I. SPECIES	*Salvia mellifera* Greene [Updated 2017]

NRCS CODE: SAME3

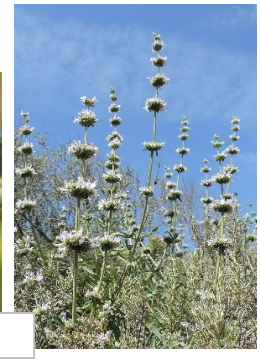
Family: **Lamiaceae**
Order: **Lamiales**
Subclass: **Asteridae**
Class: **Magnoliopsida**

fruiting inflorescence with persistent calyx

black sage stand in chaparral, Riverside Co.

juvenile plant

seedling



flowers and inflorescences

A. Subspecific taxa	None. Two taxa previously recognized as part of *S. mellifera* have been elevated to species status (USDA Plants). *S. munzii* includes what was known as *S. mellifera* subsp. *jonesii* Abrams or *S. m.* var. *jonesii* Munz; and *S. brandegeei* Munz includes what was known as *S. m.* Greene ssp. *revoluta* (Brandegee) Abrams.
B. Synonyms	*Audibertia stachyoides* Benth., *Audobertiella s.* Briq. (noted in Munz & Keck 1968)
C. Common name	black sage (other names have been used less often such as California black sage, coastal black sage, black ball sage, and honey sage (Painter 2016).
D. Taxonomic relationships	There are currently 22 taxa of *Salvia* recognized in California and about 9000 species recognized worldwide (Averett 2017, Jepson eFlora 2017). Walker et al. (2015) studied the relationships among all 19 species from the California Floristic Provence and those within neighboring provences. Relatedness based on chloroplast and nuclear ribosomal DNA with respect to geography suggests there are two monophyletic sections. Section *Audobertia* contains 15 species that organize into three subgenera. *S. mellifera* is placed in the subgenus *Audibertia,* whose recent diversification appears to have involved hybridization and chlorplast capture. The subgenus may have arisen in arid, desert areas and then diversified into the Mediterranean climate region where *S. mellifera* occurs. The study shows *S. mellifera* is most closely related to *S. brandegeei* , *S. apiana, S. vaseyi, S. eremostachya* and *S. clevelandii* . Classification is complicated by some specimens of *S. mellifera* containing choroplasts presumably captured from past hybridization with *S. columbariae.*
E. Related taxa in region	*Salvia apiana* Jeps. (Santa Barbara Co. s into Baja California and east to the western edge of the Colorado desert), *S. brandegeei* Munz (in Channel Islands), *S. munzii* Epling (in San Diego Co. and Baja California), *S. clevelandii* (A. Gray) Greene (Los Angeles Co. s. into Baja California in s South Coast and s Peninsular Ranges of San Diego Co.), *S. leucophylla* Greene (coastal foothills from the Chino Hills of Orange Co. north to San Luis Obispo Co. and where it has been planted out of range in restoration projects such as in coastal San Diego Co.)
F. Taxonomic issues	None.
G. Other	The specific epithet “mellifera” means “honey producing” and refers to its use by nectar foraging bees. The flowers are attractive to many nectar foraging bees. Black sage is the widest ranging species of shrubby *Salvia* (Sawyer et al. 2009) and is important in the restoration of pollinator habitat and in pollinator gardens throughout its range. However, its thin leaves were found to ignite relatively quickly in flammability tests with dried plant material (Montgomery & Cheo 1971), suggesting this plant should be placed away from flammable structures when used in landscaping. The plants are long-lived and are resilient to wildfire return intervals of 15 or more years (Sawyer et al. 2009).

II. ECOLOGICAL & EVOLUTIONARY CONSIDERATIONS FOR RESTORATION

A. Attribute summary list (easy guide to help navigate decision trees)

Taxonomic stability - low to intermediate
Longevity - long-lived
Parity - polycarpic
Flowering age - 3+ yr
Stress tolerance - moderate to high
Environmental tolerance - broad in adults
Reproduction after fire - facultative seeder
Fragmentation history - recent
Habitat fragmentation - high at low elevations

Seeds - dormant, long lived
Seed dispersal distance - short
Pollen dispersal - intermediate to far
Breeding system - outcrossed, self-compatible
Population structure - low
Adaptive trait variation - unknown
Chromosome number - stable
Genetic marker polymorphism - high
Average total heterozygosity - high
Hybridization potential - high betw. species

SDM projected midcentury suitable habitat - 97–100 % stable
SDM projected midcentury habitat gain - gain >> loss for all five models (assuming unlimited dispersal)

B. Implications for seed transfer (summary)

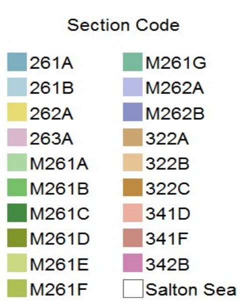
Black sage has protandrous flowers and its most common pollinating bees promote outcrossing and high levels of gene exchange through pollen movement among stands of plants. Such gene flow may help maintain genetic diversity and counter some of the adverse effects of habitat fragmentation. However, seed dispersal is unlikely to accommodate migration to new habitats in the fragmented portion of the species' range, which is primarily at low elevations. Inbreeding depression in seed production and other traits related to fitness is likely to occur in this self-compatible plant in small isolated populations or areas where bee populations are suffering. Observed low population structure and lack of outbreeding depression at the scale of ecological sections suggests historically high levels of gene migration in black sage and a relatively recent history of population fragmentation. For isolated and small populations within southern California at low elevations, inbreeding depression in this self-compatible plant is likely to be more of an issue than adverse effects of outbreeding among populations within ecological sections. However, a common garden study suggested habitat matching may increase success of translocations. Such conditions suggest that mixing populations from similar elevations within ecological subsections, or among adjacent ecological subsections could counter the potentially detrimental effects of fragmentation and inbreeding. The effect of translocating or crossing populations from higher elevations and latitudes with those from lower elevations and latitudes, or populations with different inherent flowering times has not been studied and cannot be assumed to lack risk. Trends in the change of suitable habitat in response to climate change suggest moving from more mesic occupied habitats toward drier occupied habitats would be associated with a higher level of risk of maladaptation than moving from drier toward more mesic habitats.

III. GENERAL

A. Geographic range

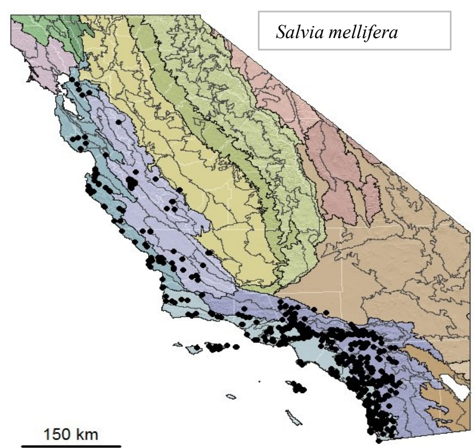
Common in western California from Contra Costa Co., CA (San Francisco Bay area) south into northern Baja California (Munz & Keck 1968, Hickman 1993).

B. Distribution in California; ecological section and subsection (sensu Goudey & Smith 1994; Cleland et al. 2007)



Map includes validated herbarium records (CCH 2016) as well as occurrence data from CalFlora (2016) and field surveys (Riordan et al. 2018).

Ecological Section/Subsection:
Great Valley 262A: w (border with M262A)
Central California Coast 261A: a,b,c,e-h,j,k,l
Central California Coast Ranges M262A: a,c-f,h,j,k
Southern California Coast 261B: a-j
Southern California Mountains and Valleys M262B: a-g,j,k,l,n,o
Mojave Desert 322A: a (border with M262B)



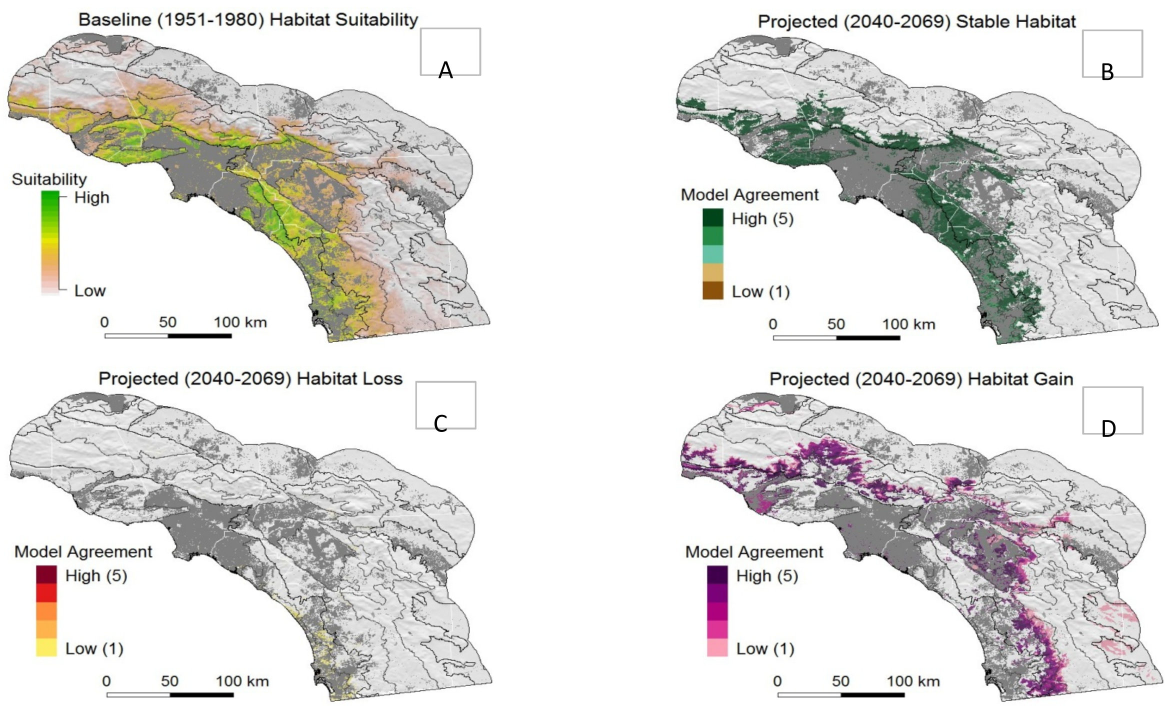
C. Life history, life form

Polycarpic, perennial shrub. Long-lived with a reproductive range of about 2-50 years (Sawyer et al. 2009).

D. Distinguishing traits	Shrubs are highly aromatic, open, 1 to 2 m tall with twisted, furrowed woody stems at the base, and herbaceous greenish branch tips that are square in cross section. Twigs and leaves are glandular, highly aromatic, and opposite. The oblong-elliptical blades are diagnostic. They are 2 to 6 cm long, dark green and rugulose above (convex between obvious veins) with crenulate (finely scalloped) margins, and taper to a few to 12 mm long petiole (Munz & Keck 1968). The many small, 6 to 12 mm long, two-lipped flowers occur in compact clusters subtended by green bracts and are spaced 2 to 6 cm apart along the often branched inflorescence. Corollas vary from pure white to pale blue or lavender. The style and stamens extend just beyond the corolla tube. Flowers bear four oblong nutlets (single–seeded fruits) within a persistent calyx. Nutlets vary from mottled gray to dark brown and are about 1 mm wide and 2 mm long. (modified from Montalvo & McMillan 2004).
E. Root system, rhizomes, stolons, etc.	Shallow, fibrous branched tap root system spreads horizontally more than deep (Hellmers et al. 1955).
F. Rooting depth	Measured maximum depth at 2 feet, but only two plants excavated (Hellmers et al. 1955).
IV. HABITAT	
A. Vegetation alliances, associations	Black sage occurs as a dominant or co-dominant plant in the shrub canopy in many coastal sage scrub, alluvial scrub, and lower montane chaparral shrubland alliances and associations: in coastal sage scrub and alluvial scrub shrub layers, it occurs primarily with *Artemisia californica, Diplacus aurantiacus* (and related taxa)*, Encelia californica, Encelia farinosa, Eriogonum fasciculatum, Acmispon glaber, Malacothamnus fasciculatus, Opuntia littoralis, Salvia apiana,* and *Hesperoyucca whipplei;* in chaparral, it occurs primarily with *Malosma laurina, Rhus ovata,* and *Adenostoma fasciculatum* (e.g., Sawyer et al. 2009). Black sage also occurs within the *Quercus agrifolia* woodland alliance.
B. Habitat affinity and breadth of habitat	Black sage occurs on dry slopes and alluvial fans within interior and coastal sage scrub and lower montane chaparral (Munz & Keck 1968, Hickman 1993). On leeward slopes of the Coast Ranges it extends into desert scrub (Keeley 1986). It is one of the dominant shrubs of sage scrub (Westman 1983) and can form dense, nearly monospecific stands on steep slopes (Montalvo & McMillan 2004). In areas of contact with *S. apiana* , *S. mellifera* tends to occur in flatter and wetter microsites, while *S. apiana* occurs on drier slopes (Epling 1947a, Anderson & Anderson 1954, Grant and Grant 1964, Meyn & Emboden 1987, Gill & Hanlon 1998). In zones of contact, hybrids between the two species occur in recently disturbed areas, suggesting that hybrids are adapted to intermediate habitats (Anderson & Anderson 1954, Meyn & Emboden 1987). Within a hybrid zone, Gill and Hanlon (1998) found that xylem pressure potential was significantly higher in white than in black sage and that putative hybrids were intermediate to the two parental species.
C. Elevation range	Sea level to 1200 m (3,900 ft) (Munz & Keck 1968, Hickman 1993).
D. Soil: texture, chemicals, depth	Plants occur on a variety of soils derived from sandstone, shale, granite, and especially serpentinite and gabbro basalt (Westman 1981).
E. Precipitation	Occurs primarily in Mediterranean climate zone with cool to cold moist winters and warm to hot dry summers Plants typically grow in areas with 10 to 50 inches of precipitation. For ecological sections occupied by black sage, annual normal precipitation ranges from 10 to 40 in (250 to 1,020 mm) in the Southern California Mountains and Valleys (M262B), from 10 to 25 in (250 to 640 mm) in the Southern California Coast (261B), from 14 to 50 in (350 to 1280 mm) in the Central California Coast (261A), and from 10 to 30 in (250 to 760 mm) in the Central California Coast Ranges (M262A).
F. Drought tolerance	Plants are thought to be drought tolerant by leaf curling rather than drought avoiding through leaf drop (Gill & Hanlon 1998). However, leaf drop does occur and is drought induced, possibly due to embolisms that occur in xylem tissues (Kolb & Davis 1994). Funk & Zachary (2010) found plants maintained photosynthetic function during water stress through high water use efficiency and were highly responsive to irrigation following water stress. Nevertheless, reproduction is sensitive to drought. During very dry years, plants forgo flowering. High water use by flowers (about 20% of total water use by shoots) may limit reproductive success in drought or in years when soil becomes dry during flowering, resulting in lower reproductive success and less flowering in the subsequent year (Lambrecht et al. 2011). When the soil becomes dry during flowering, plants may respond by shedding leaves within flowering shoots.
G. Flooding or high water tolerance	Not generally flood tolerant. An upland plant but may occur on middle to upper alluvial terraces along waterways and on alluvial fans where flooding is infrequent.
H. Wetland indicator status for California	None.
I. Shade tolerance	Generally full sun but can withstand partial shade.

V. CLIMATE CHANGE AND PROJECTED FUTURE SUITABLE HABITAT

Salvia mellifera



A. Species Distribution Models (SDM forecasts from Riordan et al. 2018) Map descriptions

Modeled habitat suitability under (A) baseline (1951–1980) and (B–D) projected midcentury (2040–2069) climate conditions. Projected future habitat suitability maps show agreement across five different climate model scenarios: (B) stable = suitable under both baseline and future conditions; (C) loss = suitable under baseline but unsuitable under future conditions; (D) gain = unsuitable under baseline and becoming suitable under future conditions. In all maps, land area that has already been converted to urban and agriculture land uses is masked in dark gray (FRAP 2015 Assessment; https://map.dfg.ca.gov/metadata/ds1327.html).

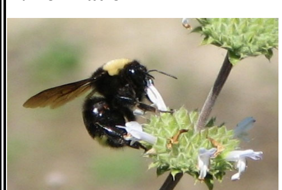
B. SDM summary

Species distribution modeling suggests black sage could maintain much of its suitable habitat in southern California under 21st century climate change. Assuming a future of continued high greenhouse gas emissions, Riordan et al. (2018) predicted 97–100% of baseline habitat in southern California would remain suitable (stable) for black sage under mid-century conditions across future climate scenarios from five different general circulation models (GCMs) (SDM maps Fig. B). The area of habitat suitable for black sage could increase by 53–97% (SDM maps Fig. D). Under all five climate scenarios, predicted gain in suitable habitat exceeded loss Areas of greatest predicted suitable habitat gain were in the Transverse and Peninsular Ranges. Riordan and Rundel (2014) also predicted high stability in suitable habitat under 21st century climate conditions. They predicted relatively low loss in suitable habitat mid-century (11–13%), rising to 22–25% by the end of the century. Principe et al. (2013) predicted relatively stable suitable habitat for black sage in lowland southern California coastal areas under mid-century climate, but losses in suitable habitat for the Perris Valley and Hills. They predicted only a small gain in suitable habitat.

Land use, altered fire regimes, invasive species, and their interaction with climate change could negatively affect black sage, even if projected habitat loss from climate change alone is relatively low. Much of the coastal, low elevation suitable habitat of black sage in southern California has been developed. Furthermore, human activity is the primary driver of fire (Keeley & Syphard 2016) with fire ignitions and fire frequency increasing with human population growth and proximity (Syphard et al. 2009). Black sage is a facultative seeder, regenerating by both resprouts and seeds after fire (see VI. D. Regeneration after fire or other disturbance). High fire frequencies, however, may be detrimental to the species, causing the conversion of mixed chaparral and CSS to annual grasslands (Haidinger & Keeley 1993, Talluto & Sudding 2008, Zedler et al. 1983). In addition, the high level of habitat conversion and fragmentation throughout lower elevations of the species' range creates a considerable barrier to seed dispersal and migration that could reduce the adaptive capacity and ability of the species to respond to changing conditions. Riordan and Rundel (2014) caution that land use may compound projected climate-driven losses in suitable habitat for southern California shrublands. They predict that the combination of projected land use and climate change could result in as much as 46% loss in currently suitable habitat for black sage by the end of the 21st century (Riordan & Rundel 2014).

C. SDM caveats (concerns)	The five general circulation models used to predict future habitat suitability assume a 'business-as-usual' scenario of high greenhouse gas emissions that tracks our current trajectory (Intergovernmental Panel on Climate Change, IPCC scenario RCP 8.5). They show how climate may change in southern California and highlight some of the uncertainty in these changes. The true conditions at mid-21st century, however, may not be encompassed in these five models. Predictions of current and future habitat suitability should be interpreted with caution and are best applied in concert with knowledge about the biology, ecology, and population dynamics/demographics of the species. They are best interpreted as estimates of exposure to projected climate change, not population level persistence. Our models characterize habitat suitability with respect to climate and parent geology but do not include other factors, such as biotic interactions or disturbance regimes, that may also influence species distributions. Additionally, they do not include the adaptive capacity of a species, which will affect its sensitivity to changes in climate. See Riordan et al. (2018) for more information on SDM caveats.

VI. GROWTH, REPRODUCTION, AND DISPERSAL

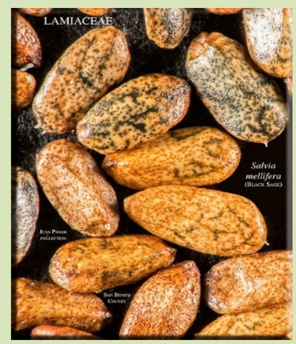
A. Seedling emergence relevant to general ecology	Seedlings emerge in clearings between shrubs in the absence of fire, but most emerge in the first to second rainy season following fire, primarily in mid-winter to early spring (e.g., Keeley 1986, Westman & O'Leary 1986). Seedlings tend to emerge within 1 m of established shrubs (Schultz 1996). Emergence following soaking rains in cool weather can be rapid. In a large experiment in Riverside, CA under ambient temperatures in an unheated greenhouse in January-February, seedlings began to emerge in 5 days, with most germination by the end of two weeks (A. Montalvo, pers. obs.).
B. Growth pattern (phenology)	Seed germination and most vegetative growth is during the cool, wet winter, and new plants flower after two or more growing seasons. Time of flowering is variable but generally occurs mid-spring, tending to wane by mid-May depending on the year and location. Plants tend to forego flowering in drought years. Plants mature seeds in June (occasionally from late May) to August and enter dormancy in the hot, dry summer (Grant & Grant 1964, Gill & Mahall 1986). In one study of plants in Santa Barbara Co., most leaves senesced between May and July, 32% persisted into the following growing season, leaf curling and uncurling was related to water stress, and leaf drop was more related to photoperiod than to low xylem potentials (Gill & Mahal 1986; but see Kolb & Davis 1994, IV. F. Drought tolerance).
C. Vegetative propagation	Plants do not have any specialized structures for vegetative reproduction, but burned plants can sometimes resprout (see VI. D, below). The green stems (soft wood) are easy to root for propagation (A. Montalvo pers. obs.).
D. Regeneration after fire or other disturbance	Facultative seeder (Keeley et al. 2006). Recruitment after wildfires is by seed and resprouts from the base (Went et al. 1952, Keeley 1986). In coastal sage scrub, especially near the coast, many plants resprout from the base after fire, supplementing establishment from seed (Keeley 1986). The relative frequency of these modes varies among sites and may be tied, in part, to the density of vegetation and intensity of fire. In a review of the literature, Keeley (1986) reported that in dense, interior populations, shrubs tend to be killed by fire and depend more on seedling recruitment, whereas near the coast, resprouting tends to be more common with variable seedling recruitment. In a survey of 90 post fire sites ranging from coast to inland valleys, he found that resprouting success was only 15.8% and completely failed at some sites. Shrubs that resprouted had significantly smaller basal diameters, suggesting plants lose the ability to resprout as they age (Keeley 1998). In a five year study at 25 coastal sage scrub sites, 73% of seedling recruitment occurred in the first year after fire and was about 2.6 times lower than at 29 denser chaparral sites (Keeley et al. 2006). Black sage made up the same proportion of the vegetation postfire as it did before fire.
E. Pollination  *Bombus californicus* in western Riverside Co.	Flowers are pollinated by small to large-sized native bees, primarily while they are seeking nectar, in families Andrenidae, Anthophoridae, Apideae, Halictidae, and Megachilidae as well as by *Apis mellifera* the introduced honey bee (Grant & Grant 1964, Moldenke & Neff 1974; Frankie et al. 2008, 2014). Honey bees and *Bombus californicus* are common visitors of black sage in Riverside County (A. Montalvo, pers. obs.). Frankie et al. (2014) studied bee visitation to black sage in gardens throughout California and found the most freqent visitors were honey bees, *Bombus melanopygus, Habropoda depressa*, and *Osmia* species. Black sage has small, two-lipped flowers that are visited less frequently by the large-bodied *Xylocopa,* a major pollinator of white sage, *S. apiana*, with which black sage is known to hybridize (see VI. H. Hybridization potential, below); however, in some areas both species may be visited commonly by *Bombus*. Syrphid and bombyliid flies and Anna's hummingbirds also visit flowers (Montalvo & McMillan 2004), and butterflies sometimes use the flowers. For more information about the bees see VII. E. Insect pollinators.

F. Seed dispersal	Each flower produces up to four seeds that are primarily gravity dispersed in June through August from the dry, persistent calyces, and they can be secondarily dispersed by harvester ants (Schultz 1996, Montalvo & McMillan 2004). In a seed trap experiment in a wild population, fewer than 1% of the seeds fell to 1 m beyond the edge of the canopy, and no seeds were found at 2 m, consistent with gravity dispersal distances being very short (Schultz 1996). Some seeds may be dispersed further by passing animals when the dried, fruiting calyx, hooked on one end, attaches to their fur or feathers (Carlquist & Pauly 1985).
G. Breeding system, mating system	The self-compatible flowers are hermaphroditic with stamens dispersing pollen before stigmas become receptive; that is, the flowers are "protandrous" (Montalvo & McMillan 2004). In a study of allozyme variation in 12 black sage populations, the low inbreeding coefficient (f = 0.072) suggests that protandry limits transfer of self pollen and facilitates outbred pollination by insects (Montalvo & McMillan 2004).
H. Hybridization potential	In areas of contact between sage species, hybridization potential can be high. Black sage hybridizes with the shrubs *S. apiana* Jeps. (n = 15), *S. leucophylla* Greene (2n = 30), and *S. clevelandii* (Gray) Greene (2n = 30), and rarely with annuals *S. columbariae* Benth (n = 13) and *S. carduacea* Benth (n = 16) (Epling 1938, 1947a; Epling et al. 1962, Munz & Keck 1968). Most hybridization is with *S. apiana,* which serves as the pollen parent. However, white sage has larger, highly modified flowers that are pollinated almost exclusively by large bees in *Xylocopa* and *Bombus* . Also, *S. apiana* flowers later than black sage, limiting the opportunity to hybridize to a short period of overlap in flowering times (Grant & Grant 1964). Although the hybrids are fully viable, they suffer reduced pollen fertility (Epling 1947a, Meyn & Emboden 1987) and numbers of seeds/flower in F_1 back crosses to parental species (Grant & Grant 1964). Hybrids differ from both parental species by a range of intermediate floral, leaf, and anatomical traits (Epling 1947a, b; Anderson & Anderson 1954, Webb & Carlquist 1964). Most are thought to be F_1 hybrids (first generation) or backcrosses to *S. mellifera* and tend to grow near parental types. Hybrid zones can be stable in location but may shift in morphology (Meyn & Emboden 1987). This suggests differences in the relative success of hybrids and backcrossed progeny over time. The influence of gene exchange on floral form of black sage does not appear to extend beyond hybrid zones (Epling 1947a, b).
I. Inbreeding and outbreeding effects	A. Montalvo and P. McMillan (unpublished data) detected inbreeding depression in seed set but did not detect outbreeding depression. Plants were grown from seeds collected from six southern California source populations (all in coastal sage scrub below 500 m) and used in a crossing experiment to determine if the genetic or environmental distance between source populations affected seed set of a cross. The populations were from Santa Barbara, Los Angeles, Orange, and Riverside Counties and included both coast and inland locations. Crosses were made among plants from all six populations, including the same source population as the pollen recipient plant. The study also included self-pollinations. Neither genetic distance or the similarity of source environment had a significant effect on seed set (proportion of ovules setting seeds); however, there were significant differences in seed set among plants from different source populations, and average seed set ranged from 46 to 62% for the six populations. Self-pollen donors (pollen from same plant as seed parent) produced the lowest seed set in these trials (44% success compared to outcross pollen sources ranging from 52 to 56% success), indicating inbreeding depression in seed set.
VII. BIOLOGICAL INTERACTIONS	
A. Competitiveness	Seedling emergence and establishment is inhibited by competition with invasive, non-native grasses, but this relationship may vary under differing environmental conditions, and mature stands may resist invasion. Cione et al. (2002) conducted a seeding experiment that included hand weeding, herbicide treatments of grasses before seeding, and unweeded controls. Seedling density was nearly 20 times lower in all the treatments where weeds were not controlled, and within a year there were no shrubs in the unweeded treatments. The competitive advantage of the non-native annuals, *Bromus madritensis* and *Erodium botrys,* may be lower in drought years. In experimental plots seeded with native shrubs and these non-native weeds, the weeds grew less than *S. mellifera* and other native shrubs under drought conditions but exceeded growth of shrubs when rainfall was suplemented with irrigaition (Ashbacher & Cleland 2015). In experimental plots with monocultures of the native shrubs *S. mellifera* and *Artemisia californica* and the non-native weedy annuals *Bromus hordeaceous* and *Brassica nigra,* Goldstein & Suding (2014) found that the two native shrubs depleted soil water and nitrogen resources to a greater extent and depth than the two weeds species, and the shrub plots resisted invasion. They concluded that a mechanism such as disturbance that could cause resources to fluctuate may be needed to facilitate invasion of the weeds into intact shrublands.
B. Herbivory, seed predation, disease	Seed predation can be high, such as in mature, natural stands in the Santa Monica Mountains in 1993 when many seeds were lost to predation by the larvae of insects (A. Montalvo pers. obs.). Undetermined species of *Salvia* were found to be among the plants infected with new invasive *Phytophthora* root pathogens that spread from nurseries to field sites (Rooney-Latham et al. 2015).

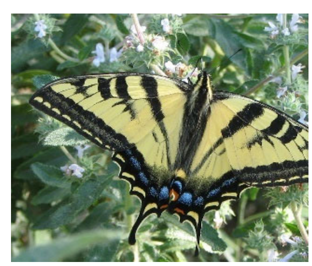
C. Palatability, attractiveness to animals, response to grazing	Plants produce numerous volatile compounds, including camphor, cineole, terpenes, and sesquiterpenes (Neisess et al. 1987, González et al. 1992, Arey et al. 1995), some of which may be important to herbivore or pathogen defense. Arey et al. (1995) noted that sesquiterpenes are important to attraction of wasps that parasitize herbivorous insects in other herbivore-injured seedlings (e.g., corn) and proposed that similar changes in emission of volatile compounds could be in response to phenology or aphid infestations in black sage.
D. Mycorrhizal? Nitrogen fixing nodules?	Roots are readily colonized by arbuscular mycorrhizal fungi (AM fungi), and plants are considered to be highly dependent on the beneficial interaction; the roots of black sage can easily be inoculated by addition of fresh soil collected from under wild plants or when grown in habitats with intact, live soil (A. Montalvo pers. obs.). After 4 months of growth in a greenhouse, root and shoot mass was higher in seedlings inoculated with AM fungi than in controls, but in younger plants the opposite occurred (E. Allen, L. Egerton-Warburton, A. Montalvo, unpublished report to Metropolitan Water District). Outdoors, Aprahamian et al. (2016) found no significant effects on root colonization by mycorrhizal fungi or growth of plants grown in inoculated compared to uninoculated control plots six months after seeding, but a depression in shoot length was seen after 10 months in plots inocuated with a commercial inoculum. The abundance of mycorrhizal fungi was not low in the uninoculated plots. Results may differ in soils where the fungi are missing. Some commercial inocula may contain fungal species that are not well suited to the growth of native shrubs. Also, the authors caution the study was performed under a severe drought. Black sage co-occurs with other species that form mycorrhizal networks and may benefit from such associations especially in the vicinity of oak woodlands. For example, the roots of black sage were found to receive compounds from the roots of oaks by way of hyphal connections between the species (Egerton-Warburton et al. 2007).
E. Insect pollinators	Several genera of black sage pollinators (see VI. C. Pollination) are known to forage over large distances, which may facilitate intermediate to long-distance pollen flow. *Apis mellifera* and several species of *Bombus* were found to fly distances of 1,000 to 10,000 m, and several species of *Osmia* were found to forage over hundreds of meters (Zurbuchen et al. 2010). However, the way different species of bees travel across fragmented habitat or respond to the spacial scale of urbanization varies. For example, Schochet et al. (2017) found the three most common species of *Bombus* in southern California, including black sage pollinators *B. californicus* and *B. melanpygus* (see VI. E. Pollination, above), respond differently to habitat variables at a range of spatial scales (variables such as amount of sage plant cover — either *S. apiana* or *S. mellifera* — impervious surfaces, distances to major roads, and distance to coast for habitat reserves, fragments, and urban areas). In particular, the three species responded to the scale of impervious surfaces associated with urbanization differently. *Bombus californicus* was strongly associated with cover by white and black sage and tended to avoid hard urban landscapes within 75 km of study plots. In contrast, *B. melanopygus* did not avoid hard urban landscapes outside plots, and it was was associated with areas closer to the coastline. The third species, *B. vosnesenskii* , crossed developed areas and foraged in urban and non-urban landscapes. Declines in native bee and honey bee populations are of great concern (Murray et al. 2009). Habitat fragmentation from agriculture and urbanization have resulted in declines in pollinator populations and decreases in pollination services (e.g., Kremen et al 2002). In San Diego coastal sage scrub, Hung et al. (2015 found that nearby habitat fragments (each 5−80 ha and surrounded by urbanization) supported 14% fewer species of native bees than the larger reserve habitats (each > 500 ha). Habitat corridors are used by bees and are needed to help maintain bee and plant populations (Townsend & Levey 2005).

VIII. ECOLOGICAL GENETICS

A. Ploidy	2n = 30 (Epling et al. 1962).
B. Plasticity	Timing of flowering appears to be controlled by a combination of genetics and the environment. Shifts in flowering time occur in years with contrasting rainfall patterns (Meyn & Emboden 1987); however, common garden studies with 12 populations revealed that date of first flowering varies with source population and ranged from early February to early May (A. Montalvo, unpublished data). Also, plants are semi-drought deciduous and can drop some leaves and become dormant depending on the severity of drought. At Stanford, CA, leaves began to senesce and drop in October in both irrigated and unirrigated treatments, leaf stomata did not control transpiration when xylem water potentials were low, and rates of photosynthesis did not decline until after leaf drop (Gigon 1979).
C. Geographic variation (morphological and physiological traits)	Populations cluster by genetic similarity (based on allozymes, see VIII. D. Genetic variation and popuation structure), and this is somewhat mirrored by distribution patterns of morphological variation and timing of flowering (A. Montalvo pers. obs., unpublished data, Montalvo & McMillan 2004). Flowers from populations in the Santa Monica Mountains and Simi Hills can be strikingly bluish. In the drier, more interior hills and valleys of Riverside Co., flowers tend to be white to pale blue or lavender, and plants flower earlier. These differences are retained in common gardens. Plants from contrasting populations also smell different, likely due to differences in composition of volatile chemicals.

D. Genetic variation and population structure	Black sage is genetically variable in both morphology and allozymes (protein genetic makers) over its geographic range. In a survey of 12 populations (Montalvo, Clegg, & Ellstrand unpublished data for 14 allozyme loci and 60 individuals per population), expected heterozygosity was high ($H_e = 0.23$), and alleles averaged 2.81 per locus. Only about 4% of the variation was due to differences among populations, a result consistent with a relatively high level of historical gene flow [Theta-p (~F_{ST}, sites relative to total population) = 0.041, F (F_{IT}) = 0.125] (Montalvo & McMillan 2004).
E. Phenotypic or genotypic variation in interactions with other organisms	In a reciprocal common greenhouse experiment, plants grown from seeds collected from a source population on non-serpentine soil differed in degree of colonization by mycorrhizal fungi compared to plants grown from seeds collected from a population on serpentine soil (A. Montalvo, J. Skillman, and J. Bever, V. Claassen, unpublished data). Sampling showed root colonization averaged about 62%.
F. Local adaptation	Montalvo & McMillan (2004) summarized the results of a study by A. Montalvo and N. Ellstrand (University of California, Riverside) that evaluated seedling survival, growth and reproduction of plants grown from seeds of 12 southern California source populations in a common garden at Fallbrook, San Diego Co., CA. A combination of climatic data and soil traits was used to calculate environmental similarity among garden and source sites. After three growing seasons, populations from sources most similar to the garden site were the most successful (measured as survival rate times number of flowers produced by survivors). The effect was small ($r^2 = 0.18$) but was consistent with the presence of weak adaptive differences among source populations. This suggests habitat matching would be good to consider when sourcing seeds for restoration.
G. Translocation risks	Observed genetic differences in flowering time and plant chemistry very likely contribute to the success of plants under particular environments. Differences in the timing of flowering could affect seed production of translocated populations if pollinator activity, seed predation, or important physical environmental factors differ from home sites.
IX. SEEDS scale bars 2 mm	Rancho Santa Ana Botanic Garden Seed Program, seed images by John Macdonald left: http://www.hazmac.biz/050919/050919SalviaMellifera.html right: http://www.hazmac.biz/170306/170306SalviaMellifera.html  
A. General	Up to four small nutlets (one-seeded indehiscent fruits that look like single seeds) form at the base of each flower. They vary from mottled gray to dark brown and are about 1 mm wide and 2 mm long (Montalvo & McMillan 2004). Unfilled achenes are frequently produced, and seed filling is variable from year to year. Meyer (2008) lists maximum germination as 69%. Standard purity of 70% and germination of 50% are used as a seed industry standard (Jody Miller, S&S Seeds, pers. com.). The intact nutlet is considered the seed for seed testing (Ransom Seed Laboratory 2017).
B. Seed longevity	Black sage seeds form a persistent seed bank in nature and can be expected to be long-lived. Nine seed lots stored for two years under ambient warehouse conditions in Carpinteria, CA, had an average germination of 41.3% in the first year and 35.1% in the second year (Jody Miller, S&S Seeds, pers. com.). Meyer (2008) reported that seeds of the related white sage showed little loss in viability during 5 to 7 years of sealed warehouse storage.
C. Seed dormancy	Physiological dormancy (Baskin & Baskin 1998). Seeds remain dormant in the seed bank until stimulated to germinate, often by fire (Keeley 1986), althought many seeds germinate without fire.
D. Seed maturation	Seeds ripen sequentially, lagging behind flowering that often lasts over a month. Meyer (2008) reported that seeds of shrubby salvias tend to ripen about 6 weeks after full flower.
E. Seed collecting and harvesting	Seeds are collected from June-August (occasionally as early as mid-May), depending on location, after the inflorescences with their persistent calyces become dry and brown. Seeds are retained inside the calyx for several weeks, making it possible to collect seeds from plants with a range of phenologies at the same time (A. Montalvo, pers. obs.). Mature seeds can be harvested by clipping, hand-stripping, or shaking seed heads into open containers (Meyer 2008, A. Montalvo pers. obs.). Shaking fruiting inflorescences over a screen (e.g., 1/4 inch holes) in the field to discard large pieces can greatly decrease the amount of non-seed material carried back for further processing.

F. Seed processing	Seeds should be cleaned to remove seed predators. If whole inflorescences or "seed heads" are collected, the material must be well dried before handrubbing (small lots) or passing through a hammermill or barley debearder (large lots) to break it up (Meyer 2008). After initial sieving of the broken up material, air separation can be used to remove lighter unfilled seeds that are sometimes abundant (Montalvo & McMillan 2004). For seed banking or perparing seeds for container planting, Wall & Macdonald (2009) recommend first rubbing floral material over a medium screen, then rub and sift through #12 and #25 sieves before air separation; the blower speed can be set low (depending on particular blower), but higher speed may be needed to separate out the unfilled, sterile seeds.
G. Seed storage	Store under cool, dry conditions. Longevity is increased under cold, dry storage. At the Riverside-Corona Resource Conservation District, cleaned seed lots dried to ambient conditions are stored in a walk-in cold room (conditions ranging from 41 to 50ºF at 37– 45% relative humidity, A. Montalvo pers. obs.).
H. Seed germination	Treatment of seeds with dry or liquid smoke, heat, or gibberellic acid increases germination substantially. Seeds should be air-dried before sowing when liquid treatments are used, because compounds on the seed coat become sticky when soaked. The dormant seeds of black sage often have low germination rates unless exposed to light or components of fire such as charred wood, smoke, or KNO_3 (Keeley 1986, 1987; Thanos & Rundel 1995, Keeley & Fotheringham 1998). Exposure to dry cool smoke for 5 min (Keeley & Fotheringham 1998) yields higher germination than charred wood. A 12 to 15 hour soak in a 1:25 dilution of Regen 2000 Smokemaster, a liquid smoke product, also breaks dormancy (A. Montalvo, pers. obs.). Wilkin et al. (2013) also found exposure to liquid smoke (dilutions of Wright's Hickory Seasoning) increased germination two to threefold relative to controls, and that exposure to heat (70 ºC for five min) increased germination fivefold. Such results may vary by geographic location of seed accession. Heat of fire may reduce germination of seeds from sage scrub (Keeley & Fotheringham 1998), whereas seeds from desert populations, where fires are less frequent, were stimulated to germinate by heat and charred wood, but not by light (Keeley 1986). Emery (1988) used gibberellic acid (GA) at 400 ppm, 1-hour soak to improve germination. In a study of seeds from 12 coastal sage scrub populations, seeds were exposed to three different treatments (A. Montalvo, unpublished data). Seeds treated with 250 ppm GA had 66% germination compared to 42% treated with plain, cool water and 50% percent for seeds treated with boiling water. When one-year-old seeds were incubated at 19/26 ºC on moist filter paper, 36% germinated after 500 ppm overnight GA treatment, 26% germinated after cold smoke treatment, and 20% germinated in pure water (J. Burger, pers. obs., unpublished data). Peak germination occurred 6-9 days after imbibition. Generic germination tests for shrubby sages incubate seeds at 15/25 ºC alternating night and day temperatures (Meyer 2008).
I. Seeds/lb	258,000 average live seeds/bulk lb (S&S Seeds 2017, http://www.ssseeds.com/plant-database/). 576,000 pure seeds/lb (1,270 pure seeds/g, Ransom Seed Laboratory 2017). 413,000 seeds/lb (Meyer 2008).
J. Planting	Treated or untreated seeds can be sown shallowly (to 1/8 in deep) in flats for subsequent transplanting or directly sown into the ground in the fall (Montalvo & McMillan 2004). Hydroseeding works well. Hand sowing after scarifying the soil with a springtooth harrow and then dragging the harrow upside down over the sown seed was successful in a plot in western Riverside Co. (Montalvo, pers. obs.). Container plants or seedling plugs can easily be established when planted after the beginning of the rainy season and given supplemental water to ensure that the roots do not dry out before they grow into the native soil.
K. Seed increase activities or potential  young plant in Orange Co. field, J. Burger	Potential is high. Plants are easy to establish in agricultural fields. In a research plot at the University of California, Riverside, one-gallon sized plants were planted in rows spaced 10 feet apart and received supplemental water the first year. The large spacing allowed a cultivator to weed between rows of plants. Plants reached maturity by the second year and seed filling was high (A. Montalvo, pers. obs.). Plants are long lived and, if occasionally provided supplemental water in the winter, can be expected to flower and produce good seed crops. The Irvine Ranch Conservancy in Orange County established a seed multiplication plot at two different sites, one in fall 2009 and the second in fall 2015 using 2 1/2 inch liners transplanted at three foot spacing (1 plant/28 square feet; J. Burger & M. Garrambone pers. com.). After occasional applications of supplemental water, the majority of plants flowered within the first year in June. The first plot had its highest seed production in the second year, but the other three years of production had lower than average rainfall. Success was measured in terms of the weight of live seeds (discounts debris and dead seeds). The first plot produced an average of 25 pure live seed pounds (PLS) over four years of production while the second plot produced 21 PLS in its first production year. Low yields from the first site may not accurately reflect the potential production for this species (M. Garrambone, pers. com). Plants were very responsive to irrigation and rainfall and seeds were easy to harvest and process.

K. ….continued common garden with plants at U.C. Riverside, A. Montalvo	
X. USES	
A. Revegetation and erosion control	Black sage is used for erosion control along roadsides, after mining, and after construction (McMurray 1990). Newton & Claassen (2003) recommend its use for land rehabilitation in central western and southwestern California. Vourlitis et al. (2017) examined shrub recovery and N storage on burned chaparral slopes after hydroseeding with a mixture of native grasses and suffrutescent shrubs compared to untreated controls. Seeding reduced woody shrub growth (including *S. mellifera*), woody shoot biomass, and total species richness relative to the controls, but the biomass of herbs was higher on the seeded plots. Hydroseeding also resulted in lower soil N, reduced potential soil N mineralization, and higher above ground plant N, potentially increasing the chance of type conversion.
B. Habitat restoration	Black sage is important for restoration of coastal sage scrub, alluvial scrub, and chaparral vegetation within its natural range in California (McMurray 1990, Montalvo & McMillan 2004). Both seeding and container planting can be highly successful. Seeding should be done in the fall to early winter to take advantage of rainfall. Seedlings can emerge over several years, depending on rainfall patterns. Hydroseeding, seed imprinting, hand sowing over a scarified seed bed with raking and tamping, or harrowing to scarify soil followed by hand seeding and dragging harrow all work well. Hydroseeding can be very successful on slopes (A. Montalvo pers. obs.).
C. Horticulture or agriculture  young plant in 2 inch wide D-40 pot, UC Riverside, A. Montalvo	Plant production: Plants can be started easily from seeds or cuttings. If cuttings are used to propagate plants for restoration or production fields, the cuttings must be taken from many wild parents, otherwise genetic variation in the planting stock will be very low. Seedling plugs can be produced rapidly from seed to transplant size. To produce plants with mycorrhizal roots, the soil in seedling flats can be inoculated with fresh whole soil collected from under healthy wild adult plants before sowing seeds, or young seedlings can be inoculated when shifted into larger pots by mixing about a half teaspoon of whole soil into the top two inches of soil before planting seedlings (A. Montalvo pers. obs.). However, this practice is no longer recommended owing to the potential for spread of *Phytophthora* pathogens that infect root systems (Rooney-Latham et al. 2015). Black sage is used in native landscape gardening. Plants grow in well-drained soil in sunny locations and can tolerate hot weather and some summer water in a garden (see the Jepson Horticultural Database at link provided in XIII. Jepson Interchange). Pruning a quarter to third of the stems is best done in the first few years in late fall or early winter, changing to less cutting and more dead-heading after old wood develops (O'Brien et al. 2006). Prostrate cultivars selected from plants along the wind-swept coastal bluffs of central coastal California are used as ground covers (e.g., Clebsch 1997, Perry 2010) and should not be used in restoration. *Salvia. m.* 'Terra Seca' has a spreading form; a hybrid with *S. sonomensis* is called *Salvia* 'Mrs. Beard' (Perry 2010).
D. Wildlife value	Plants provide cover and seeds for wildlife, and in western Riverside Co. the listed California gnatcatcher frequently nests in vegetation containing black sage (Weaver 1998). Gnatcatchers nested most frequently in sites with a high proportion of *Eriogonum fasciculatum* or *Encelia californica*, rather than a high proportion of *S. mellifera.* Althought not likely to be efficient pollinators, butterflies such as this western tiger swallowtail feed on the nectar of black sage flowers. The long tongue of the butterfly allows less body contact with the anthers and stigmas compared to the major bee pollinators (see VI. E. Pollination, A. Montalvo pers. obs.). 
E. Plant material releases by NRCS and cooperators	None.

F. Ethnobotanical	The seeds were eaten and the leaves used for flavoring by native California tribes such as the Cahuilla and Luiseno (Bean & Saubel 1972). In addition, the leaves have a long history of medicinal use by native tribes (Bocek 1984); for example, the Costanoan people made an infusion of the leaves to treat coughs, and a poultice of the leaves was applied to the neck for sore throat (NAE, http://herb.umd.umich.edu/). The Chumash people placed crushed leaves and stems of black sage in hot water and soaked feet and lower legs to relieve pain (Adams & Garcia 2005). The diterpene compounds in the plants also have antimicrobial activity against gram (+) bacteria (Moujir et al. 1996).
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XII. CITATION	Montalvo, A. M., E. C. Riordan, and J. L. Beyers. 2017. Plant Profile for *Salvia mellifera,* Updated 2017. Native Plant Recommendations for Southern California Ecoregions. Riverside-Corona Resource Conservation District and U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Riverside, CA. Online: https://www.rcrcd.org/plant-profiles

XIII. LINKS TO REVIEWED DATABASES & PLANT PROFILES

Fire Effects Information System (FEIS)	https://www.fs.fed.us/database/feis/plants/shrub/salmel/all.html
Calflora	https://www.calflora.org/cgi-bin/species_query.cgi?where-calrecnum=7311
Jepson Interchange	https://ucjeps.berkeley.edu/cgi-bin/get_cpn.pl?43071
Jepson eFlora (JepsonOnline, 2nd ed.)	https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=43071
USDA PLANTS	https://plants.usda.gov/core/profile?symbol=SAME3
Native Plant Network Propagation Protocol Database (NPNPP)	https://npn.rngr.net/propagation
Native Seed Network (NSN)	https://nativeseednetwork.org/
GRIN (provides links to many resources)	https://npgsweb.ars-grin.gov/gringlobal/taxonomydetail.aspx?id=32906
Wildand Shrubs	https://www.fs.usda.gov/treesearch/pubs/27005
Flora of North America (FNA) (online version)	no matches: http://www.efloras.org/flora_page.aspx?flora_id=1
Native American Ethnobotany (NAE)	http://naeb.brit.org/uses/search/?string=Salvia+mellifera
Woody Plant Seed Manual	https://rngr.net/publications/wpsm
XIV. IMAGES	

Bibliography for *Salvia mellifera*

Adams, J. D., Jr., and C. Garcia. 2005. Palliative care among Chumash people. Evidence-based Complementary and Alternative Medicine **2**:143-147.

Anderson, E., and B. R. Anderson. 1954. Introgression of *Salvia apiana* and *Salvia mellifera*. Annals of the Missouri Botanical Garden **41**:329-338.

Aprahamian, A. M., M. E. Lulow, M. R. Major, K. R. Balazs, K. K. Treseder, and M. R. Maltz. 2016. Arbuscular mycorrhizal inoculation in coastal sage scrub restoration. Botany **94**:493-499.

Arey, J., D. E. Crowley, M. Crowley, M. Resketo, and J. Lester. 1995. Hydrocarbon emissions from natural vegetation in California's South Coast Air Basin. Atmospheric Environment **29**:2977-2988.

Ashbacher, A. C., and E. E. C. a. Cleland. 2015. Native and exotic plant species show differential growth but similar functional trait responses to experimental rainfall. Ecosphere **6**:1-14.

Averett, D. E. 2012. *Salvia apiana*. Pages 852-855, 857 *in* B. G. Baldwin et al., editors. The Jepson Manual: Vascular Plants of California, 2nd Edition. University of California Press, Berkeley, CA.

Averett, D. E. 2017. *Salvia apiana* in Jepson Flora Project (eds.) Jepson eFlora: https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=43038. [Accessed 26 October 2017].

Baskin, C. C., and J. M. Baskin. 1998. Seeds: Ecology, Biogeography and Evolution of Dormancy and Germination. Academic Press, San Diego, CA.

Bean, J. L., and K. S. Saubel. 1972. Temalpakh: Cahuilla Indian Knowledge and Usage of Plants. Malki Museum Press, Morongo Indian Reservation.

Bocek, B. 1984. Ethnobotany of Costanoan Indians, California, based on collections by John P. Harrington. Economic Botany **38**:240-255.

Brattstrom, B. H. 2000. The range, habitat requirements, and abundance of the orange-throated whiptail, *Cnemidophorus hyperythrus beldingi*. Bulletin of the Southern California Academy of Sciences **99**:1-24.

Calflora. 2016. Information on California plants for education, research and conservation [web application]. The Calflora Database [a non-profit organization], Berkeley, California. Available: https://www.calflora.org/. [Accessed 6 Apr 2016]

Carlquist, S., and Q. Pauly. 1985. Experimental studies on epizoochorous dispersal in Californian plants. Aliso **11**:167-177.

CCH. 2016. Consortium of California Herbaria. Regents of the University of California, Berkeley, California. Available: https://ucjeps.berkeley.edu/consortium/. [Accessed 20 July 2016].

Cione, N. K., P. E. Padgett, and E. B. Allen. 2002. Restoration of a native shrubland impacted by exotic grasses, frequent fire, and nitrogen deposition in southern California. Restoration Ecology **10**:376-384.

Clebsch, B. 1997. A Book of Salvias: Sages for Every Garden. Timber Press Inc., Portland, Oregon.

Cleland, D. T., J. A. Freeouf, J. E. Keys, G. J. Nowacki, C. A. Carpenter, and W. H. McNab. 2007. Ecological Subregions: Sections and Subsections for the Conterminous United States. General Technical Report WO-76D [Map on CD-ROM] (A.M. Sloan, cartographer). U.S. Department of Agriculture, Forest Service, Washington, DC.

Cohen, W. B. 1991. Temporal versus spatial variation in leaf reflectance under changing water stress conditions. International Journal of Remote Sensing **12**:1865-1876.

Cohen, W. B., and P. N. Omi. 1991. Water-stress effects on heating-related water transport in woody plants. Canadian Journal of Forest Research **21**:199-206.

Davis, C. M. 1994. Succession in California Shrub Communities Following Mechanical Anthropogenic Disturbance. Thesis. San Diego State University, San Diego, CA.

Davis, F. W., P. A. Stine, and D. M. Stoms. 1994. Distribution and conservation status of coastal sage scrub in southwest California. Journal of Vegetation Science **5**:743-756.

Davis, Z. W. J. 1980. The Effects of Applied Nutrients on *Salvia mellifera* (Black Sage) Stands of Different Ages. Masters thesis. University of California, Los Angeles.

De Hart, J. 1994. Propagation Secrets for California Native Plants. Jeanine De Hart, Encinitas, California.

Dement, W. A., B. J. Tyson, and H. A. Mooney. 1975. Mechanism of monoterpene volatilization in *Salvia mellifera*. Phytochemistry **14**:2555-2557.

Egerton-Warburton, L. M., and E. B. Allen. 2000. Shifts in arbuscular mycorrhizal communities along an anthropogenic nitrogen deposition gradient. Ecological Applications **10**:484-496.

Egerton-Warburton, L. M., J. I. Querejeta, and M. F. Allen. 2007. Common mycorrhizal networks provide a potential pathway for the transfer of hydraulically lifted water between plants. Journal of Experimental Botany **58**:1473-1483.

Emery, D. E. 1988. Seed Propagation of Native California Plants. Santa Barbara Botanical Garden, Santa Barbara, CA.

Epling, C. 1938. The California salvias. Annals of the Missouri Botanical Garden **25**:95-188.

Epling, C. 1947a. The genetic aspects of natural populations: Actual and potential gene flow in natural populations. The American Naturalist **81**:104-113.

Epling, C. 1947b. Natural hybridization of *Salvia apiana* and *S. mellifera*. Evolution **1**:69-78.

Epling, C., H. Lewis, and P. H. Raven. 1962. Chromosomes of *Salvia*: Section Audibertia. Aliso **5**:217-221.

Frankie, G. W., R. W. Thorp, R. E. Coville, and B. Ertter. 2014. California Bees and Blooms: A Guide for Gardeners and Naturalists. Heyday and California Native Plant Society, Berkeley, CA.

Frankie, G., R. Thorp, J. Hernandez, M. Rizzardi, B. Ertter, J. Pawelek, S. Witt, M. Schindler, R. Coville, and V. Wojcik. 2009. Native bees are a rich natural resource in urban California gardens. California Agriculture **63**:113.

FNA 2016. Editorial Committee. 1993+. Flora of North America north of Mexico. 10+ volumes. New York and Oxford. Available: http://beta.floranorthamerica.org/Main_Page. [Accessed 4 September 2016].

Friedman, J. 1983. Allelopathy and autotoxicity in arid regions. Pages 97-106 *in* C. H. Chou and G. R. Waller, editors. Proceedings of the Seminar on Allelochemicals and Pheromones, June 21-26. Monographs series no. 5. Institute of Botany, Academia Sinica, Taipei, Taiwan.

Funk, J. L., and V. A. Zachary. 2010. Physiological responses to short-term water and light stress in native and invasive plant species in southern California. Biological Invasions **12**:1685-1694.

Gigon, A. 1979. CO_2 gas exchange, water relations and convergence of Mediterranean shrub-types from California and Chile. Oecologia Plantarum **14**:129-150.

Gill, D. S., and B. J. Hanlon. 1998. Water potentials of *Salvia apiana*, *S. mellifera* (Lamiaceae), and their hybrids in the coastal sage scrub of southern California. Madroño **45**:141-145.

Gill, D. S., and B. E. Mahall. 1986. Quantitative phenology and water relations of an evergreen and deciduous chaparral shrub. Ecological Monographs **56**:127-143.

Goldstein, L. J., and K. N. Suding. 2014. Applying competition theory to invasion: Resource impacts indicate invasion mechanisms in California shrublands. Biological Invasions **16**:191-203.

González, A. G., L. S. Andrés, Z. E. Aguiar, and J. G. Luis. 1992. Diterpenes from *Salvia mellifera* and their biogenetic significance. Phytochemistry **31**:1297-1305.

González, A. G., L. S. Andrés, J. G. Luis, I. Brito, and M. L. Rodríguez. 1991. Diterpenes from *Salvia mellifera*. Phytochemistry **30**:4067-4070.

González, A. G., L. S. Andrés, A. G. Ravelo, J. G. Luis, I. L. Bazzocchi, and J. West. 1990. Terpenoids from *Salvia mellifera*. Phytochemistry **29**:1691-1693.

Gonzalez Marrero, J., L. San Andres, and J. Gutierrez Luis. 2005. Quinone derivatives by chemical transformations of 16-hydroxycarnosol from *Salvia* species. Chemical & Pharmaceutical Bulletin (Tokyo) **53**:1524-1529.

Gordon, H., and T. C. White. 1994. Ecological Guide to Southern California Chaparral Plant Series: Transverse and Peninsular Ranges: Angeles, Cleveland, and San Bernardino National Forests. R5-ECOL-TP-005. USDA Forest Service, Pacific Southwest Region, San Diego, CA.

Goudey, C. B., and D. W. Smith, editors. 1994. Ecological Units of California: Subsections (map). Scale 1:1,000,000; colored. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, San Francisco, CA.

Grant, K. A., and V. Grant. 1964. Mechanical isolation of *Salvia apiana* and *Salvia mellifera* (Labiatae). Evolution **18**:196-212.

Haidinger, T. L., and J. E. Keeley. 1993. Role of high fire frequency in destruction of mixed chaparral. Madroño **40**:141-147.

Hargrave, K. R., K. J. Kolb, F. W. Ewers, and S. D. Davis. 1994. Conduit diameter and drought-induced embolism in *Salvia mellifera* Greene (Labiatae). New Phytologist **126**:695-705.

Hellmers, H., J. S. Horton, G. Juhren, and J. O'Keefe. 1955. Root systems of some chaparral plants in southern California. Ecology **36**:667-678.

Hickman, J. C., editor. 1993. The Jepson Manual: Higher Plants of California. University of California Press, Berkeley, CA.

Horton, J. S., and C. J. Kraebel. 1955. Development of vegetation after fire in the chamise chaparral of southern California. Ecology **36**:244-262.

Hung, K.-L. J., J. S. Ascher, J. Gibbs, R. E. Irwin, and D. T. Bolger. 2015. Effects of fragmentation on a distinctive coastal sage scrub bee fauna revealed through incidental captures by pitfall traps. Journal of Insect Conservation **19**:175-179.

Jepson eFlora. 2017. Jepson Flora Project (eds.), Jepson eFlora, https://ucjeps.berkeley.edu/eflora/. [Accessed 26 October 2017]

Keator, G. 1994. Complete Garden Guide to the Native Shrubs of California. Chronicle Books, San Francisco, CA.

Keeley, J. E. 1986. Seed germination patterns of *Salvia mellifera* in fire-prone environments. Oecologia **71**:1-5.

Keeley, J. E. 1987. Role of fire in seed germination of woody taxa in California chaparral. Ecology **68:**434-443.

Keeley, J. E. 1995. Seed-germination patterns in fire-prone Mediterranean-climate regions. Pages 239-273 *in* M. T. Kalin Arroyo, P. H. Zedler, and M. D. Fox, editors. Ecology and Biogeography of Mediterranean Ecosystems in Chile, California, and Australia. Springer-Verlag Inc., New York.

Keeley, J. E. 1998. Postfire ecosystem recovery and management: The October 1993 large fire episode in California. Pages 69-90 *in* J. M. Moreno, editor. Large Forest Fires. Backhuys Publishers, Leiden, The Netherlands.

Keeley, J. E. 2006. Fire severity and plant age in postfire resprouting of woody plants in sage scrub and chaparral. Madroño **53**:373-379.

Keeley, J. E., and C. J. Fotheringham. 1998. Mechanism of smoke-induced seed germination in a post-fire chaparral annual. Journal of Ecology **86**:27-36.

Keeley, J. E., C. J. Fotheringham, and M. Baer-Keeley. 2006. Demographic patterns of postfire regeneration in Mediterranean-climate shrublands of California. Ecological Monographs **76**:235-255.

Keeley, J. E., and A. D. Syphard. 2016. Climate change and future fire regimes: Examples from California. Geosciences **6**:37.

Kirkpatrick, J. B., and C. F. Hutchinson. 1980. The environmental relationships of California coastal sage scrub and some of its component communities and species. Journal of Biogeography **7**:23-28.

Kolb, K. J., and S. D. Davis. 1994. Drought tolerance and xylem embolism in co-occurring species of coastal sage and chaparral. Ecology **75**:648-659.

Kremen, C., N. M. Williams, and R. W. Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences of the United States of America **99**:16812-16816.

Lambrecht, S. C., L. S. Santiago, C. M. DeVan, J. C. Cervera, C. M. Stripe, L. A. Buckingham, and S. C. Pasquini. 2011. Plant water status and hydraulic conductance during flowering in the southern California coastal sage shrub *Salvia mellifera* (Lamiaceae). American Journal of Botany **98**:1286-1292.

Lewis, H. 1966. Speciation in flowering plants. Science **152**:167-172.

Lincoln, D. E. 1981. Mechanism of monoterpene volatilization from *Salvia mellifera*. Pages 97-106 *in* J. J. Bufalini and R. R. Arnts, editors. Atmospheric Biogenic Hydrocarbons. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

Malanson, G. P. 1985. Simulation of competition between alternative shrub life history strategies through recurrent fires. Ecological Modelling **27**:271-283.

Malanson, G. P., and J. F. O'Leary. 1995. The coastal sage scrub-chaparral boundary and response to global climatic change. Pages 203-224 *in* J. M. Moreno and W. C. Oechel, editors. Global Change and Mediterranean-type Ecosystems. Springer-Verlag Inc., New York.

McMurray, N. E. 1990. *Salvia mellifera*. *in* Fire Effects and Information System, [Online] U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us/database/feis/plants/shrub/salmel/all.html.

Meyer, S. E. 2008. *Salvia* L. sage. Pages 1010-1013 *in* F. T. Bonner and R. P. Karrfalt, editors. The Woody Plant Seed Manual. Agricultural Handbook 727. U.S. Department of Agriculture, Forest Service, Washington, DC.

Meyn, O., and W. A. Emboden. 1987. Parameters and consequences of introgression in *Salvia apiana* X *S. mellifera* (Lamiaceae). Systematic Botany **12**:390-399.

Minnich, R. A., and R. J. Dezzani. 1998. Historical decline of coastal sage scrub in the Riverside-Perris plain, California. Western Birds **29**:366-391.

Moldenke, A. R., and J. L. Neff. 1974. Studies on pollination ecology and species diversity of natural California plant communities, III. Technical Report 74-14, International Biological Programme, Origin and Structure of Ecosystems, 233 pp.

Montalvo, A. M., and P. McMillan. 2004. *Salvia mellifera* Greene. Pages 676-680 *in* J. K. Francis, editor. Wildland Shrubs of the United States and its Territories: Thamnic Descriptions. Volume 1. General Technical Report IITF-GTR-26, U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry and Rocky Mountain Research Station, Fort Collins, CO.

Montgomery, K. R., and P. Cheo. 1971. Notes: Effect of leaf thickness on ignitibility. Forest Science **17**:475-478.

Mooney, H. A. 1989. Chaparral physiological ecology paradigms revisited. Pages 85-90 *in* S. C. Keeley, editor. The California Chaparral: Paradigms Reexamined. Natural History Museum of Los Angeles County, Science Series No. 34, Los Angeles, CA.

Moujir, L., A. M. Gutiérrez-Navarro, L. S. San Andres, and J. G. Luis. 1993. Structure-antimicrobial activity relationships of abietane diterpenes from *Salvia* species. Phytochemistry **34**:1493-1495.

Moujir, L., A. M. Gutiérrez-Navarro, L. San Andres, and J. G. Luis. 1996. Bioactive diterpenoids isolated from *Salvia mellifera*. Phytotherapy Research **10**:172-174.

Muller, C. H., R. B. Hanawalt, and J. K. McPherson. 1968. Allelopathic control of herb growth in the fire cycle of California chaparral. Bulletin of the Torrey Botanical Club **95**:225-231.

Munz, P. A. 1974. A Flora of Southern California. University of California Press, Berkeley, CA.

Munz, P. A., and D. D. Keck. 1968. A California Flora with Supplement. University of California Press, Berkeley, CA.

Murray, T. E., M. Kuhlmann, and S. G. Potts. 2009. Conservation ecology of bees: Populations, species and communities. Apidologie **40**:211-236.

NAE. 2016. Native American Ethnobotany Database. Online: http://naeb.brit.org/.

Neisess, K. R., R. W. Scora, and J. Kumamoto. 1987. Volatile leaf oils of California *Salvias*. Journal of Natural Products **50**:515-517.

Newton, G. A., and V. Claassen. 2003. Rehabilitation of Disturbed Lands in California: A Manual for Decision-Making. California Department of Conservation, California Geological Survey, Sacramento, CA.

O'Brien, B., B. Landis, and E. Mackey. 2006. Care & Maintenance of Southern California Native Plant Gardens. Rancho Santa Ana Botanic Garden, Claremont, CA.

Padgett, P. E., and E. B. Allen. 1999. Differential responses to nitrogen fertilization in native shrubs and exotic annuals common to Mediterranean coastal sage scrub of California. Plant Ecology **144**:93-101.

Padgett, P. E., S. N. Kee, and E. B. Allen. 2000. The effects of irrigation of revegetation of semi-arid coastal sage scrub in southern California. Environmental Management **26**:427-435.

Painter, E. 2016. Common (vernacular) names applied to California vascular plants. University of California Jepson Herbarium, Online database: https://ucjeps.berkeley.edu/cgi-bin/get_painter_common.pl?43071.

Perry, R., Jr. 2010. Landscape Plants for California Gardens: An Illustrated Reference of Plants for California Landscapes, 1st edition. Land Design Publishing, Claremont, CA.

Preston, K. P. 1988. Effects of sulphur dioxide pollution on a Californian coastal sage scrub community. Environmental Pollution **51**:179-195.

Principe, Z., J.B. MacKenzie, B. Cohen, J.M. Randall, W. Tippets, T. Smith, and S. A. Morrison. 2013. 50-Year Climate Scenarios and Plant Species Distribution Forecasts for Setting Conservation Priorities in Southwestern California v.1. The Nature Conservancy of California, San Francisco, CA. 36 pages + Appendices. Available at: https://www.scienceforconservation.org/products/50-year-climate-and-plant-distributions. [Accessed 29 December 2017]

Ransom Seed Laboratory. 2017. Knowledgebase of native seeds: https://www.ransomseedlab.com/seed-databse. Last accessed: June 29, 2017.

Riordan, E.C, A.M. Montalvo, and J. L. Beyers. 2018. Using Species Distribution Models with Climate Change Scenarios to Aid Ecological Restoration Decisionmaking for Southern California Shrublands. Research Paper PSW-RP-270. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. 130 p. Available: https://www.fs.fed.us/psw/publications/documents/psw_rp270/. [Accessed 6 September 2018]

Riordan, E. C., and P. W. Rundel. 2009. Modelling the distribution of a threatened habitat: The California sage scrub. Journal of Biogeography **36**:2176-2188.

Riordan, E. C., and P. W. Rundel. 2014. Land use compounds habitat losses under projected climate change in a threatened California ecosystem. PLoS One **9**:1-15.

Roberts, F. M., Jr. 2008. The Vascular Plants of Orange County, California: An Annotated Checklist. F. M. Roberts Publications, San Luis Rey, CA.

Rooney-Latham, S., C. L. Blomquist, T. Swiecki, E. Bernhardt, and S. J. Frankel. 2015. First detection in the US: New plant pathogen, *Phytophthora tentaculata*, in native plant nurseries and restoration sites in California. Native Plants Journal **16**:23-27.

S&S Seeds. 2017. S & S Seeds Inc. Plant database: http://www.ssseeds.com/plant-database/. [Accessed June 29, 2017]

Sawyer, J. O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation, 2nd edition. California Native Plant Society Press, Sacramento, CA.

Schlesinger, W. H. 1985. Decomposition of chaparral shrub foliage. Ecology **66**:1353-1359.

Schochet, A. B., K.-L. J. Hung, and D. A. Holway. 2017. Bumble bee species exhibit divergent responses to urbanisation in a southern California landscape. Ecological Entomology **41**:685-692.

Schultz, G. P. 1996. Seedling Establishment and Competition in Coastal Sage Scrub and Annual Grassland. Thesis. University of California, Riverside.

Storms, N. 1999. Restoration of a Native Shrubland in an Area of Frequent Disturbance and High Nitrogen Deposition. Thesis. University of California, Riverside.

Swank, S. E., and W. C. Oechel. 1991. Interactions among the effects of herbivory, competition, and resource limitation on chaparral herbs. Ecology **72**:104-115.

Syphard, A. D., V. C. Radeloff, T. J. Hawbaker, and S. I. Stewart. 2009. Conservation threats due to human-caused increases in fire frequency in Mediterranean-climate ecosystems. Conservation Biology **23**:758-769.

Talluto, M. V., and K. N. Suding. 2008. Historical change in coastal sage scrub in southern California, USA in relation to fire frequency and air pollution. Landscape Ecology **23**:803-815.

Thanos, C. A., and P. W. Rundel. 1995. Fire-followers in chaparral: Nitrogenous compounds trigger seed germination. Journal of Ecology **83**:207-216.

Townsend, P. A., and D. J. Levey. 2005. An experimental test of whether habitat corridors affect pollen transfer. Ecology **86**:466-475.

Tyson, B. J. 1974. Volatilisation of terpenes from *Salvia mellifera*. Nature **252**:119-120.

USDA PLANTS. 2016. The PLANTS Database (https://plants.usda.gov/java/). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Vourlitis, G. L., J. Griganavicius, N. Gordon, K. Bloomer, T. Grant, and C. Hentz. 2017. Hydroseeding increases ecosystem nitrogen retention but inhibits natural vegetation regeneration after two years of chaparral post-fire recovery. Ecological Engineering **102**:46-54.

Vourlitis, G. L., S. C. Pasquini, and R. Mustard. 2009. Effects of dry-season N input on the productivity and N storage of mediterranean-type shrublands. Ecosystems **12**:473-488.

Walker, J. B., B. T. Drew, and K. J. Sytsma. 2015. Unravelling species relationships and diversification within the iconic California Floristic Province sages (*Salvia* subgenus *Audibertia*, Lamiaceae). Systematic Botany **40**:826-844.

Wall, M., and J. Macdonald. 2009. Processing Seeds of California Native Plants for Conservation, Storage, and Restoration. Rancho Santa Ana Botanic Garden Seed Program, Claremont, CA; available online: http://www.hazmac.biz/seedhome.html.

Walters, D. R., M. McLeod, A. G. Meyer, D. Rible, R. O. Baker, and L. Farwell. 1977. NATIVE Plants: A Viable Option. California Native Plant Society, Sacramento, CA.

Watkins, J. F., III, and S. D. Davis. 1996. Comparative water relations of chaparral and coastal sage seedlings after wildfire. Abstract. Bulletin of the Ecological Society of America **77** (supplement):470.

Weaver, K. L. 1998. Coastal sage scrub variations of San Diego County and their influence on the distribution of the California gnatcatcher. Western Birds **29**:392-405.

Webb, A.-A., and S. Carlquist. 1964. Leaf anatomy as an indicator of *Salvia apiana-mellifera* introgression. Aliso **5**:437-449.

Went, F. W., G. Juhren, and M. C. Juhren. 1952. Fire and biotic factors affecting germination. Ecology **33**:351-364.

Westman, W. E. 1981. Seasonal dimorphism of foliage in Californian coastal sage scrub. Oecologia **51**:385-388.

Westman, W. E. 1983. Xeric Mediterranean-type shrubland associations of Alta and Baja California and the community/continuum debate. Vegetatio **52**:3-19.

Westman, W. E., and J. F. O'Leary. 1986. Measures of resilience: The response of coastal sage scrub to fire. Vegetatio **65**:179-189.

White, S. D., and W. D. Padley. 1997. Coastal sage scrub series of western Riverside County, California. Madroño **44**:95-105.

Wilkin, K. M., V. L. Holland, D. Keil, and A. Schaffner. 2016. Mimicking fire for successful chaparral restoration. Madroño **60**:165-172.

Winner, W. E. 1981. The effect of SO_2 on photosynthesis and stomatal behavior of Mediterranean-climate shrubs and trees. Pages 91-103 *in* N. S. Margaris and H. A. Mooney, editors. Components of Productivity of Mediterranean-climate Regions: Basic and Applied Aspects. Dr W. Junk Publishers, The Hague.

Young, J. A., and C. G. Young. 1986. Collecting, Processing, and Germinating Seeds of Wildland Plants. Timber Press, Portland, OR.

Zedler, P. H., C. R. Gautier, and G. S. McMaster. 1983. Vegetation change in response to extreme events: The effects of a short interval between fires in California chaparral and coastal scrub. Ecology **64**:809-818.

Zurbuchen, A., L. Landert, J. Klaiber, A. Müller, S. Hein, and S. Dorn. 2010. Maximum foraging ranges in solitary bees: Only few individuals have the capability to cover long foraging distances. Biological Conservation **143**:669-676.