals with small burls were most susceptible to fire kill. However, among the five dominant shrub species, Eastwood's manzanita had the lowest seedling establishment and highest seedling mortality [79] (table 3).

Table 2—Postfire responses of mixed chaparral shrub species in stands burned in the Laguna Fire compared with shrubs in stands in adjacent unburned mixed chaparral. Data were collected in postfire year 1 [79].

Species	Regeneration Strategy	Relative dominance[a]		Relative density[b]	
		Unburned	Burned	Unburned	Burned
bigberry manzanita	nonsprouting	33.2	1.4	8.4	16.6
Eastwood's manzanita	sprouting	32.2	26.9	14.0	1.6
chamise	sprouting	19.3	49.8	48.0	29.1
desert ceanothus	nonsprouting	9.4	3.9	15.9	44.9
coastal sage scrub oak	sprouting	5.0		2.5	
all other shrubs or subshrub species	variable	0.9	18.0	11.2	7.8
Total basal area, all species (cm^2/10 m^2)	not provided	463.9	26.3	not provided	not provided
Total density, all species (plants/10 m^2)	not provided	not provided	not provided	12.0	41.4

[a]Relative dominance expressed as a percentage of total basal area.
[b]Relative density expressed as a percentage of total number of live stems of all species per unit area (stems/10 m^2).

Table 3—Shrub cover and seedling density in unburned chaparral compared to estimates of prefire shrub cover and shrub seedling density for each of the dominant species on the Laguna Burn. Transect and plot data are presented separately for bigberry manzanita and Eastwood's manzanita to show the relationship between seedling density and prefire cover. Unburned stands were sampled along 50-m transects. Adapted from [79].

Species	Stand	Cover[a] (m^2/ha)	Seedlings/ha[b]			Manzanita seedling group/ha[c]		
			total number	number alive	% dead	total number	number alive	% dead
bigberry manzanita	Unburned	16.4	0	NA	NA	NA	NA	NA
	Burned (50-m transects)	17.9	10,600	6,440	33	NM	NM	NM
	Burned (20 × 30 m plots)	2.3	6,400	3,560	44	3,000	2,130	30
Eastwood's manzanita	Unburned	316.0	0	NA	NA	NA	NA	NA
	Burned (50-m transects)	109.0	550	160	71	NM	NM	NM
	Burned (20 × 30 m plots)	296.0	1,550	700	55	800	630	28
chamise	Unburned	251.0	0	NA	NA	NA	NA	NA
	Burned (50-m transects)	107.0	14,400	8,784	39	NA	NA	NA
desert ceanothus	Unburned	7.4	0	NA	NA	NA	NA	NA
	Burned (50-m transects)	0.0	18,900	18,500	2	NA	NA	NA

[a]Basal burl area, live and dead, for the burl-forming species (Eastwood's manzanita and chamise) or basal area, live and dead, for the nonburl-forming species (bigberry manzanita and desert ceanothus). Seedlings were excluded. For the burn, this was used to estimate prefire population size.
[b]In postfire year 1.
[c]Consisting of one or more seedlings arising from nearly the same point.

Recovery of mixed chaparral communities is typically rapid, and early-season fire may result in the most rapid postfire growth of Eastwood's manzanita. In Mendocino County, shrubs in mixed chaparral with Eastwood's manzanita recovered biomass rapidly. Total aboveground biomass averaged about 1,100 pounds/acre (1,200 kg/ha) in postfire year 1, and about 9,000 pounds/acre (10,100 kg/ha) in postfire year 6. Growth slowed by postfire year 6, and by postfire year 8, annual growth had "declined appreciably" [120]. Based on vegetation surveys in the San Bernardino Mountains, Horton (1960) observed that postfire growth of chamise-Eastwood's manzanita stands was similar to that of chamise-ceanothus stands. He stated that both stands had ~45% crown cover in postfire year 10, ~75% in postfire year 40, and ~60% in postfire year 60. Crown heights ranged from 4 to 15 feet (1-5 m) at maturity [48]. In chamise-manzanita stands north of Ukiah, California, burning and mastication treatments that occurred over different seasons reduced total vegetation cover by 90% to 100%. Mastication reduced shrub cover more than prescribed fire. Shrub cover was similar to that of the untreated control stand within 10 posttreatment years. Shrub cover was 1% to 2% less than of the untreated stand on plots

treated with prescribed fire or spring mastication, while shrub cover on plots treated with fall mastication was 8% less than that of plots on the untreated stand. Spring prescribed fire was the only treatment where cover of Eastwood's manzanita was similar to that of the unburned stand, although this was not tested for significance. Treatments were conducted on sites that had not burned for >40 years. Cover of Eastwood's manzanita in these stands is shown in table 4 [155,156].

Table 4—Percent Eastwood's manzanita cover[a] before and after prescribed fire or mastication in chamise-manzanita[b] chaparral. Data are means (SE). Adapted from [155].

Treatment	Treatment year					
Fire	Prefire	Postfire year 1	Postfire year 2	Postfire year 3	Postfire year 4	Postfire year 10
Control	13(2)	not provided	not provided	not provided	not provided	not provided
Fall fire (Nov.)	11(3)	no data	7(5)	5(4)	11 (not calculated)	4(1)
Spring fire (April-early June)	7(5)	7(not calculated)	15(3)	15(not calculated)	13(<1)	15(5)
Winter fire (Jan.)	17(5)	no data	10(2)	no data	10(4)	4(1)
Mastication	Preshred	Postshred year 1	Postshred year 2	Postshred year 3	Postshred year 4	Postshred year 10
Control	13(2)	not provided	not provided	not provided	not provided	not provided
Fall shred (Nov.)	13(2)	5(<1)	7(2)	8(3)	no data	8(4)
Spring shred (April-early June)	8(3)	no data	5(4)	5(not calculated)	3(1)	4(1)

[a]*n* = twenty-four 2-ha units; cover measured along fifteen 15-m transects/unit.
[b]Manzanita species present in the community included Eastwood's manzanita, common manzanita, and Stanford's manzanita.

Few studies had been conducted on recovery of Eastwood's manzanita in oak or conifer woodlands as of 2020. In Tecate cypress stands in the Santa Ana Mountains, Eastwood's manzanita was not present in unburned stands. Its density averaged 2 plants/acre (6/ha) on 3-year-old burns and 68 plants/acre (168/ha) on 17-year-old burns. Its cover averaged 1.7% on 17-year-old burns (Armstong and Vogl, unpublished data cited in [4]). In knobcone pine woodlands, Eastwood's manzanita averaged 1,521 plants/acre (3,759/ha) and 1,314 plants/acre (3,246/ha) on unburned and burned plots, respectively. Cover averaged 21.4% and 18.3% on unburned and burned plots, respectively. Burned plots were sampled in either postfire year 4 or 16 [145].

The Research Project Summary "Response of vegetation to prescribed burning in a Jeffrey pine-California black oak woodland and a deergrass meadow at Cuyamaca Rancho State Park, California" provides information on the postfire response of Eastwood's manzanita and other plant species of that community.

FUELS AND FIRE REGIMES

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

Fuels: Eastwood's manzanita foliage and branches are highly flammable [157]. Chaparral fires are stand-replacing, in part, due to the high flammability of Eastwood's manzanita and other chaparral species and the

horizontal and vertical continuity of fuels [97,113]. Retention of dead branches, fine branching patterns that increase the air/fuel mix, and the presence of volatile oils all enhance the flammability of manzanitas and other chaparral shrubs [119,127]. Mature Eastwood's manzanita plants often have dead and partially dead branches (fig. 4). In mixed chaparral of southern California, > 25% of standing Eastwood's manzanita consisted of dead branches [30]. Li et al. (2017) provide measurements of bulk density and biomass of Eastwood's manzanita foliage and branches collected in 4-year-old chamise-Eastwood's manzanita chaparral on the North Mountain Experimental Area near Riverside, California [87].

Figure 4—Dead branchwood (ribbonwood) of Eastwood's manzanita. Photo ©Neal Kramer, used with permission.

Moisture content of live chaparral fuels declines through spring, summer, and fall. It also varies with plant age. A study on the Stanislaus National Forest found fuel moisture of manzanitas peaked in late June to early July. Of course, this varies with year-to-year precipitation. Leaf moisture content of Eastwood's manzanita is lowest in late fall, before seasonal rains begin [51]. Fuel moisture of Eastwood's manzanita plants may average 150% to 200% for new growth and 90% to 150% for old growth [34].

Eastwood manzanita accumulates live and dead standing fuels rapidly because it grows quickly after fire. [158]. In chamise-redshanks-Eastwood's manzanita stands on the Cleveland National Forest, Eastwood's manzanita plants had substantial die-back of stems, which contributed to standing dead fuel loads as stands matured. Biomass of Eastwood's manzanita plants is comprised of more fine fuels than course fuels, which tends to enhance flammability. Over 65% of the biomass of all Eastwood's manzanita plants sampled was composed of tissues with diameters of ≤0.4 inch (1 cm). However, surface:volume ratio and calorie count of Eastwood's manzanita were less than that of chamise and redshanks [147]. Wakimoto (1978) provides calorie count of live and dead Eastwood's manzanita fuels and models to predict aboveground biomass and rate of fuel build-up for Eastwood's manzanita. In his study, mixed chaparral with Eastwood's manzanita reached peak biomass around age 25, with 90% of this peak occurring at stand age 16 [147]. Eisele (2015) provides data on live and deal fuels loads of 13- and 55-year-old chamise-Eastwood's manzanita-chaparral burns in San Diego County [24].

Eastwood's manzanita may be slower to ignite than species with thinner, nonsclerophylous leaves that are less able to retain moisture. Pickett et. al (2010) provide a model for ignition of Eastwood's manzanita leaves based on moisture content [114]. Weise et al. (1991) provide information on the seasonal changes in moisture content of Eastwood's manzanita branches and foliage, and of carbon and particulate emissions of Eastwood's manzanita fuels. Their data were collected in southern California [149]. Using fuel beds constructed in the laboratory, Weise et. al (2016) developed a model to predict fire spread success and rate of fire spread across Eastwood's manzanita fuel beds [148].

Chaparral dieback causes sudden increases in standing dead fuel loads. Sudden diebacks have been attributed to a fungus (*Botryosphaeria dothidea*) that infects Eastwood's manzanita and other shrubs weakened by extended drought [97].

Litter fuels accumulate slowly on the nutrient-poor, unproductive soils typical of chaparral [72]. Litter deposition in pure Eastwood's manzanita stands can be considerable but decay rates rapid [147]. In the Santa Ana Mountains, Wilson and Vogl (1965) noted that litter accumulated more rapidly in Eastwood's manzanita stands than in chamise stands, but subsequent decomposition of litter appeared more rapid in Eastwood's manzanita stands [158].

In chaparral, fires are nearly always carried in canopy fuels, with surface fuels playing little or no role in fire spread [72,73]. In a review of fire in chaparral, Keeley and Syphard (2018) wrote that "several lines of evidence suggest the primary determinant of fire size is the coincidence of ignitions and Santa Ana winds", not fuel buildup [77].

Fire Regimes: The mediterranean climate [11] and the flammability and continuity of fuels [97,113,157] make chaparral very susceptible to fire ignition and spread. Because California's chaparral region has a low frequency of lightning, most presettlement chaparral fires likely started as lightning-ignited fires in higher-elevation forests [8,11,70], although lightning-ignited fires likely started in chaparral in some years [11]. It is unclear how often and when American Indians set fires in chaparral [8,11,85,86,120]. They mostly used fire in lower-elevation grasslands and higher-elevation woodlands [8,120].

Historically, California's fire season occurred during warm, dry periods from June through October, peaking at the end of the fire season [9,59,77,152]. Nearly rainless summers with high daytime temperatures and low humidity dry out the vegetation and soils, and high winds (Santa Ana or other foehn winds) blow from the interior deserts and valleys to the Pacific Ocean in late summer and fall [11,59]. Fire behavior in chaparral is strongly controlled by wind. Without strong winds, fire spread is driven by topography and the proportion of living and dead canopy biomass. Fires are nearly always active crown fires carried by living and dead fuels in the canopy, with surface fuels playing little or no role in fire spread [72,73].

Chaparral fires are severe [71] and stand replacing [71,93,146], typically consuming the shrub canopy, understory, and litter [146]. Fires are particularly severe during high winds [72] and sometimes with long fire-free periods (>70 years), particularly on sites with heavy fuel loads. In the San Bernardino Mountains, California black oak-canyon live oak/ceanothus-Eastwood's manzanita montane chaparral burned at higher severity, and less often, on relatively wet sites compared to dry sites. High severity in the previous fire tended to reduce severity in the next fire. Time-since-fire tended to increase with increases in mean annual precipitation. Shrub cover was negatively associated with annual grass cover (cheatgrass, compact brome, red brome, ripgut brome, and wild oat), and shrubs tended to increase at the expense of nonnative annual grasses with time-since-fire ($P < 0.05$ for all variables) [132].

Mean historical fire interval in California chaparral is estimated at 55 years [25], with a range of 10 to 90 years [15,25,90]. Because fires consume fuels completely, fire recurrence at a site is reduced until sprouters like Eastwood's manzanita and obligate seeders like bigberry manzanita gain enough biomass to support fire continuity [97]. Unburned stands over 50 years old might have been historically uncommon [6]. However, Keeley and Zedler (1978) suggest that presettlement chaparral had both short and long fire-free periods, with southern coastal California remaining fire-free for up to a century [79]. Historically, southern California chaparral landscapes are described as having many modest-size summer lightning-ignited fires that burned a

relatively small portion of the landscape, and massive wind-driven fires once or twice a century (review by [77]). Some studies suggest that fire intervals of <6 years were rare [94] because stands <7 to 8 years old are unlikely to carry fire [120]. However, other studies suggest that the probability of burning increases only moderately with time-since-fire, and fuels are limited only in certain areas. Rather, fire may spread through all age classes of fuels under high winds. Fuel age may be important in areas lacking high winds [99,100].

Sprouting chaparral species may withstand fire intervals as short as 10 years, which allows enough time for them to grow, produce seeds, and replenish the soil seedbank. Short fire intervals tend to favor facultative sprouting species such as Eastwood's manzanita over obligate seeding species such as bigberry manzanita [29,42,85,93]. Fire intervals of <10 years can substantially deplete occurrence of sprouting shrubs such as Eastwood's manzanita [96]. Very frequent fire may convert chaparral to annual grasslands [70,132].

Urban development and associated human ignitions have apparently shortened intervals between chaparral fires, particularly in southern California. Human-ignited wildfires every 20 to 30 years throughout chaparral types are common [63]. There is disagreement as to whether fire sizes have increased for chaparral in southern California under fire exclusion (see Fire regimes of California chaparral communities for details). Historically, fire sizes ranged from small [92,93,98] to large [72,77,84]. Because chaparral plant species rely on sprouting and a long-lived soil seedbank, they are not as affected by large fires as many forest plant species and usually recover quickly regardless of fire size [93].

Changes in the fire cycle have led to the state ranking of Del Mar manzanita as imperiled [106] (see Other Status).

For additional information about Fire Regimes of California chaparral, see Fire regimes of California chaparral communities.

FIRE MANAGEMENT CONSIDERATIONS

Eastwood’s manzanita occurs in fire prone ecosystems and is often dominant in chaparral. It persists on chaparral sites as long as fires intervals are longer than 10 years [98] and on sites that do not transition to nonnative, invasive grasses. In conifer forests, frequent low-severity fire helps control manzanita understories. On the Blodgett Forest Research Station, for example, manzanita cover was low (6%) on three plots that were burned under prescription at low severity [56].

Mule deer browse Eastwood's manzanita sprouts in postfire years 1 and 2, and may browse the seedlings "rather closely" [121] (see Importance to Wildlife and Livestock).

Nonnative Grasses: Eastwood's manzanita litter contains phytotoxins that retard germination of annual grasses. Chou and Mueller (1972, 1973) identified 12 allelopathic substances in Zaca manzanita leaf leachate. These substances were concentrated in newly burned soil after a wildfire in chamise-Zaca manzanita chaparral in San Barbara County. However, the substances leached out quickly after rainfall, providing a seedbed favorable for germination of brome grass and other nonnative annual grasses [18,19].

Mastication may result in increases of nonnative invasive herbs [13,155]. Ten years after treatments in chamise-manzanita chaparral north of Ukiah, masticated stands had higher cover of nonnative, invasive annual grasses than burned stands ($P < 0.001$). Stands that were treated (mastication or prescribed fire) in fall had greater mean density of nonnative plants than those treated in spring, and fall-burned plots had 10 to 40 times fewer nonnative annual grasses than masticated plots ($P < 0.01$). For spring treatments, there was ~10 times the cover of nonnative, invasive annual grasses with fire, and 100 times the cover with mastication compared to untreated plots. Annual grasses present included cheatgrass, red brome, soft brome, and wild oat [155].

Seeding with nonnative grasses for postfire erosion control may slow recovery of Eastwood's manzanita and other native vegetation [5,39,104,107]. By rapidly creating a mat of fibrous roots at the soil surface, a stand of ryegrass can inhibit the cotyledons of shrub seedlings from pushing through the soil to light. This reduces the chances of shrub establishment [80,125,126]. Because chaparral seedlings establish primarily in the first 1 to 3 years after fire, future stand density and composition may be influenced by this early competition. After wildfire

in the Ventura River Watershed on the Los Padres National Forest, postfire seeding with nonnative perennial ryegrass resulted in lower Eastwood's manzanita importance in seeded (relative importance value = 3%) compared to unseeded (relative importance value = 7%) plots [104].

MANAGEMENT CONSIDERATIONS

SPECIES: Arctostaphylos glandulosa

FEDERAL LEGAL STATUS
None [143]

OTHER STATUS
Three Eastwood's manzanita infrataxa have state protection status in California. Del Mar manzanita and *Arctostaphylos glandulosa* subsp. *glaucomollis* are ranked as imperiled (T2). Transverse Range manzanita is ranked as vulnerable (T3). Del Mar manzanita is considered imperiled due to proposed and ongoing development; this is the most imminent threat facing the taxon. Associated change in the natural fire cycle is also considered a threat. *Arctostaphylos glandulosa* subsp. *glaucomollis* and Transverse Range manzanita are listed due to their rarity and very limited distributions [106]. Information on state- and province-level protection status of plants in the United States and Canada is available at NatureServe.

IMPORTANCE TO WILDLIFE AND LIVESTOCK
Eastwood's manzanita provides resting, hiding, and nesting cover for wildlife. Wildlife and livestock generally browse only seedlings and sprouts of Eastwood's manzanita.

Palatability and Nutritional Value: Eastwood's manzanita leaves and branches are unpalatable to most browsing animals [20,121,136], and overbrowsing of Eastwood's manzanita and other manzanitas indicates a rangeland in poor condition [20]. Wildlife and domestic goats browse seedlings and new sprouts [20,121], and domestic goats may browse mature foliage lightly [36,121,141]. In mixed chaparral, browsing ungulates prefer oak scrub and chamise to Eastwood and other manzanita species [130,131]. On the Cleveland National Forest, domestic goats did not browse mature Eastwood's manzanita when free ranging, but they showed 80% utilization of leaves and small twigs when confined in fenced pastures at night [33,35]. After discking, they readily browsed sprouts [36] and 1-year-old seedlings [35]. The rigid branches and often dense structure of Eastwood's manzanita stands impedes movement of large game animals and livestock through chaparral [141].

Arctostaphylos is Greek for "bear grape" [141,159]; manzanita is Spanish for "little apple" [20]. As these names imply, the fruits are palatable to many frugivorous animals [20] including American black bears [20,141,159], mule deer, rabbits [74], rodents [74,121], wild turkeys, and grouse [20,141]. They are a staple for American black bears, coyotes [20], northern raccoons [20,137], and quail [20]. Rodent predators of Eastwood's manzanita fruits include brush mice, deer mice, dusky-footed woodrats, and Heermann's kangaroo rats [74].

Seed predators generally prefer large manzanita seeds [74,110]. A review reported that seed bank predators removed bigberry manzanita seeds before Eastwood's manzanita seeds, and Eastwood's manzanita seeds before hoary manzanita seeds, which have the smallest seeds of the three manzanita species [110].

Protein and other nutrient levels are relatively low for Eastwood's manzanita browse. See these publications for information on nutritional content of Eastwood's manzanita browse: [21,136]. These publications provide information on seasonal variation in Eastwood's manzanita browse: [10,105].

Cover Value: Eastwood's manzanita often forms dense stands that provide good hiding, resting, and nesting sites for small birds and mammals. Horton (1960) reported that dusky-footed woodrats used Eastwood's manzanita as cover for their food caches [48]. Open stands of Eastwood's manzanita provide good hiding and resting cover for mule deer [135].

VALUE FOR RESTORATION OF DISTURBED SITES

Eastwood's manzanita provides watershed protection [45,141,158], particularly after fire, when it is among the first species to sprout [141]. See Young and Young (1992) for information regarding propagation of Eastwood's manzanita [159].

OTHER USES

Manzanita wood is used in the craft industry. The wood is hard, and it warps and cracks easily when drying [1].

Eastwood's manzanita fruits can be eaten raw or used to make jelly [1].

American Indians traditionally eat the fruits fresh and dried, and use them to make cider [7,20,141]. The seeds can be ground into meal [7,20,140]. Tea from the leaves was traditionally used as a wash to treat Pacific poison-oak rash [20].

OTHER MANAGEMENT CONSIDERATIONS

Eastwood's manzanita is allelopathic: it releases water-soluble toxins from its aboveground tissues and litter, inhibiting establishment and growth of herbaceous and woody species [101]. Laboratory experiments have identified allelopathic substances in Zaca manzanita that likely inhibit germination and establishment of potentially competitive species [19]. However, Eastwood's manzanita may facilitate establishment of conifers, particularly in montane chaparral (see Successional Status). In Marin County, planted coast Douglas-fir seedlings established in plots with Eastwood's manzanita but not in plots with chamise. Successful establishment was credited to ectomycorrhizal fungi associated with Eastwood's manzanita, but not with chamise [49].

Control: Domestic goats have been used successfully to control chaparral on fuelbreaks and in the urban-wildland interface. However, they will likely select more palatable browse species over Eastwood's manzanita [35,36], resulting in increases of Eastwood's manzanita at the expense of the species they select [103]. Eastwood's manzanita is also controlled by disking [136].

APPENDIX

SPECIES: Arctostaphylos glandulosa

- **Table A1: Plant names**
- **Table A2: Plant communities**

Table A1—Common and scientific names of plants mentioned in this Species Review. Links go to other FEIS Species Reviews.

Common name	Scientific name
Graminoids	
brome grass	*Bromus rigidus*
cheatgrass	*Bromus tectorum*

compact brome	*Bromus madritensis*
perennial ryegrass	*Lolium perenne* subsp. *perenne*
red brome	*Bromus rubens*
ripgut brome	*Bromus diandrus*
ryegrass	*Lolium* spp.
soft brome	*Bromus hordeaceus*
wild oat	*Avena fatua*
Shrubs	
Adams' manzanita	*Arctostaphylos glandulosa* subsp. *adamsii*
Campbell's manzanita	*Arctostaphylos* × *campbelliae*
barranca brush	*Ceanothus verrucosus*
bigberry manzanita	*Arctostaphylos glauca*
bigpod ceanothus	*Ceanothus megacarpus*
birchleaf mountain-mahogany	*Cercocarpus montanus* var. *glaber*
bush chinquapin	*Chrysolepis sempervirens*
California buckwheat	*Eriogonum fasciculatum*
California scrub oak	*Quercus berberidifolia*
ceanothus	*Ceanothus* spp.
chaparral yucca	*Hesperoyucca whipplei*
coastal sage scrub oak	*Quercus dumosa*
common manzanita	*Arctostaphylos manzanita*
cupleaf ceanothus	*Ceanothus greggii* var. *perplexans*
deerbrush	*Ceanothus integerrimus*
Eastwood's manzanita	*Arctostaphylos glandulosa*
subspecies with the same common name:	*Arctostaphylos glandulosa* subsp. *atumescens*
	Arctostaphylos glandulosa subsp. *erecta*
	Arctostaphylos glandulosa subsp. *glandulosa*
	Arctostaphylos glandulosa subsp. *glaucomollis*
	Arctostaphylos glandulosa subsp. *leucophylla*
Encinitis false willow	*Baccharis vanessae*
Campbell's manzanita	*Arctostaphylos* × *campbelliae*
ceanothus	*Ceanothus* spp.
chamise	*Adenostoma fasciculatum*
chaparral whitethorn	*Ceanothus leucodermis*
Del Mar manzanita	*Arctostaphylos glandulosa* subsp. *crassifolia*
desert ceanothus	*Ceanothus greggii*
eastern Mojave buckwheat	*Eriogonum fasciculatum*
hairy ceanothus	*Ceanothus oliganthus*

hoaryleaf ceanothus	*Ceanothus crassifolius*
hoary manzanita	*Ceanothus crassifolius*
manzanita	*Arctostaphylos* spp.
oak scrub	*Quercus* spp.
Pacific poison-oak	*Toxicodendron diversilobum*
Parry manzanita	*Arctostaphylos parryana*
pinkbracted manzanita	*Arctostaphylos pringlei* subsp. *drupacea*
pointleaf manzanita	*Arctostaphylos pungens*
Pringle manzanita	*Arctostaphylos pringlei*
redshank	*Adenostoma sparsifolium*
Roof's manzanita	*Arctostaphylos manzanita* subsp. *roofii*
San Gabriel manzanita	*Arctostaphylos gabrielensis*
Sonoran scrub oak	*Quercus turbinella*
Stanford's manzanita	*Arctostaphylos stanfordiana*
sugar sumac	*Rhus ovata*
Transverse Range manzanita	*Arctostaphylos glandulosa* subsp. *mollis*
woolyleaf ceanothus	*Ceanothus tomentosus*
woolyleaf manzanita	*Arctostaphylos tomentosa*
Zaca manzanita	*Arctostaphylos glandulosa* subsp. *zacaensis*
Trees	
bigcone Douglas-fir	*Pseudotsuga macrocarpa*
bigleaf maple	*Acer macrophyllum*
Bishop pine	*Pinus muricata*
blue oak	*Quercus douglasii*
Bolander beach pine	*Pinus contorta* var. *bolanderi*
bristlecone fir	*Abies bracteata*
canyon live oak	*Quercus chrysolepis*
coast Douglas-fir	*Pseudotsuga menziesii* var. *menziesii*
Coulter pine	*Pinus coulteri*
interior live oak	*Quercus wislizeni*
Jeffrey pine	*Pinus jeffreyi*
juniper	*Juniperus* spp.
knobcone pine	*Pinus attenuata*
oak	*Quercus* spp.
pine	*Pinus* spp.
pinyon	*Pinus*, subsection *Cembroides*
ponderosa pine	*Pinus ponderosa* var. *benthamiana*, *P. ponderosa* var. *ponderosa*
Tecate cypress	*Hesperocyparis forbesii*

Torrey pine	*Pinus torreyana*
valley oak	*Quercus lobata*

Table A2—Representative plant community classifications in which Eastwood's manzanita occurs.
FRES Ecosystems
FRES20 Douglas-fir
FRES21 Ponderosa pine
FRES 28 Western hardwoods
FRES 34 Chaparral-mountain shrub [32]
Kuchler Plant Association
K002 Cedar-hemlock-Douglas-fir forest
K005 Mixed conifer forest
K009 Pine-cypress forest
K010 Ponderosa shrub forest
K029 California mixed evergreen forest
K030 California oakwoods
K033 Chaparral
K034 Montane chaparral [83]
SAF Cover Types
229 Pacific Douglas-fir
234 Douglas-fir-tanoak-Pacific madrone
244 Pacific ponderosa pine-Douglas-fir
245 Pacific ponderosa pine
246 California black oak
246 California black oak
247 Jeffrey pine
248 Knobcone pine
249 Canyon live oak
250 Blue oak-gray pine
255 California coast live oak [26]
SRM (Rangeland) Cover Types
109 Ponderosa pine shrubland
201 Blue oak woodland
202 Coast live oak woodland
206 Chamise chaparral
207 Scrub oak mixed chaparral
208 Ceanothus mixed chaparral
209 Montane shrubland [129]

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