




<b>I. SPECIES</b> <b>NRCS CODE:</b> <b>ADFA</b>	<b><i>Adenostoma fasciculatum</i> Hooker &amp; Arnott</b>	
<p><i>A. f. var. obtusifolium</i>, Ron Vanderhoff (Creative Commons CC)</p> 	<p>Family: <b>Rosaceae</b>  Order: <b>Rosales</b>  Subclass: <b>Rosidae</b>  Class: <b>Magnoliopsida</b></p> 	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;"> <i>A. f. var. fasciculatum</i>, Riverside Co., A. Montalvo, RCRCD </div> 
<b>A. Subspecific taxa</b> <b>1. ADFAF</b> <b>2. ADFAO</b> <b>3. (no NRCS code)</b>	<ol style="list-style-type: none"> <li><i>Adenostoma fasciculatum</i> var. <i>fasciculatum</i> Hook. &amp; Arn.</li> <li><i>A. f.</i> var. <i>obusifolium</i> S. Watson</li> <li><i>A. f.</i> var. <i>prostratum</i> Dunkle</li> </ol>	
<b>B. Synonyms</b>	<ol style="list-style-type: none"> <li><i>A. f.</i> var. <i>densifolium</i> Eastw.</li> <li><i>A. brevifolium</i> Nutt.</li> <li>none. Formerly included as part of <i>A. f.</i> var. <i>f.</i></li> </ol>	
<b>C. Common name</b>	<ol style="list-style-type: none"> <li>chamise, common chamise, California greasewood, greasewood, chamise (Painter 2016)</li> <li>San Diego chamise (Calflora 2016)</li> <li>prostrate chamise (Calflora 2016)</li> </ol>	
<b>D. Taxonomic relationships</b>	Phylogenetic studies using molecular sequence data placed <i>Adenostoma</i> closest to <i>Chamaebatiaria</i> and <i>Sorbaria</i> (Morgan et al. 1994, Potter et al. 2007) and suggest tentative placement in subfamily Spiraeoideae, tribe Sorbarieae (Potter et al. 2007).	
<b>E. Related taxa in region</b>	<i>Adenostoma sparsifolium</i> Torrey, known as ribbon-wood or red-shanks is the only other species of <i>Adenostoma</i> in California. It is a much taller, erect to spreading shrub of chaparral vegetation, often 2–6 m tall and has a more restricted distribution than <i>A. fasciculatum</i> . It occurs from San Luis Obispo Co. south into Baja California. Red-shanks produces longer, linear leaves on slender long shoots rather than having leaves clustered on short shoots (lacks "fascicled" leaves). Its bark is cinnamon-colored and in papery layers that sheds in long ribbons.	
<b>F. Taxonomic issues</b>	The Jepson eFlora and the FNA recognize <i>A. f.</i> var. <i>prostratum</i> but the taxon is not recognized by USDA PLANTS (2016). Variety <i>prostratum</i> was first described in 1941 but was not widely recognized as a distinct taxon in floras until the release of the second edition of the Jepson Manual in 2012. <i>A. f.</i> var. <i>obusifolium</i> has been widely recognized. The type was collected by Nuttall in San Diego Co. and described as <i>A. brevifolia</i> ; it was reassigned as a variety of <i>A. f.</i> by Watson in 1876 (McMinn 1939, Munz & Keck 1968). In San Diego Co. and southern Orange Co., the taxon is said to hybridize with var. <i>fasciculatum</i> and form plants with intermediate traits (McMinn 1939, FNA 2016). Lardner (1985) was unable to distinguish varieties of <i>A. fasciculatum</i> in an analysis of allozyme variation.	
<b>G. Other</b>	One of the most common shrubs of lower elevation chaparral vegetation in California. It is also common in transition areas between coastal sage scrub and chaparral. Mature plants produce specialized lignotubers which are partially buried, expanded woody burls at the base of the stem that produce dormant buds capable of sprouting new shoots after stems are cut or burned. The lignotubers store nutrients and carbohydrates (James 1984). The common name "greasewood" refers to the plant's high flammability (Bornstein et al. 2005); many authors refer to the flammability of the "resinous" foliage, sap, or cuticle.	

## II. ECOLOGICAL & EVOLUTIONARY CONSIDERATIONS FOR RESTORATION

### A. Attribute summary list (based on referenced responses in full table)

Taxonomic stability - high  
 Longevity - long-lived  
 Parity - polycarpic  
 Flowering age - ~ 4 yr  
 Stress tolerance - high  
 Environmental tolerance - broad  
 Reproduction after fire - facultative seeder  
 Fragmentation history - recent  
 Habitat fragmentation - low to high; highest at lowest elevations  
 Distribution - wide in Mediterranean climate region

Seeds -small, dormant, long-lived  
 Seed dispersal distance - short to medium  
 Pollen dispersal - intermediate  
 Breeding system - outcrossed- intermediate to high  
 Population structure - low  
 Adaptive trait variation - unknown  
 Chromosome number - stable  
 Genetic marker polymorphism - high  
 Average total heterozygosity - high  
 Hybridization (interspecific) potential - low

SDM projected midcentury suitable habitat - 53–100 % stable  
 SDM projected midcentury habitat gain - gain > loss under 4 of 5 climate scenarios (assuming unlimited dispersal)

### B. Implications for seed transfer (summary)

The wide tolerance, high diversity, low population structure, outcrossed mating system, and high gene flow suggest risks of translocation to similar environments or from combining seeds from nearby populations within ecological sections would be low. Furthermore, if the often-low seed set is found to be a result of high genetic load, mixing of nearby populations could be beneficial. The plethora of traits exhibited by chamise, when coupled with its commonness and results of species distribution modeling with climate forecasting, suggest that there is no need to actively assist movement of plants to accommodate climate change except in areas of very high fragmentation. Documented differences in physiological tolerances in different geographic areas suggest that longer ecological distances in seed transfer could carry risks, although genetic differences in such tolerances have not been studied. Similarly, the risks of maladaptation or mating incompatibility upon mixing infraspecific taxa of chamise have not been quantified.

## III. GENERAL

### A. Geographic range

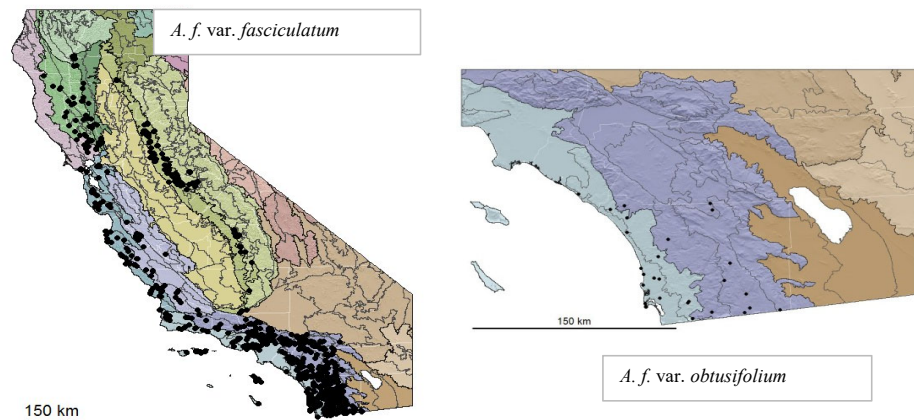
1. Widespread across cismontane California from Mendocino, Trinity, and Shasta counties, south into Baja California to El Rosario about 150 miles south of the border (Hanes 1965; CCH 2016).
2. Restricted to southern California from southern Orange Co., San Diego Co., northern Baja California (McMinn 1939, FNA 2016, CCH 2016).
3. Channel Islands (San Nicolas, Santa Catalina, Santa Cruz, Santa Rosa Islands) and adjacent mainland in San Luis Obispo Co. (FNA 2016).

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

Section Code

261A	M261G
261B	M262A
262A	M262B
263A	322A
M261A	322B
M261B	322C
M261C	341D
M261D	341F
M261E	342B
M261F	Salton Sea

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




### Distribution in California; Ecological section and subsection (Goudey & Smith 1994; Cleland et al. 2007)

Ecological Section/subsection:

1. *A. f. var. fasciculatum*:  
 Northern California Coast 263A: g,l,m  
 Klamath Mountains M261A: r,u (bordering M261C)  
 Northern California Coast Ranges M261B: a,b,d,f  
 Northern California Interior Coast Ranges M261C: a,c  
 Sierra Nevada M261E: g,m,p,r  
 Sierra Nevada Foothills M261F: a-e  
 Great Valley 262A: o (bordering M261F)  
 Central California Coast 261A: a,c,e-h,j,k,l  
 Central California Coast Ranges M262A: b,c,e,f,h,j  
 Southern California Coast 261B: a-c,e-j  
 Southern California Mountains and Valleys M262B: a-p  
 Mojave Desert 322A: g (bordering M262B)

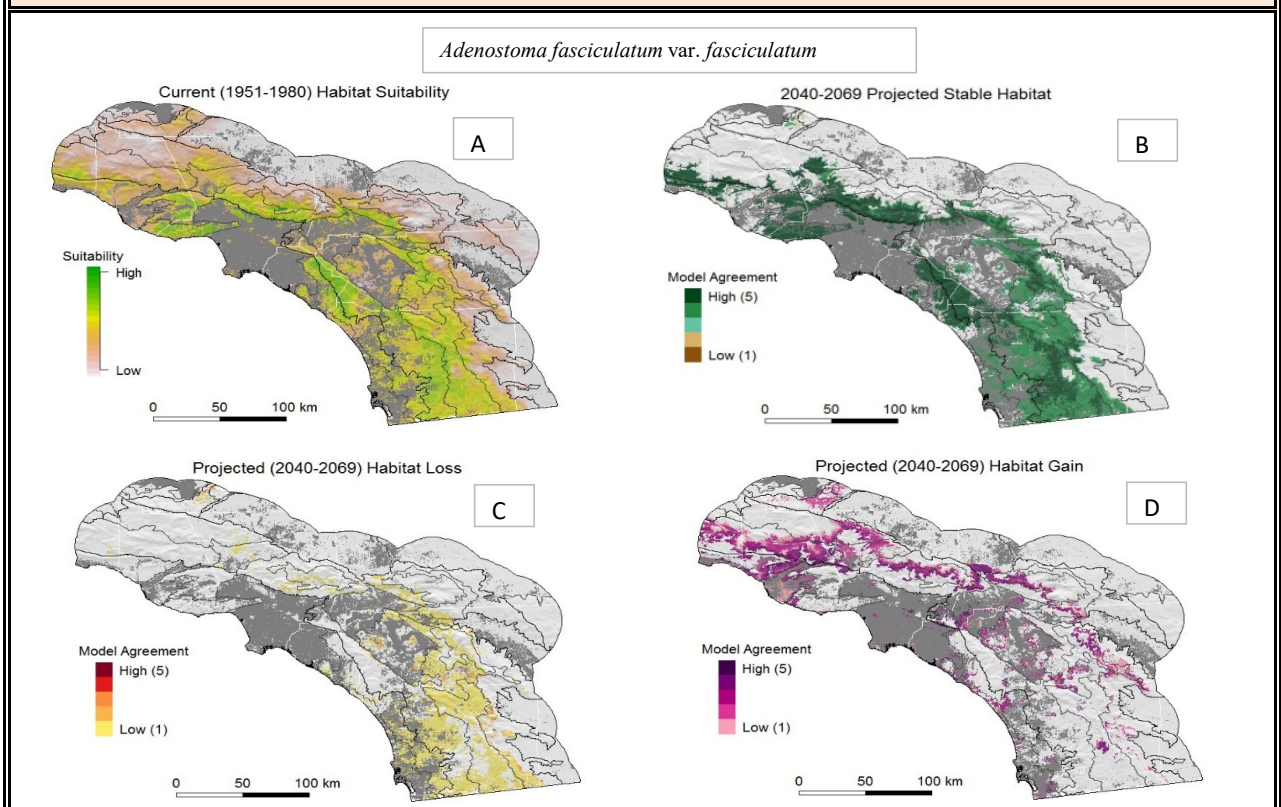
2. *A. f. var. obtusifolium*:  
 Southern California Mountains and Valleys  
 M262B: f,l,n,o,p  
 Southern California Coast 261B: i,j

3. *A. f. var. prostratum*:  
 Southern California Coast 261B: a,c  
 (map not shown)

<b>C. Life history, life form</b>	Evergreen, woody shrub, long-lived, iteroparous, facultative resprouter.
<b>D. Distinguishing traits</b>  <p data-bbox="217 541 440 632">New leaves on resprouts are divided and more prone to drought damage. photo: A. Montalvo</p>	<p>Shrubs with often long, arching, grayish to brown stems with alternate spirally arranged leaves and branches. The nodes along the main stem are clearly separated but they produce short shoots that support crowded, linear, dark green leaves that appear to be in "fascicles". The often 5–10 mm linear leaves are thick (nearly round in cross section) and end in a sharp tip (apiculate). The small, perfect flowers have short pedicels, five white petals (corolla lobes), a green hypanthium with 5 calyx lobes alternate the corolla lobes, 10–15 stamens, and they occur in cylindrical to pyramid-shaped panicles at the tips of branches. The petals are retained and become rusty-colored during fruit maturation. The fruit is a small, oboboid achene (single seeded indehiscent fruit) which develops within the hypanthium and disperses with the hypanthium as a single unit (Wiens et al. 2012).</p> <p><i>A. f.</i> var. <i>fasciculatum</i> is as above, erect–ascending to about 2 m tall, linear to oblanceolate leaves, usually has glabrous stems and is broadly distributed. The var. <i>obtusifolium</i> is also erect–ascending, but has pubescent to villous young stems and shorter (4–6.5 mm) oblanceolate leaves with usually an obtuse apex. The island, coastal var. <i>prostratum</i> has a low, decumbent, mounded structure, 2–6.3 mm long leaves.</p> <p>Juvenile leaves of seedlings and stump sprouts are often divided into two to three lobes at the apex (McMinn 1939).</p>
<b>E. Root system, rhizomes, stolons, etc.</b>	Plants produce a well developed basal burl (lignotuber) that is partially buried (Borchert et al. 2004).
<b>F. Rooting depth</b>	Excavation studies showed that plants produce deeply penetrating roots of small diameter (Hellmers et al. 1955), but most roots are within 20 cm of the soil surface (Kummerow et al. 1977). Root depth was 8 ft and the maximum length of roots was 16 ft. with a radial spread of 12 ft and along road cuts fine roots extended into tiny rock cracks up to 25 ft deep (Hellmers et al. 1955). In some plants, a deeply penetrating root with horizontal branches grows from the lignotuber, but usually multiple lateral roots develop.
<b>IV. HABITAT</b>	
<b>A. Vegetation alliances, associations</b>	<p>Chamise sometimes occurs in nearly single-species stands but also co-occurs with many species of trees, shrubs and vines throughout its range within many different chaparral and coastal sage scrub vegetation alliances. See McMurray (1990) for detailed lists of associated species. Chamise is listed as a dominant component within the following shrubland alliances and associations in Sawyer et al. (2009, MCV2):</p> <p><i>Adenostoma fasciculatum</i> shrubland alliance (membership rule: &gt; 50% relative cover <i>A. fasciculatum</i>).</p> <p>Many associations. Some include more restricted indicator species, or edaphic conditions. Five common associations are listed that include the co-dominant shrubs <i>Diplacus aurantiacus</i>, <i>Eriodictyon californicum</i>, <i>Eriogonum fasciculatum</i>, <i>Heteromeles arbutifolia</i>, or <i>Hesperoyucca whipplei</i>.</p> <p><i>Adenostoma fasciculatum</i> - <i>Salvia apiana</i> alliance (the two associations listed include the codominant shrubs <i>Artemisia californica</i> or <i>Eriogonum fasciculatum</i>)</p> <p><i>Adenostoma fasciculatum</i> - <i>Salvia mellifera</i> alliance (the 6 associations listed include the co-dominant shrubs <i>Artemisia californica</i>, <i>Ceanothus crassifolius</i>, <i>Malosma laurina</i>, and <i>Rhus ovata</i>)</p> <p><i>Adenostoma fasciculatum</i> - <i>Xylococcus bicolor</i> alliance (the 9 associations listed include various combinations of codominant species, including <i>Ceanothus tomentosus</i>, <i>Ceanothus crassifolius</i>, <i>Cneoridium dumosum</i>, <i>Eriogonum fasciculatum</i>, <i>Malosma laurina</i>, <i>Quercus berberidifolia</i>, <i>Salvia mellifera</i>, <i>Rhus integrifolia</i>)</p> <p><i>Quercus berberidifolia</i> - <i>Adenostoma fasciculatum</i> alliance</p>
<b>B. Habitat affinity and breadth of habitat</b>	Chamise is common on dry slopes, mesas and ridges below 1800 m in the foothills of mountain ranges throughout the state on a wide range of soil types. The San Diego chamise (var. <i>obtusifolium</i> ) is usually associated with dry mesas along the coast, but also occurs in the San Jacinto Mountains and Garner Valley in habitat typical of chamise and red-shanks.
<b>C. Elevation range</b>	<ol style="list-style-type: none"> <li>1. Mostly below 1530 m, up to 1830 m (Jepson E-Flora 2016)</li> <li>2. Below 1300 m (Jepson eFlora 2016)</li> <li>3. Below 750 m (Jepson eFlora 2016)</li> </ol>
<b>D. Soil: texture, chemicals, depth</b>	Chamise is a soil generalist growing even on serpentine soils (Safford et al 2005), but does not tolerate alkaline soils (Bornstein et al. 2005). It grows primarily in shallow soils that form over bedrock or sedimentary colluvium, but also occurs on deeper soils and is most often is on sandy loams and loamy sands (Borchert et al 2004). San Diego chamise may be more restricted in its soils.
<b>E. Precipitation</b>	Precipitation falls primarily from November through May during the cool season. Though rainfall is variable across its range, chamise tends to grow in areas with a total annual precipitation of 15 to 50 in (38 to 128 cm). In southern California, annual precipitation normals range from 10 to 40 in for interior Southern California Mountains and Valleys (M262B), 14 to 50 in for areas along the Southern California Coast (261B), and 20 to 40 inches for the Sierra Nevada Foothills (M261F).

<b>F. Drought tolerance</b>	Drought tolerant, xerophytic shrub. Plants can be physiologically active into the summer drought and have mechanisms to tolerate drought conditions. They exhibit changes in water potential over the year as well as over the course of a day, even in the dry season (Burk 1978). The lowest water potentials occurred during the height of summer drought and oddly were lower in north-facing slopes than on south-facing slopes (Poole & Miller 1975). Water potentials became high again in December. Leaf resistance was highest during the summer drought and was low throughout the winter, increasing in May.
<b>G. Flooding or high water tolerance</b>	Not flood tolerant. Occasionally in course, well drained alluvial deposits on fans and along streams where water from occasional flooding evacuates rapidly.
<b>H. Wetland indicator status for California</b>	None.
<b>I. Shade tolerance</b>	Full sun. Shade intolerant (Hanes 1965, Keeley 1981).

## V. CLIMATE CHANGE AND PROJECTED FUTURE SUITABLE HABITAT





### A. Species Distribution Models (SDM forecasts, 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; [http://frap.fire.ca.gov/data/frapgisdata-sw-fveg\\_download](http://frap.fire.ca.gov/data/frapgisdata-sw-fveg_download)).

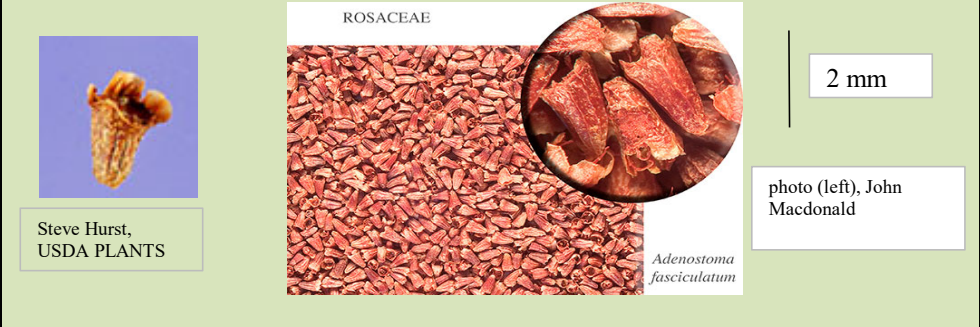
### B. SDM summary

Species distribution model predictions of future suitable habitat for chamise under 21st century climate change are variable. Assuming a future of continued high greenhouse gas emissions, Riordan et al. (2018) predicted 53–100% of baseline habitat for chamise in southern California would remain suitable (stable) under mid-century conditions across five different general circulation model (GCMs) (V. A. Fig. B). Predicted stable suitable habitat was high ( $\geq 97\%$ ) and gain in suitable habitat (18–44%) exceeded loss under four of five climate scenarios (V. A. Figs. C-D). Only under the wettest future climate scenario did predicted loss in suitable habitat (42%) exceed gain (6%). Under this scenario, sizeable losses in suitable habitat were predicted in the Peninsular Ranges throughout San Diego and Riverside Counties. In contrast, a previous SDM study by Principe et al. (2013) predicted widespread loss in habitat for chamise throughout southern California with only 18% of currently suitable habitat remaining suitable for the species at mid-century.

<b>B. SDM summary (continued)</b>	<p>Land use, altered fire regimes, invasive species, and their interaction with climate change could negatively affect chamise, even if the projected loss in habitat from climate change alone is relatively low. In southern California human activity is the primary driver of fire (Keeley &amp; Syphard 2016) with fire ignitions and fire frequency increasing with human population growth (Syphard et al. 2009). High frequency of fire is detrimental to chamise and can result in an abrupt shift to annual grasses (Zedler et al. 1983, Haidinger &amp; Keeley 1993). Severe drought following fire can cause high mortality of resprouts (Pratt et al. 2014). In addition, the distribution of chamise is not as continuous as SDM habitat suitability maps suggest. The high level of habitat conversion and fragmentation in southern California at low elevations poses considerable barriers to dispersal and gene flow that could negatively impact the adaptive capacity and ability of the species to move across the landscape in response to changing conditions.</p>
<b>C. SDM caveat (concerns)</b>	<p>The five GCMs used to predict future habitat suitability assume a ‘business-as-usual’ scenario of high greenhouse gas emissions that tracks our current trajectory (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. 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.</p>
<b>VI. GROWTH AND REPRODUCTION</b>	
<b>A. Seedling emergence relevant to general ecology</b>	<p>Seedling emergence is episodic and postfire. Seedlings are shade intolerant so openings in the canopy are necessary for successful seedling emergence and establishment. A high majority of seeds (over 90 %) germinate in the first spring after fire (Keeley et al. 2006). At a postfire site in Colusa Co., seedlings emerged in April following an August wildfire (Bieger et al. 2014). Emergence may occur earlier in warmer areas.</p>
<b>B. Growth pattern (phenology)</b>	<p>In mature chamise, growth often initiates in January, speeds up in March, peaks in May, then declines and has low activity from July to December (Hanes 1965). Similarly, root growth begins in early spring, with root biomass peaking in July, but summer rainfall events stimulate the growth of fine roots (Kummerow et al. 1978). Plants are able to remain physiologically active during the summer drought by extracting water deep within the soil and using extensive shallow roots to make quick use of shallow moisture (Poole &amp; Miller 1975). This may be especially important to resprouting plants. After a February fire in San Diego Co., both burned and unburned control plants flushed new growth from March to late May, but burned plants continued to grow into late summer (Moreno &amp; Oechel 1991).</p> <p>Most seedling growth occurs in late winter and spring. Plants grown from seed can reach reproductive maturity within three to four years (Everett 2012) and seed production of mature shrubs does not seem to decrease as plants age (McMurray 1990). Plants flower primarily from April to June, peaking in May (CCH 2016), and occasionally flowering up until September (Minnich 1985) depending on location. Seeds mature through the summer and the achenes disperse late summer to fall (Sampson &amp; Jespersen 1963).</p>
<b>C. Vegetative propagation</b>	<p>Plants are vigorous resprouters, but do not spread vegetatively (see Regeneration after fire, below). Plants can be propagated from cuttings of green wood (see Horticulture, below).</p>
<b>D. Regeneration after fire or other disturbance</b>	<p>Regeneration after fire is by both seeds and resprouts, with similar percentages at coastal and interior sites (Keeley et al. 2006). Chamise is well adapted to fire and can withstand a wide range of fire cycles. A typical fire frequency has been estimated as 30–80 years (Stohlgren &amp; Rundel 1986), but chamise is likely sensitive to repeated, short fire-return intervals owing to seed bank depletion and exhaustion of lignotubers. This may be an issue of climate change results in increased fire frequency.</p> <p><b>Resprouts:</b> Chamise resprouts from specialized basal burls (lignotubers) after fire. Chamise also resprouts after cutting off at the base but repeated cutting can kill plants (Howe 1981). Lignotuber age and size and season and frequency of fire are associated with the relative success of lignotuber survival and establishment from seeds (Stohlgren et al. 1989). Under conditions of high lignotuber survival, most postfire seedlings fail to reach maturity, but establishment rates are sufficient to replace dead shrubs. High fire frequency (short fire return intervals) can exhaust the lignotubers and cause mortality (Zedler et al. 1983) whereas a very long fire return interval can increase fire-caused mortality because larger burls are killed by fire (Keeley &amp; Zedler 1978). Severe drought after fire can also result in exhaustion of lignotubers and death of resprouts (Pratt et al. 2014).</p>
	<p>First year resprouts from burned stump. A. Montalvo</p>

	<p><b>Fire intensity:</b> Moreno &amp; Oechel (1991) showed experimentally that increasing fire intensity is associated with an increasing mortality of chamise shrubs. Small burls died at higher rates than large burls, and the higher the fire intensity, the fewer sprouts and the longer the time to resprouting. Herbivory also increased with fire intensity (see Herbivory).</p> <p><b>Fire season:</b> Because stored carbohydrate reserves are depleted by spring growth and flowering, plants burned or cut back in late spring or early summer are more likely to be killed by fire or to regrow slowly (Jones &amp; Laude 1960, Shaver 1981). Less postfire mortality has been observed after fall fires compared to late spring/early summer (Baker et al. 1982b, Beyers &amp; Wakeman 2000).</p> <p><b>Seedlings:</b> Establishment from seeds is episodic, variable among sites and years, and is negatively correlated with regeneration from lignotubers owing to competition from resprouts (Stohlgren et al. 1989). In a study of 46 postfire sites in southern California, seedling survivorship curves differed for coastal and interior sites (Keeley et al. 2006). Survival decreased substantially each year, with a mean of 0–1% percent of seedlings surviving to the fifth year (Keeley et al. 2006). In Colusa Co., survival of postfire seedlings was compared for serpentine vs. sandstone soil and north vs. south-facing slopes (Bieger et al. 2014). After two fairly typical rainfall years, seedling height was higher on south-facing slopes but percent survival was higher on north-facing slopes, but only for the sandstone site. Second year survival was much higher than for the southern California sites, averaging 51–62%.</p>
<p><b>E. Pollination</b></p>	<p>Pollen dispersal distances are likely limited but variable depending on the pollinator. In a study of bee visitation to chaparral shrubs, chamise had very low visitation rates compared to other shrubs such as <i>Ceanothus</i>, <i>Heteromeles</i>, <i>Rhamnus</i>, and <i>Eriodictyon</i> (Dobson 1993). Moldenke (1976) also found that <i>A. fasciculatum</i> was visited at low rates and primarily by beetles and Halictid bees in the genera <i>Perdita</i> and <i>Hesperapis</i> (Moldenke 1979). However, visitation by bees can be very different among years (Messinger &amp; Griswold 2002). For example, chamise had nearly twice as many species of bees visiting flowers for pollen and over twice the visitation rates in 1997 compared to 1998. Chamise was found to be an important plant for attracting bees that also pollinate crops (Kremen et al. 2002).</p>
<p><b>F. Seed dispersal</b></p>	<p>The seeds are light but have no specialized dispersal mechanism (Keeley 1981). The mature achenes typically fall to the ground or detach and disperse during strong winds. The dried hypanthium and parianth parts likely provide the tiny achenes with some buoyancy but not as much as in achenes equipped with specialized plumes (such as in <i>Cercocarpus</i>).</p>
<p><b>G. Breeding system, mating system</b></p>	<p>The breeding system in chamise needs verification. Based on results of minimal bagging studies, Moldenke (1976) listed chamise as self-incompatible and therefore outcrossed. The results of allozyme analysis for 25 populations of chamise (Lardner 1985) are also consistent with a high rate of outcrossing (see VII. D. Genetic variation and Population structure, below). However, the closely related <i>Adenostoma sparsifolium</i> was found to be self-compatible, partially cleistogamous, and likely highly selfing for two populations studied, contrary to the finding of high levels of expected heterozygosity and a significant excess of heterozygotes (Weins et al. 2012).</p>
<p><b>H. Hybridization potential</b></p>	<p><i>A. fasciculatum</i> and <i>A. sparsifolium</i> frequently grow together where their ranges overlap (Hanes 1965), but they flower at different times and are unlikely to hybridize (Weins et al. 2012). In contrast, different varieties of <i>A. fasciculatum</i> can co-occur, flower in the same season, hybridize and introgress (FNA 2016). The high morphological variation observed in chamise leaf shape and pubescence has long been hypothesized to be due to hybridization and introgression of different varieties (McMinn 1939, Anderson 1954, Lardner 1985).</p>
<p><b>I. Inbreeding and outbreeding effects</b></p>	<p><b>Related species:</b> A high genetic load may be responsible for high levels of abortion of self-fertilized ovules in the related <i>A. sparsifolium</i> (Weins et al. 2012). Chamise often has a high proportion of sterile achenes (Hanes 1965, Wall &amp; McDonald 2009), suggesting that the plants are either under pollinated, not receiving enough compatible pollen, resource limited, or suffering from high genetic load.</p>
<p><b>VII. BIOLOGICAL INTERACTIONS</b></p>	
<p><b>A. Competitiveness</b></p>	<p>Thought to be an aggressive shrub (Sampson &amp; Jespersen 1963). The resprouts and mature chamise shrubs are highly competitive unlike seedlings which do not compete well with resprouting plants (Stohlgren et al. 1984) or with seedlings of co-occurring fire-following species and non-native grasses (Roy 2009). Chamise seedlings also grow slower than competing shrub species after fire, but resprouts were able to dominate stands with <i>Ceanothus cuneatus</i> (an obligate seeder) by 15 years after fire (Stohlgren et al. 1989). The concentrated leachate from living chamise inhibits germination of some species (e.g., <i>Helianthemum scoparium</i>, <i>Calandrinia cilita</i>, <i>Silene multinervia</i>, <i>Bromus diandrus</i>) but promotes germination of others (e.g., <i>Paeonia californica</i>, <i>Salvia columbariae</i>) (Baskin &amp; Baskin 1998).</p>

<b>B. Phytochemistry, allelopathy</b>	The chemicals in chamise are thought to deter germination of competing plants. Chamise was found to contain nine phenolic compounds and another non-phenolic compound in leachate (McPherson et al. 1971). Five of the compounds were found in soil collected from under shrubs and several of the compounds were found to inhibit germination of lettuce seeds at bioassay concentrations thought to be present naturally. Later studies also found multiple phenolic and other potentially toxic compounds, but found no evidence that chemical concentrations were high enough in litter and soil to inhibit seed germination (Proksch et al. 1985).
<b>C. Herbivory, seed predation, disease</b>	Herbivory of resprouts tends to be higher for plants that flush outside the season of main flush (Moreno & Oechel 1991). Small mammals may consume seedlings after fire (Mills 1983). No reports of seed predation by insects were found.
<b>D. Palatability, attractiveness to animals, response to grazing</b>	<b>Palatability:</b> Considered poor to useless for cattle and useless for horses, but important to sheep, goats and deer (Sampson & Jespersen 1963). Mature plants considered to have low nutritional value and not highly palatable to livestock especially when in dense, impenetrable stands. Young resprouts have the highest palatability for the first few years after fire. Goats and sheep browse the plants mostly from spring to early summer but deer browse throughout the year. <b>Response to browsing:</b> Deer and other herbivores (likely rabbits) reduced the growth of resprouting chamise after fire (Howe 1981). New sprouts from the root crowns are sometimes stripped bare by goats or clipped very short by deer and other herbivores; plants resprout after being stripped but multiple close clipping can kill plants (Sampson & Jespersen 1963, Howe 1981).
<b>E. Mycorrhizal? Nitrogen fixing nodules?</b>	Chamise forms both ectomycorrhizal and endomycorrhizal associations with many genera of fungi (Allen et al. 1999). The associations can be variable among sites and years and the structures typical of the associations do not always form.
<b>VIII. ECOLOGICAL GENETICS</b>	
<b>A. Ploidy</b>	$2n = 9$ (Jepson E-Flora 2016). No variation in ploidy has been reported.
<b>B. Plasticity</b>	Both morphological and physiological traits show evidence of plastic response to the environment and drought stress. Leaf morphology, including the number of leaves in "fascicles" is highly plastic (Rundel & Parsons 1979, Lardner 1985). Resistance to cavitation from water stress can vary across seasons, suggesting trait plasticity that may be adaptive (Jacobsen et al. 2014).
<b>C. Geographic variation (morphological and physiological traits)</b>	<b>Morphology:</b> A prostrate growth form, now accepted as var. <i>prostratum</i> , occurs in the Channel Islands and along the windswept coast of San Luis Obispo Co., an adaptive trait seen in many other plant species with populations in coastal windswept places. The prostrate form is retained when plants are grown inland (FNA 2016). Some geographic variation in leaf structure correlates with infraspecific taxonomic status, but the genetic basis and adaptive significance of these traits have not been studied. Lardner (1985) measured pubescence and leaf traits (used to separate varieties) on samples collected from 25 populations (those sampled for allozyme analyses, see Population structure below) and found populations clustered into three groups. There was no obvious geographic pattern to the clusters except for one group of three Channel Island (CI) populations. Two other CI samples grouped with mainland samples. <b>Physiology:</b> There are differences in cavitation resistance for plants measured within different mountain ranges in southern California (e.g., Jacobsen et al. 2014), but common garden tests are needed to confirm whether or not the differences are primarily controlled by genetic or environmental differences.
<b>D. Genetic variation and population structure</b>	Chamise has high levels of genetic polymorphism, high gene diversity, little population structure, and a very low deficit of heterozygotes which together suggest an outcrossing species with reasonable rates of gene flow. Lardner (1985) sampled 25 populations of <i>A. fasciculatum</i> (23 from across its southern California range, including two samples of var. <i>obtusifolium</i> , and two populations of <i>A. sparsifolium</i> for comparison. Based on an analysis of allozyme variation at 14 isozyme loci, mean gene diversity and allele polymorphism were high ( $H_T = 0.31$ , average alleles/locus = 3.8 alleles/locus, and there was a mean of 75.7% polymorphic loci per population). Eighty seven percent of the variation was within rather than between populations (mean $F_{ST} = 0.13$ , range = 0.06–0.22), suggesting a high level of gene exchange among populations. The average deviation in heterozygosity within populations ( $F_{IS}$ was 0.07, consistent with a randomly mating taxon with no significant inbreeding. The average deviation in heterozygosity in the total population ( $F_{ST}$ was 0.18. The average Nei's unbiased genetic distance between var. <i>obtusifolium</i> and var. <i>fasciculatum</i> was 0.05, much smaller than the average genetic distance of 0.34 of each variety to <i>A. sparsifolium</i> . No analysis was performed to detect isolation by distance. Weins et al. (2012) studied allozyme variation in <i>A. fasciculatum</i> and <i>A. sparsifolium</i> from two sites in the Santa Monica Mountains and found both species to be genetically diverse with chamise about half as diverse as redshank. Their results were consistent with only low levels of inbreeding in chamise.

<b>E. Phenotypic or genotypic variation in interactions with other organisms</b>	None found.
<b>F. Local adaptation</b>	Unknown. A field study within a postfire area of Walker Ridge, Colusa Co., showed higher mortality of reciprocally transplanted chamise seedlings on serpentine compared to sandstone soil but found no evidence for local adaptation to soil type or slope (Bieger et al 2014). It is not known if there would be a difference if planted from seed, but the data suggest chamise is a soil generalist.
<b>G. Translocation risks</b>	Translocation risks of juvenile plants among slopes and soil type within close geographic and climatic proximity are low (see VIII. F. Local adaptation, above). There have been no common garden or provenance tests to determine extent of translocation risks across regions or across larger geographic/ environmental scales occupied by the taxon. There have been no evaluations of the effects of hybridization among varieties or among plants from contrasting environments.
<b>IX. SEEDS</b>	 <p>Steve Hurst, USDA PLANTS</p> <p>ROSACEAE</p> <p>2 mm</p> <p>photo (left), John Macdonald</p> <p><i>Adenostoma fasciculatum</i></p>
<b>A. General</b>	The fruit is a one-seeded achene, about 2–3 mm long and half as wide and is enclosed within the hypanthium of the flower, often referred to collectively as the seed. Seed lots may average about 50% purity and 20% germination (Stover Seed Co. 2016).
<b>B. Seed longevity</b>	Expected to be long-lived in storage and mixed (short to long-lived) in soil seedbanks. Germinable seeds in the soil seed bank increases with stand age (measured up to 85 years after fire) suggesting chamise forms long-lived seed banks (Zammit & Zedler 1988). Although seeds germinate after fire, a portion of the seed bank is sensitive to high fire temperatures, especially after seeds have imbibed water (McMurray 1990). Seeds are especially sensitive to spring burns.
<b>C. Seed dormancy</b>	Dormant, form seed banks. Stone & Juhren (1953) found high germination (~80%) of untreated seeds that were freshly collected from plants but high dormancy in seeds collected from duff beneath plants. Untreated seed lots can produce very low (<5%) germination; however, Zammit & Zedler (1988) found that approximately 20% of seeds germinated from untreated soil collected from under plants. Seeds that germinated from untreated soil seed banks could have been scarified naturally. Seeds germinate in nature after fire and heat or smoke can be used to break dormancy (see IX. H. Seed Germination).
<b>D. Seed maturation</b>	Most seeds mature late summer to fall. The achenes remain on plants into the fall and have been collected as late as October (Meyer & Sale 2014).
<b>E. Seed collecting and harvesting</b>	Harvest the dry achenes from the tips of stems by stripping into open containers, mid summer into fall. The proportion of filled seeds is often very low, so a lot of material should be collected (Meyer & Sale 2014).
<b>F. Seed processing</b>	Stems with achenes are first thrashed over a medium screen to separate large debris from achenes. The fine fraction is then sorted through #10 to #18 sieves to break up and remove the floral chaff (Wall & Macdonald 2009). The lighter chaff can be blown off with a seed blower. Higher speeds can be used to blow off empty/aborted seeds from filled, viable seeds. Blower speed depends on the blower.
<b>G. Seed storage</b>	Dry storage. Cool, dry storage is recommended.
<b>H. Seed germination</b>	Heat and charred wood can increase seed germination (McMurray 1990), but treatment with liquid smoke has provided the highest and most consistent germination. Heat applied to smoked seeds and seed burial before smoke application can increase germination synergistically. Keeley et al. (2005) treated seeds collected from Tulare or Fresno counties that were either stored at room temperature for ~6 mo or buried outside for ~1 yr. Smoke treatments included Wright's Concentrated Hickory Seasoning, B&G Foods, Inc. diluted with distilled water at 1:100, 1:500, and 1:1000, and heat treatments included exposure of seeds to 80°C for 1 hr; and 100°C, 110°C, 130°C, 140°C and 150°C for 5 min. Water was added to heat-treated seeds and controls and smoke water was added to seeds. Liquids



<b>H. Seed germination (continued)</b>	<p>were added to seeds on filter paper in petri dishes, and all treatments were incubated at ~ 4°C (cold stratification) for 1 month followed by alternating 18°C day and 12°C nights and followed for about 6 wk. For 6-mo old seeds, an average of about 15% of control seeds germinated; all smoke treatments significantly increased germination but the middle dilution (1:500) was the highest at ~70%. Germination was highest for seeds that had been buried; germination of controls approximately doubled; smoke treatments had higher germination than for "fresh" seeds and the middle dilution (1:500) was the highest at ~94%. Seeds treated at 100°C and 110°C for 5 min had nearly twice the germination of the control, but differences were not significant likely owing to small sample size.</p> <p>Wilkin et al. (2013) used a different approach and larger sample size. They treated seeds collected from southern California that had been stored at room temperature from ~3 mo to 1 yr. Seeds were soaked in dilutions of the same liquid smoke product and dried; and heat treatment was for 1 hr at 70°C. The liquid smoke (LS) treatments included undiluted product (PLS) for 10 min, 1, 4, or 18 hrs, and dilutions of LS:water at 1:2000, 1:1000, 1:100, and 1:10 for 10 min. They added heat treatment to wet seeds treated with 1:100, 1:10 LS, and PLS. Controls were simply dried. Incubation conditions mirrored Keeley (2005), except germination percentages were not reported to be adjusted for unviable seeds. Controls had 4% germination and five of the 14 treatments did not differ significantly from controls (heat only, dilutions of 1:1000 and 1:2000 LS, and seeds soaked more 18 hours or more). The highest germination was for PLS at 10 min, 1 and 4 hr and for 1:10 LS plus heat.</p>
<b>I. Seeds/lb</b>	<p>Variable reports. Ransom Seed Lab (Caltrans 2016) 790,414 seeds/lb.  Stover Seed Co (2016): 450,000 seeds/lb  S&amp;S Seeds (2016): Average live seed/ bulk pound: 108,000.</p>
<b>J. Planting</b>	<p>To grow plants from seeds, seeds must first be treated to break dormancy (see XI. H. Seed germination, above then sown into seed flats in winter to spring with a well-drained mixture (RSA uses a mix of peat moss, perlite, and dolomite limestone). Alternatively, flats of sown seeds can be exposed to burning, watered with smoke water, or planted in a growing medium that has been smoked. Transplant seedlings to two inch pots when about one to two inches high. If plug flats are used, transplant plugs to deep pots, such as 3" x 9" squares, when roots have begun to fill plugs.</p>
<b>K. Seed increase activities or potential</b>	<p>Large, wild populations of chamise are abundant and collecting sufficient seeds for seeding and propagation projects from wild populations is easy (A. Montalvo pers. obs.). Seed increase programs are not likely to be needed. Collecting and storing seeds during good years for seed set is more economical and produces more genetically diverse seed lots than farming plants for seeds.</p>
<b>X. USES</b>	
<b>A. Revegetation and erosion control</b>	<p>Seeds, container plants, and bareroot stock have been used for roadside and other revegetation projects on dry chaparral slopes in the Sierra Nevada, central western, and southwestern regions of California (McMurray 1990, Newton &amp; Claassen 2003). The extensive root system, drought resistance, and ability to grow in shallow or deep soils are important characteristics for use in revegetation, especially for slope restoration (Calscape 2017).</p>
<b>B. Habitat restoration</b>	<p>Chamise is used in restoration of chaparral throughout its natural range with mixed success, in part owing to the germination requirements to break seed dormancy. Chamise has been recommended for areas with shallow soils to about 1,067 m in elevation and for areas with deeper soils from 1,067 to 1,829 m (McMurray 1990). When planting seeds to restore unburned sites, pre-treating seeds with liquid smoke, or smoke and heat is expected to increase germination success (Wilkin et al. 2013), but other forms of smoke treatment may be more suitable for large scale seeding projects. One study examining effects of herbicides to control weeds and pre-treating seeds with liquid smoke yielded no chamise seedlings in any of the treatments (Engel 2014). Results were inconclusive and could have been affected by seed viability and drought (no check for percentage of filled seeds was conducted prior to planting). Research on large-scale seed treatment and planting trials are needed.</p> <p><b>Establishment from seed:</b> Seedling mortality can be high from drought, competition, and herbivory. Weeding of competing species is necessary for establishment in unburned areas and although irrigation is not necessary for successful establishment, supplemental irrigation in the first summer can increase survival, plant height and cover significantly (Roy 2009). However, in seeding trials (in weeded plots protected from deer) on Santa Catalina Island a seeding rate of 70 seeds/m<sup>2</sup> (untreated seeds) in a mixture with 10 other species (total rate of 319 seeds/m<sup>2</sup>) resulted in 12 seedlings/ 12 x 12 m plot; survival over two years was 54% for irrigated plots and 66% for unirrigated plot (Stratton 2004).</p> <p><b>Establishment from containerized plants:</b> For plants installed in early winter, survival of 2-gallon sized container plants to ~13 months was significantly higher for plots treated with both glyphosate (general herbicide) and fluzafob (kills grasses) than for control plots (all died) and plots treated with only fluzafob (Engel 2014). Plantings were hand watered with only 1 L of water once to twice a month.</p>

<b>C. Horticulture or agriculture</b>	<p><b>Propagation from cuttings:</b> Plants can be propagated from seeds or cuttings (Meyer &amp; Sale 2014, report from Rancho Santa Ana Botanic Garden, RSA). At RSA, cuttings are taken from semi-woody stems (green wood), usually January-June depending on growing season, and can take three months to root. Cuttings from hardwood are less successful and take longer. Cuttings are placed in perlite in flats and watered as needed (once or twice a week in summer, once in winter). Rooted cuttings are transferred to two inch pots and grown before shifting up to larger containers. Plants are also propagated from seeds (see IX. Seeds J. Planting, above).</p> <p><b>Horticulture:</b> The low, sprawling prostrate chamise, <i>A. f. var. prostratum</i>, has been used successfully as an attractive ground cover and the garden cultivar <i>Adenostoma fasciculatum</i> 'Black Diamond' is a dense, upright selection (Bornstein et al. 2005). All forms of chamise are valued for their evergreen foliage, heat and drought tolerance, and ability to naturalize on steep, rocky slopes (Keator 2003, Bornstein et al. 2005). Keator also notes that the woolly paintbrush (<i>Castilleja foliosa</i>) can be sown around the base of plants as chamise is a host (Keator 2003). However, owing to its high flammability (White et al. 1996, Weise et al. 2005), chamise should be planted well away from flammable structures (Keator 2003, Bornstein et al. 2005). Its use in landscaping is often discouraged in high fire severity zones, especially within the first 30 feet of structures. Mature shrubs accumulate dead branches and the small, linear structure of the leaves increases surface area and ignition potential. Trimming deadwood and keeping plants hydrated during fire season may reduce flammability (Calscape 2017).</p>
<b>D. Wildlife value</b>	<p>Resprouting chamise provides much of the available forage on recently burned sites (McMurray 1990). The sprouts of chamise are browsed by mule deer and likely rabbits (see Palatability, above) and dusky-footed woodrats store leaves and bark for food year round (McMurray 1990). Chamise also provides habitat and cover for nesting birds, mule deer, and many species of wildlife, including sensitive species (e.g., McMurray 1990). Open chamise scrub provides habitat for the orange-throated whiptail lizard (<i>Cnemidophorus hyperythrus beldingi</i>, Brattstrom 2000), and the federally threatened California gnatcatcher (<i>Poliophtila californica</i>) nests in chamise in mixed coastal sage scrub, especially late in the season (Sockman 2000).</p>
<b>E. Plant material releases by NRCS and cooperators</b>	<p>None. There are some horticultural selections (see X. C. Horticulture or agriculture).</p>
<b>F. Ethnobotanical</b>	<p>Native people had many uses for chamise. For example, Costanoans used the wood in arrow foreshafts and in basketry (Bocek 1984). The Cahuilla used branches for construction material, for making arrows, and for ramadas and fences. They also boiled the leaves and branches and used the liquid to bathe sores and swollen body parts, and sometimes ate the seeds (Bean &amp; Saubel 1972). The Chumash made an infusion from the bark or salve from twigs for sores; leaves were used in a tea for stomach ulcers and respiratory problems; coals from the wood for flavoring roasting food; and wood was used for the tips of arrow shafts (Garcia &amp; Adams 2009). They also used the hard wood for tools (Timbrook 2007).</p>
<b>XI. ACKNOWLEDGMENTS</b>	<p>Partial funding for production of this plant profile was provided by the U.S. Department of Agriculture, Forest Service, Pacific Southwest Region Native Plant Materials Program, and the Riverside-Corona Resource Conservation District. We thank Kathryn Kramer for reviewing this profile.</p>
<b>XII. CITATION</b>	<p>Montalvo, A. M., E. C. Riordan, and J. L. Beyers. 2017. Plant Profile for <i>Adenostoma fasciculatum</i>. 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: <a href="https://www.rccrd.org/plant-profiles">https://www.rccrd.org/plant-profiles</a></p>
<b>XIII. LINKS TO REVIEWED DATABASES &amp; PLANT PROFILES</b>	
Calflora	<a href="https://www.calflora.org/">https://www.calflora.org/</a>
Calscape	<a href="https://calscape.org/Adenostoma-fasciculatum-/">https://calscape.org/Adenostoma-fasciculatum-()</a>
Fire Effects Information System (FEIS)	<a href="https://www.fs.fed.us/database/feis/plants/shrub/adeffas/all.html">https://www.fs.fed.us/database/feis/plants/shrub/adeffas/all.html</a>
Jepson Flora Project (JepsonOnline)	<a href="https://ucjeps.berkeley.edu/">https://ucjeps.berkeley.edu/</a>
Jepson eFlora (JepsonOnline, 2nd ed.)	<a href="https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=11939">https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=11939</a>

USDA PLANTS	<a href="https://plants.usda.gov/core/profile?symbol=ADFA">https://plants.usda.gov/core/profile?symbol=ADFA</a>
Native Plants Journal	<a href="https://npn.rngr.net/journal">https://npn.rngr.net/journal</a>
Native Seed Network (NSN)	<a href="https://www.nativeseednetwork.org/">https://www.nativeseednetwork.org/</a>
GRIN (provides links to many resources)	<a href="https://www.ars-grin.gov/">https://www.ars-grin.gov/</a>
Flora of North America (FNA) (online version)	<a href="http://www.efloras.org/florataxon.aspx?flora_id=1&amp;taxon_id=100594">http://www.efloras.org/florataxon.aspx?flora_id=1&amp;taxon_id=100594</a>
Native American Ethnobotany Database (NAE)	<a href="http://naeb.brit.org/">http://naeb.brit.org/</a>
Rancho Santa Ana Botanic Garden Seed Program, seed photos (RSA)	<a href="http://www.hazmac.biz/041129/041129AdenostomaFasciculatum.html">http://www.hazmac.biz/041129/041129AdenostomaFasciculatum.html</a>
<b>XIV. IMAGES</b>	Image of <i>A. f.</i> var. <i>obtusifolium</i> by Ron Vanderhoff has a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 license (CC BY-NC-SA 3.0, <a href="https://creativecommons.org/licenses/by-nc-sa/3.0/">https://creativecommons.org/licenses/by-nc-sa/3.0/</a> ) and may be not used for commercial purposes. The image was cropped for use in this profile. Seed images by John McDonald used with permission from Rancho Santa Ana Botanic Garden, and may be used for educational purposes only; seed image by John Hurst may be used freely with author recognition. All other images are by Arlee Montalvo or Arlee Montalvo for RCRC (copyright 2017) and may be used freely for non-commercial purposes with author recognition.

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