**Supplement 1. Taxonomic Accounts for Priority Plant Species**

This supplement provides accounts of 57 taxonomic groups (e.g., species or related groups of species) of plants for use in restoration. Some of the accounts represent single plant species while others represent information for several different species and even multiple genera with similar phylogenetic associations or functions. The accounts include: common names; functional group and bloom season; distribution in the Mojave Desert and habitats; flower color and shape; pollinator use; desert tortoise use; propagation, production and cultivation; and recoverability. Plant taxonomic nomenclature generally follows Jepson Flora Project (2018; and citations therein), or for plants outside California, the Integrated Taxonomic Information System (ITIS 2020). Latin names generally are to species level, and on their first introduction the taxonomic authority is provided. Sometimes a synonym is no longer valid but often appears in recent or older literature (see example below).

Ex. “*Acmispon brachycarpus* Benth. D.D. Sokoloff (*=Lotus humistratus*) – foothill deervetch”

This exampledenotes that the same species may be recognized in some literature as *Lotus humistratus*, but that the authority we cite now uses *Acmispon brachycarpus*. Vertebrate and invertebrate nomenclature also follow the ITIS database (2020) except as noted.

## *Abronia* spp*.* (Nyctaginaceae)

***Common Name(s):*** *Abronia villosa* S. Watson – sand verbena; *A. fragrans* Nutt. Ex Hook. – sweet sand verbena.

**Functional group and bloom season:** *Abronia villosa* is an annual flowering from February to May (Murdock 2017a).

**Distribution in Mojave/Habitat:** *Abronia villosa* occurs primarily in sandy soils in creosote bush scrub below 1000 m in the eastern Mojave Desert but also in the Sonoran Desert of southwestern Arizona (Murdock 2017a) and the northwest Colorado Desert of southern California (Went 1948).

**Flower color and shape:** Pink to purple; salverform.

**Pollinator use:** *Abronia villosa* enhances pollinator habitat in Arizona (USDA Natural Resources Conservation Service, and the Xerces Society 2012). The native bee *Anthophora abroniae* Timberlake uses *Abronia*, and “its long tongue may be especially adapted to the flowers of the *Abronia*” (Timberlake 1937). A survey of Lepidoptera in dune systems of the California Desert reported *Euphyia implicata* Guenée in Boisduval and Guenée larvae – a moth in the Geometridae, beneath *A. villosa* (Powell 1978). White-lined sphinx moth larvae (*Hyles lineata* Fabricius) sometimes feed on patches of *A. villosa* in large numbers (Fenenga and Fisher 1978). The genus *Abronia* is larval host to six other moth genera in the United States(Robinson et al. 2010).

**Tortoise use:** The congener *A. fragrans* Nutt. *ex* Hook. occurs in the diets of desert tortoises in the northeastern Mojave Desert (Esque 1994).

**Propagation, production, and cultivation:** Initially*A. villosa* (var. *aurita*) had “good” storability, but after 30 months of storage, the best germinability rate was 4% (Kay et al. 1988). Use of the chemical ethephon (100 micromol/L) significantly increased germination in *A. villosa* (Drennan 2008). This species is said to be commercially available (Kay et al. 1988), but we could not locate any southwestern vendors selling seed.

**Recoverability:** Studies or observations on natural recovery or establishment success during restoration are unknown.

## *Acmispon* (*=Lotus*)spp.(Fabaceae)

**Common Name(s):** *Acmispon brachycarpus* Benth. D.D. Sokoloff (=*Lotus humistratus*)– foothill deervetch; *A. glaber* (Vogel) Brouillet- deer weed; *A. oroboides* (Kunth) Brouillet (=*L. plebeius*) [ITIS taxonomy) – New Mexico strigose bird’s foot trefoil; *A. rigidus* Benth. Brouillet *–* shrubby deervetch; and *A. strigosus* (Nutt.) Brouillet (=*Lotus tomentellus*)– strigose bird’s foot trefoil.

**Functional group and bloom season**: In the Mojave Desert these taxa are mostly herbaceous and low growing, but other species can grow to be large shrubs, especially at higher elevations. *A. brachycarpus* is an annual flowering March to June (Brouillet 2012a); *A. glaber* is a subshrub and blooms in June (Brouillet 2012b);*A. oroboides* is a herbaceous perennial flowering March to July;*A. rigidus* is a herbaceous perennial flowering March to May (Brouillet 2012c); and *A. strigosus* is an annual flowering March to June (Brouillet 2012d).

**Distribution in Mojave/Habitat:** Species are widespread in the Mojave Desert region and grow in a variety of habitats. *A. brachycarpus* can be found in desert flats and mountains below 1700 m throughout the Mojave Desert (Brouillet 2012a) but has few observations in the Mojave Desert proper. *A. oroboides* grows on slopes, mesas, and in woodlands between 762 m and 2286 m in the eastern Mojave Desert (SEINet 2020) and is restricted to Utah sites. *A. strigosus* grows in disturbed areas below 2300 m in the eastern Mojave (Brouillet 2012d).

**Flower color and shape:** Generally yellow, sometimes white or pink; papilionaceous.

**Pollinator use:** *Anthidium* Lowe and *Dianthidium* Cockerell bees visit *A. brachycarpus* (Hurd and Linsley 1975a)*.* A study of pollination in a non-native relative – *Lotus tenuis* Waldst. & Kit. Ex Willd. indicated that it is also visited by other native bees such as *Anthidium collectum* Huard*, Bombus californicus* Smith*, B. sonorus* Say*, Osmia bruneri* Cockerell*,* and *Hoplitis sambuci* Titusas well as*, Apis mellifera* Linnaeus (Jones and Cruzan 1999).

*Acmispon* species generally host Lepidopterans in the Nearctic region, most notably *Epargyreus clarus* Cramer*, Erynnis persius* Scudder*, Thorybes pylades* Scudder and seven others not listed here(Robinson et al. 2010). *A. brachycarpus* also hosts the Acmon blue butterfly (*Plebejus acmon* Westwood). *A strigosus* hosts two gossamer-winged butterflies (Lycaenidae) in the USA including: *Callophrys dumetorum* Boisduval, and *Cupido* (=*Everes*) *comyntas* Godart (Robinson et al. 2010). The larvae of one of the most common butterflies in north America, the orange sulfur butterfly (*Colias eurytheme* Boisduvall) is hosted by *A. strigosus*.

**Tortoise use:** *Acmispon* species are widely used by tortoises across the Mojave Desert Ecoregion. At least five *Acmispon* species were observed in tortoise diets*. A. brachycarpus* was the third most frequently used plant species at one site in the west Mojave Desert and at Joshua Tree National Park, California. It was followed by *A. oroboides* as the sixth most frequently used species at two different sites in the northeast Mojave Desert: City Creek, Utah and Littlefield, Arizona. *Acmispon strigosus* was used by tortoises in the east Mojave (Oftedal 2002) and was also observed in tortoise diets at Joshua Tree National Park. The taller *Acmispon* *rigidus* (Benth.) Brouillet may also be used by tortoises where they co-occur, including southwest Utah (Esque 1994), because it has also been observed in diets of Sonoran desert tortoise (*Gopherus morafkai* Murphy, Berry, Edwards, Leviton, Lathrop and Riedle) (Oftedal 2002).

**Propagation, production, and cultivation:** There is not much information on seed germinability for most *Acmispon*/*Lotus* spp. Seedscan be cleaned by allowing fruits to dry and dehisce in a paper bag or, if fruits do not dehisce easily, they can be rubbed over a coarse screen or #16 sieve (Wall and MacDonald 2009). *A. rigidus* seeds collected in June and germinated at 15 °C had initial germinability of 59%, and long-term cold storage at 4 °C or -15 °C maintained consistent germinability for up to seven years of storage (Kay et al. 1988). As legumes, *Acmispon* species exhibit physical dormancy, so scarification would likely increase germination rates (Baskin and Baskin 2014). Mechanical scarification (70% germination rate) and a 90°C hot water soak (30% germination rate) can be effective scarification treatments for *L. oroboides* (Dreesen and Harrington 1997).

**Recoverability:** Although typically a minor component of annual vegetation, Steers and Allen (2010) noted increases in *A. glaber* seedling recruitment after fire in the western Mojave, suggesting that these species may be suitable to include in native mixes for seeding tortoise habitat. *A. brachycarpus* has demonstrated competitive capability (i.e., high germination rates, low suppressibility) in cheatgrass-invaded habitats (Barak et al. 2015).

## *Ambrosia dumosa* (A. Gray) W.W. Payne (Asteraceae)

**Common Name(s):** white bur-sage, burro bush.

**Functional group and bloom season:** *A. dumosa* are medium to long-lived shrubs that flower from February to May, and sometimes again from September to November (Baldwin et al. 2002). *A. dumosa*, along with creosotebush are defining species for the majority of low elevation Mojave Desert shrubland habitats.

**Distribution in Mojave/Habitat:** *A. dumosa* is widespread across the Mojave and Colorado deserts (Benson and Darrow 1981; Turner et al 1994) and ubiquitous in low elevation habitat (creosote bush scrub) below 1600 m (Baldwin et al. 2002).

**Flowers color and shape:** *A. dumosa* have both male and female flowers on the same plant (monoecious). The pistillate flowers are green, and the color of the staminate flowers range from translucent to yellow to reddish. The involucral heads are composed of disc flowers only. **Pollinator use:** *Ambrosia* species are wind-pollinated and thus not used as nectar or pollen resources by pollinators. However, *A. dumosa* is a host plant for small moths of the families Geometridae (*Animomyia morta* Dyar*,* and *Synchlora frondaria* Guenée), Noctuidae (*Schinia dobla* J.B. Smith), and Tortricidae (*Carolella beevorana* Comstock*,* and *Platynota stultana* Walsingham; Robinson et al. 2010).

**Tortoise use:** *A. dumosa* was the second-most frequently used plant species for cover by tortoises (23%) and found at all nine sites (Table 3). *Ambrosia* *dumosa* is ubiquitous within low elevation tortoise habitats but is a minor diet species (Esque 1994).

**Propagation, production, and cultivation:** Field-collected seed can have low germinability (≤ 10% at 15 °C); thus, higher application rates may be needed to overcome lower seed fill (Kay et al. 1984, 1988). Long-term storage in sealed containers at room temperature or 4 °C can maintain some germinability (Kay et al. 1984, 1988). Optimal seed germination is at 15-25 °C at 1 cm depth (Kay et al. 1977b). Young plants can be reproductive within two years of establishment in disturbed areas where competition with adult plants is low (Hunter 1989). The spiny seeds of *A. dumosa* are undesirable to rodents or ants when other seeds are available in seed mixes (Suazo et al. 2013). Once established as mature plants, *A. dumosa* can provide cover for seedling establishment of other co-dominant shrubs, such as *Larrea tridentata* (McAuliffe 1988). *A. dumosa* was among five of the best woody species out of 17 that were evaluated for their ability to be increased by stem cutting from wild stock (Wieland et al. 1971). Salvage of adult *A. dumosa* resulted in 68% survival after 12 months of care in a nursery; surviving *A. dumosa* were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 60% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *A. dumosa* does not resprout well after wildfire (Abella 2009) or recover in denuded areas (Lathrop and Archbold 1980, Hunter 1989) unless there is an abundance of seed available and favorable rainfall conditions (Vasek 1983).This species is a prodigious seed producer, and the seeds may be generally avoided by rodent granivores (DeFalco and Esque, unpublished data). *A. dumosa* re-establishes new seedlings in response to summer/fall rains and warm temperatures, especially when protected from granivores (Kay et al. 1988; Hunter 1989). Light incorporation into the soil surface, such as raking or harrowing (DeFalco et al. 2012) assists seedling establishment. Protection of young seedlings from jackrabbits and other herbivores enhances establishment (L. DeFalco, unpublished data).

## *Ambrosia (=Hymenoclea) salsola* (Torr. & A. Gray) Strother & B.G. Baldwin (Asteraceae)

**Common Name(s):** cheesebush.

**Functional group and bloom season:** *A. salsola* is a short-lived ruderal shrub that blooms from March to May (Keil 2017a).

**Distribution in Mojave/Habitat:** *A. salsola* distribution is widespread throughout the Mojave and Lower Sonoran deserts (Benson and Darrow 1981) and is found in washes, canyons, and other disturbed areas (Shreve and Wiggins 1964).

**Flowers color and shape:** Flowers of *A. salsola* are monoecious. The pistillate flowers are green, and the color of the staminate flowers range from translucent to yellow to reddish. The involucral heads are composed of disc flowers only.

**Pollinator use:** Like other *Ambrosia* species, *A. salsola* is wind-pollinated and does not provide nectar resources (or, presumably, pollen) to pollinator fauna (Keil 2017a). The British Natural History Museum’s HOSTS Database only lists the moth (*Somatolophia cuyama* Comstock*,* Geometridae) that uses *A. salsola* as a larval host (Robinson et al. 2010).

**Tortoise use:** *A. salsola* was the sixth most frequently used taxon as a cover plant for tortoises and was used at five of eight sites where data were collected (Table 3). While this species represents only a fraction of tortoise diet, it was observed in the diets of tortoises at three sites.

**Propagation, production, and cultivation:** Bulk seed may be collected with a vacuum harvester and cleaned by running the material through a fanning mill equipped with a #30 top screen and a #10 bottom screen (Kay et al. 1977b). Broadcast seeds can be protected from granivores such as ants and small mammals by burial below the soil surface (DeFalco et al. 2012). *A. salsola* can be established from seed when timed with warm seasonal rains at 15 – 25 °C (Brum et al. 1983, Kay et al. 1988). This species has high initial seed germinability (68%) and does not seem to have particularly rigorous temperature storage requirements. Kay et al. (1984, 1988) found that germinability of mature seed increased after more than 9 years of storage under room temperature (85%), 4 °C (78%), or -15 °C (84%). Optimal germination is 20 °C at a depth of 1 cm (Kay et al. 1977c). *A. salsola* was among the best 5 out of 17 (Wieland et al. 1971), and 47 (Everett et al. 1978) woody perennial shrub species evaluated for increase from stem cuttings. Salvage of adult *A. salsola* resulted in 72% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 19% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *A. salsola* is a short-lived ruderal shrub that often inhabits disturbed areas, and shows some recovery following wildfire (Shryock et al. 2014) and surface soil disturbance (Lathrop and Archbold 1980, Vasek and Lund 1980). Pelletizing *A. salsola* seeds or fencing seeded areas did not increase seedling establishment (Abella et al. 2015a). Such efforts may not be necessary because this speciesrapidly reseeds after disturbance such as wildfire (Medica et al. 1993) and can become the dominant vegetation of burned areas until longer-lived species like *Larrea tridentata* mature (Minnich 1994, 1995).

## *Amsinckia tessellata* A. Gray (Boraginaceae)

**Common Name(s):** rough fiddleneck.

**Functional group and bloom season:** *Amsinckia tesselata* is an annual forb that flowers between February and June (Kelley and Ganders 2017).

**Distribution in Mojave/Habitat:** Rough fiddleneck is a widespread species, occurring throughout central and southern California into the Great Basin (Baldwin et al. 2002). Both varieties (*A. t*. var. *gloriosa* (Suksd.) Hooverand *A. t.* var. *tessellata* occur in the Mojave Desert, but *A. t.* var. *gloriosa* is restricted to the western portions (Baldwin et al. 2002) where it grows in sand/shale soils from 50 m – 1700 m. In contrast *A. t.* var. *tessellata* grows in rocky/sandy soils from 50 m to 2280 m. However, both are common and often grow in disturbed places (Baldwin et al. 2002).

**Flower color and shape:** Yellow; funnelform.

**Pollinator use:** This species hosts a wide variety of pollinator species, including bees in the *Anthophora* Hulst*,* and *Osmia* Panzer;three bee fly genera (Bombyliidae), and it is a larval host to the moth *Ethmia tricula* Powell(Moldenke 1976; Powell and Hogue 1979; Robinson et al. 2010). Desert orangetip butterflies (*Anthocharis cethura* C. Felder and R. Felder) nectar on *Amsinckia* sp. (Walker 2020).

**Tortoise use:** This species was recorded in desert tortoise diets in both the eastern and western Mojave (Esque 1994; Jennings and Berry 2015).

**Propagation, production, and cultivation:** Winter annuals of Boraginaceae in the Mojave Desert germinated in December in response to fall/winter rains (Beatley 1974), so seeding *A. tessellata* just prior to this time would likely result in successful germination. The seeds of *Amsinckia* can easily be cleaned by rubbing floral parts through #12 and #25 sieves; blower speed should be set at 1.75 or greater (Wall and MacDonald 2009). In one study, a cold stratification treatment (four weeks at 2°C) resulted in a 67% germination rate for this species (Forbis 2010). In the same study a dry after-ripening treatment (4 weeks at 40°C) did not have a significant effect on germination rate (Forbis 2010). In a propagation study of the critically endangered congener *A. grandiflora* (A. Gray) Kleeb. Ex Greene. nutlets grown in petri dishes in a dark culture room with daily temperature fluctuations between 10 and 19°C had an average germination rate of 80% (Pavlik 1988). Because borage species exhibit physiological dormancy (Baskin and Baskin 2014), a period of hot and dry conditions would seem prerequisite for germination. However, *A. tessellata* seeds stored at room temperature (presumably 20 to 25°C) had 94% viability after nine months (Forbis 2010).

**Recoverability:** *Amsinckia* species have demonstrated resilience to soil disturbance (Suazo et al. 2012). *A. tessellata* has no requirement for cold stratification and germinates during the same season as the invasive annual grass cheatgrass (Forbis 2010); thus, it has also been shown to competitively exclude cheatgrass (*Bromus tectorum* L.) in the Great Basin (Leger et al. 2014). *Amsinckia* frequently grow on the berms of desert tortoise burrows, rodent colonies, and similar small natural disturbances (T. Esque pers. obs.).

## *Androstephium breviflorum* S. Watson (Liliaceae)

**Common Name(s):** pink funnel lily, small-flowered Androstephium.

**Functional group and bloom season:** *Androstephium breviflorum* is a perennial forb. This geophyte reproduces from an underground spheric corm (Baldwin et al. 2002) and flowers from March to June (Pires 2017).

**Distribution in Mojave/Habitat:** *Androstephium breviflorum* grows in open desert scrub from 700 m to 1600 m in the eastern Mojave Desert (Baldwin et al. 2002).

**Flowers color and shape:** White with blue midlines on petals; stellate.

**Pollinator use:** Little is known about the pollination ecology of *Androstephium* species (Sanders 1999). The floral syndrome suggests that insect pollination occurs, and the native bee *Eucera phaceliae* Cockerell uses this species on the Colorado Plateau in south-central Utah (Carril et al. 2018).

**Tortoise use:** This small geophyte was ranked sixteenth based on bites by tortoises but was only observed in diets at one site in the northeast Mojave Desert (Table 2).

**Propagation, production, and cultivation:** There are several other geophytes found across the deserts that survive as membranous bulbs, fibrous corms, or rhizomes while dormant, such as lilies *Calochortus* Pursh spp., *Hespercallus* spp., *Dichelostemma* Kunth spp., larkspur (*Delphinium* L. *sp.*), and wild onion (*Allium* L. spp.; Keator 2002a; 2002b; McNeal 2002; Fiedler and Ness 2002). Some of these types of plants are cultivated by specialty growers for people to use in their native wildflower gardens, and such groups likely could share valuable propagation information, but nothing specific was found in our searches.

**Recoverability:** We found no published information about the recoverability of *A. breviflorum*. The bulb and other structures that occur deep (> 10 cm) in sandy desert soils are protected from high temperatures of desert fires that can incinerate native soil seed banks within the top 2 cm (Esque et al. 2010). The surviving geophytes may be targeted by herbivores as they resprout, and thus reduce their survival, but with protection they could do well. The restoration potential for this species is unknown, but propagation and burial of bulbs and corms in degraded habitat may provide an alternative to seeding or seedling transplanting.

***Aristida purpurea* Nutt. (Poaceae)**

**Common names:** purple three-awn.

**Functional group and bloom season:** *Aristida purpurea* is an erect perennial bunchgrass flowering February through June in the Mojave Desert.

**Distribution in Mojave/Habitat:** *A. purpurea* is widespread on dry rocky slopes and hills throughout the Mojave and Colorado deserts. It is found in upper Mojave Desert shrublands and extending into pinyon and junipers woodlands.

**Flower color and shape:** As grasses, the inflorescence is a raceme, and each floret has three long awns.

**Pollinator use:** As other grasses, purple three-awn is wind pollinated. However, it provides nesting materials or structure to native bees (wildflower.org, accessed 22 April 2020, TCE). This grass is a larval host to skippers and satyr butterflies.

**Tortoise use:** *A. purpurea* was observed in bite counts at two sites in the Mojave Desert, but was not observed as cover.

**Propogation, production, and cultivation:** *A. purpurea* was greenhouse grown for outplanting at Zion National Park, in Springdale, Utah (Decker 2003b). Seed was planted in a soil mixture of vermiculite, sterile sand, turface, and peat in a ratio of 1.5:1:1:2; respectively. The Calscape website notes that *A. purpurea* readily reseeds itself (Calscape.org 2020). Purple three awn seeds were recently available from 12 different growers in the southwest (USDA-NRCS 2014). Because it is noted to be invasive in gardens, we suspect it will thrive with enough precipitation and the correct soils. As a perennial grass, *A. purpurea* is expected to start well from plugs separated from parent plants.

**Recoverability:** We found no published information about the recoverability of A*. purpurea*; however, this species is recommended for reclaiming dry rocky slopes because its fibrous roots help to stabilize soils (wildflower.org).

## *Asclepias erosa* Torr. (Apocynaceae)

**Common Name(s):** desert milkweed.

**Functional group and bloom season:** *A. erosa* is an herbaceous perennial that flowers from May to July in the Mojave (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** This species inhabits disturbed areas such as washes, roadsides, and dry slopes from 150 m to 1900 m throughout the Mojave Desert (Baldwin et al. 2002; Nabhan et al. 2015).

**Flower color and shape:** White and green. The flower shape is highly specialized. The petals and sepals are reflexed, revealing five petal-like appendages, each composed of a hood and horn structure. These appendages surround the stamens and pistil, that are fused at the anthers and stigma to form a structure called a gynostegium. The gynostegium contains slits where the pollen is maintained. When insects visit *Asclepias* flowers, their legs slip into these slits and pick up pollen. Pollination occurs when this process is repeated at the next flower that is visited.

**Pollinator use:** *Asclepias* species are beneficial to many pollinator species and a single plant that is in flower may have a swarm of Diptera, Hymenoptera, and Lepidoptera including nectar feeders and larvae (T. Esque pers. obs.). Nectar of *Asclepias* flowers attract 104 species of native bees in the Desert Southwest, including those of Genera *Agapostemon* Guérin-Méneville*, Anthophora, Bombus* Latreille*, Centris* Fabricius*, Diadasia* Patton*, Halictus* Latreille*, Lasioglossum* Curtis*, Megachile* Latreille*, Melissodes* Latreille*, Protandrena* Cockerell*,* and *Xylocopa* Latreille (Ikerd and Griswold 2014; Nabhan 2014; Wilson and Carril 2016). At the Nevada National Security Site (formerly Nevada Test Site), *A. erosa* is associated with the following bees: *Agapostemon texanus* Cresson*, Anthophora urbana* Cresson*, Chelostomoides lobatifrons* (taxonomy not traceable)*, Lasioglossum albohirtum* Crawford*, L. hyalinus* Crawford*, D. microlepoides* Ellis*, D. pruinosum* Robertson, an unnamed *Lasioglossum* sp., and *Xeromelecta* (=*Melectamorpha) californica* Cresson (Allred 1969).

*Asclepias erosa* are most well known as the primary larval host plants of monarch butterflies (*Danaus plexippus* L.)*,* and their close relative the queen butterfly (*D. gilippus* Cramer;Nabhan et al. 2015; USDA Natural Resources Conservation Service and the Xerces Society 2012). The larvae feed on the leaves of milkweeds and accumulate toxic cardenolide compounds found in the sap of the plant in their own bodies, as a predator deterrent (Nabhan et al. 2015). Monarchs were observed hatching from chrysalises at a community vegetable garden in Green Valley, NV in November and December 2019 (T. Esque, pers. obs.). Desert milkweeds are visited by butterflies of genus *Strymon* Hübner*.*

**Tortoise use:** Despite its importance to pollinators, no information was available for how it may be used by desert tortoises. Considering its tall branchless structure and the toxicity of *Asclepias* species to most animals, it is unlikely that desert tortoises would use it for cover, and it has not been documented in diets.

**Propagation, production, and cultivation:** Clean seedsby rubbing mature fruits over a rubber mat, then separate loosened hairs with a screen or a blower (Wall and MacDonald 2009). This species is already in commercial production (Nabhan et al. 2015). Southwestern nurseries that cultivate *A. erosa* include Las Pilitas Nursery (Santa Margarita, CA) and Desert Survivors, Inc. (Tucson, AZ). Outplanting the perennial tuberous roots could be beneficial to avoiding the vulnerable germination and establishment stages for restoration.

**Recoverability:** Where it is native,*A. erosa* is a recommended species for reclamation, erosion control, and early successional habitat development (Nabhan et al. 2015). Its tendency to grow along roadsides and washes suggests that this species is a successful colonizer of disturbed areas. This species also shows some resilience to repeated surface distrubances where roadsides are maintained by road-graders.

## *Astragalus* spp. (Fabaceae)

**Common Name(s):** *Astragalus acutirostris* S. Watson *–* sharpkeel milkvetch; *A. didymocarpus* Hook. & Arn. – two-seeded milkvetch; *A. layneae* Greene – Layne milkvetch; *A. lentiginosus* Douglas – freckled milkvetch; and *A. nuttallianus* (Rydb.)Barneby – small-flowered milkvetch.

**Functional group and bloom season:** *Astragalus acutirostris* is an annual plant blooming April to May; *A. didymocarpus* is a winter annual blooming February to May; *A. layneae* is a herbaceous perennial blooming March to June; *A. lentiginosus* is an herbaceous perennial that blooms from March to June; *A. nuttallianus* is a winter annual blooming May to June (Baldwin et al. 2002; Wojciechowski and Spellenberg 2017).

**Distribution in Mojave/Habitat:** *Astragalus didymocarpus* occurs throughout the Mojave Desert and grows in gravelly or sandy soils in open areas below 1550 m (Baldwin et al. 2002). *Astragalus layneae* is also widespread throughout the Mojave Desert, growing in sandy washes and flats between 450 m and 1550 m (Baldwin et al. 2002). *Astragalus nuttallianus* var. *imperfectus* occurs mainly in the eastern Mojave Desert and grows in sandy or gravelly flats and washes from 300 m to 1950 m (Baldwin et al. 2002). *Astragalus lentiginosus* has numerous varieties that grow from the western Mojave to the southern Sierra Nevada Range down into Sonoran Desert, but generally the species can be found in dry, open sites, at a wide elevation range (-30 m to 3600 m; Baldwin et al. 2002).

**Flower color and shape:** Corolla color for *A. acutirostris* is white and light pink to purple; *A. didymocarpus* is also white blending to purple at the tips; *A. layneae* is light yellow and blending to purple at the tips; *A. lentiginosus* is mostly light purple, but fading to white deep in the flower; *A. nuttallianus* is white turning to purple at the margins. Flowers are papilionaceous.

**Pollinator use:** No information was found on use of *A. didymocarpus, or A. layneae* bypollinators. The rare congener *A. aequalis* Clokey is pollinated by *Anthidium, Ashmeadiella* Cockerell*,* and *Protosmia* Ducke bees (Griswold et al. 2006). *Astragalus* species in the southwest are also visited by *Anthophora,* Scropoli*,* and *Osmia* bees(Allred 1969; Wilson and Carril 2016)*.*

*Astragalus lentiginosus* is a larval host to the *Plebejus acmon* butterfly (Robinson et al. 2010). *A. nuttallianus is also* a larvalhost to the Northern cloudywing butterfly (*Thorybes pylades* Hesperiidae) (*Cupido Amyntula* Robinson et al. 2010; Stewart et al. 2001).

**Tortoise use:** Several species of *Astragalus* have been recorded in desert tortoise diets (Esque 1994; Jennings and Berry 2015). The perennial forb *A. layneae* was the eleventh most abundant species in diets and observed at two sites in the west Mojave and the Colorado Desert. Related species *A. acutirostris* (annual), *A. didymocarpus* (annual), *A. lentiginosus* (perennial) were also observed in diets of tortoises in the west Mojave Desert. *Astragalus nuttallianus* (annual) was observed in diets in the northeast Mojave Desert, and was among the most frequently eaten species by juvenile desert tortoises in Hidden Valley, Nevada in 2015 (M. Nafus, San Diego Zoo, *pers. comm.*). This is a speciose genus and undoubtedly more species occur in tortoise diets that have not yet been identified.

**Propagation, production, and cultivation**: Information on seed ecology is lacking for a variety of *Astragalus* spp. However, seeds of *A*. *lentiginosus* var. *micans* Barneby had 24% germinability at 15 °C and maintained germinability up to seven years of storage at 4 °C or −15 °C (Kay et al. 1988). As legumes, *Astragalus* species exhibit physical dormancy and likely require scarification in order to germinate (Baskin and Baskin 2014). For collection, separate the seeds from dried pods by hand, or use a coarse screen if pods do not dehisce easily.

**Recoverability:** Studies on establishment success during restoration efforts are rare. The tendency of *Astragalus* to grow in open areas may help protect the seed reserves of these species from incineration through avoidance of high-heat fire patches that occur under shrubs (Brooks 2002).

## *Atriplex* spp. L. (Chenopodiaceae)

**Common Name(s):** *Atriplex canescens* (Pursh.) Nutt. *–* Fourwing saltbush; *A. confertifolia* (Torr. & Frém.) S. Watson *–* shadscale; *A. hymenelytra* (Torr.) S. Watson – desert holly; and *A. polycarpa* (Torr.) S. Watson *–* Cattle saltbush.

**Functional group and bloom season:** Shrubs. The flowering periods of these four species are asynchronous, with *A. hymenelytra* blooming from January and April, *A. confertifolia* from April to July, *A. canescens* from June to August, and *A. polycarpa* from July to October (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** *A. hymenelytra* is widespread across the Mojave Desert (Benson and Darrow 1981) and grows in some of the hottest, driest areas on slopes, washes, and shrublands below 1500 m) but plant densities are typically low (Baldwin et al. 2002). *A. canescens* occurs extensively across the western US in a wide range of habitats. In the Mojave, it grows on flats and slopes in shrubland in a variety of soil types below 2400 m (Baldwin et al. 2002). *Atriplex confertifolia* grows in alkaline flats and on gravelly slopes in shrubland up to pinyon-juniper woodland (< 2400 m; Baldwin et al. 2002). *Atriplex polycarpa* grows on alkaline flats and in dry lakes below 1500 m (Baldwin et al. 2002).

**Flowers color and shape:** Saltbush are dioecious (male and female flowers on separate plants), with staminate flowers that range in color from silvery to yellow to red-brown, and green pistillate flowers. Both flower types are borne in clusters on spike-like panicles and are highly reduced.   
**Pollinator use:** *Atriplex* species are wind-pollinated (Blackwell and Powell 1981) but are larval hosts for at least 14 Lepidopteran species (Simpson and Neff 1987). All four *Atriplex* spp. are larval hosts to the western pygmy blue (*Brephidium exilis* Boisduval), the common sootywing (*Pholisora catullus* Fabricius), and the Mojave sootywing (*Hesperopsis libya* Scudder). *A. canescens* hosts twirler moths (Gelechiidae: *Scrobipalpa atriplex* Busck; *Perizoma custodiata* Guenée in Boisduval and Guenée), the owlet moth *Trichoclea antica* (Noctuidae), and the specialist the saltbush sootywing (*Hesperopsis alpheus* W.H. Edwards; Stewart et al. 2001; Calscape.org 2020). The San Emigdio blue butterfly larvae is hosted by *A. polycarpa*, *A. hymenelytra*, and *A. canescens*. The alfalfa looper moth (*Autographa californica* Speyer) is hosted by *A. polycarpa*, *A. hymenelytra*, and *A. confertifolia*. The western tussock moth (*Orgyia vetusta* Boisduval) is hosted by *A. polycarpa*, and *A. confertifolia*. The morning glory plume moth (*Emmelina monodactylax* Linnaeus– taxon not in ITIS) is hosted by *A*. *polycarpa* and *A. confertifolia*. Meske’s pero moth (*Pero meskaria* Packard is hosted by *A. hymenelytra* and *A. canescens*. *Glaucina ochrofuscaria* moths are hosted by *A. canescens*. Together, *A. canescens* and *A. polycarpa* also support thirty-seven gall-forming species of parasitoid and predatory insects (Hawkins and Geoden 1984).

**Tortoise use:** As the ninth most frequently used cover species, *A. hymenelytra* was used at one site for cover in 1.26 % of the total occurrences (Table 3). *Atriplex confertifolia* was used at one site, comprising 0.41% of cover use, and *A. canescens* was used at two sites and comprising 0.29% of cover use (Supplement 3).

**Propagation, production, and cultivation:** Initial germinability of mature field-collected *A. hymenelytra* seed was 26% (Kay et al. 1988). Long-term storage (7 years) can increase germinability of *A. hymenelytra* to greater than 30 percent, while storage conditions can range from room temperature to cooler temperatures without loss of germinability (Kay et al. 1988). For *A. canescens,* Kay et al. (1984, 1988) reported no loss in seed viability following nine years of hermetic storage at -15°C, Stevens et al. (1981) found no loss in viability following 15 years in open storage, and Plummer (1983) found no viability loss after 10 years storage. Germination of *A. canescens* is highest at 12°C to 23°C and improved by removal of the seed wings (Springfield 1969, 1970). Germinability of *A. polycarpa* seeds increased significantly when stored at room temperature (Kay et al. 1984), but the length of storage time was not specified. *A. polycarpa* experiences optimal germination under a day/night temperature cycle of 24°/16°C (Chatterton and McKell 1969; Graves et al. 1975). *Atriplex confertifolia* germinated best at a constant 12°C, and germination success greatly decreases with increasing temperature (Sabo et al. 1979). However, germination characteristics in *A. confertifolia* vary with temperature (Sanderson et al. 1990), and warmer germination temperatures may be successful for Mojave Desert populations.

*Atriplex canescens* performed very well in evaluations of increasing plant materials using stem cuttings from wild stock (Everett et al. 1978). Salvage of adult *A. confertifolia* and *A. hymenelytra* resulted in 84% and 59% survival, respectively, after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 54% and 47% survival, respectively, 27 months after transplanting (Abella et al. 2015b).

**Recoverability:***Atriplex canescens* resprouts after fire (Brooks and Minnich 2006), but recovery may require several years. *Atriplex canescens* is used widely in restoration projects throughout the southwestern US. In a New Mexico grassland, *A. canescens* sustained 62% mortality after a fire, and survivors did not fully recover until 5–6 years later (Parmenter 2008). The seeds of this species are of medium weight and wind-dispersed, facilitating recolonization. After disturbance. *A. canescens* has been used in restoration projects in desert regions for decades and establishes well when seeded or outplanted (Abella and Newton 2009). *Atriplex confertifolia* can reseed burned areas but does not resprout after fire (West 1994; Haubensak et al. 2009). *Atriplex polycarpa* establishes well from seed and has high outplant survival (Abella and Newton 2009), but seedlings and outplants must be protected from herbivory (Graves et al. 1978). *A. hymenelytra* has not been tested in restoration in the Mojave Desert.

## *Baccharis* spp. (Asteraceae)

**Common Name:** *Baccharis glutinosa* Pers*.* *(=salicifolia*) – marsh baccharis; *B. sarothroides* A. Gray – broom baccharis; and *B. sergiloides* A. Gray – desert baccharis.

**Functional group and bloom season:** Shrubs; *B. glutinosa* blooms year-round, *B. sarothroides* blooms from August to November, and *B. sergiloides* blooms from July to October (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** *B. glutinosa* is found along canyon bottoms and other relatively mesic areas below 1250 m (Baldwin et al. 2002). *Baccharis sarothroides* grows in disturbed habitats such as washes and roadsides in sandy/gravelly soil below 850 m (Baldwin et al. 2002). *Baccharis sergiloides* can be found in sandy/gravelly streambeds between 600 m and 1575 m (Baldwin et al. 2002).

**Flower color and shape:** White; involucral heads composed entirely of disc florets.

**Pollinator use:** *Baccharis glutinosa* is pollinated by *Nomia* Latreillebees (Hurd and Linsley 1975a). *Baccharis sergiloides* and *B. sarothroides* are described as pollinator host species (Eldredge et al. 2013; USDA Natural Resources Conservation Service and the Xerces Society 2012*).* Carril et al. (2018) collected *Hylaeus mesillae* Cockerell*,* an undescribed *Hylaeus* *sp., Lasioglossum albohirtum, L. hyalinum* Crawford*, L. nevadense* Crawford*,* a few additional *Lasioglossum* morphospecies*, Perdita dubia* Cockerell*, P. festiva* Timberlake*, P. phymatae* Cockerell*, P. similis* Timberlake*, P. subfasciata* Cockerell*, P. zebrata* Cresson*, Ceratina nanula* Cockerell*, Melissodes tristis* Cockerell*,* and *Colletes slevini* Cockerellon *B. glutinosa.* Moths in the Geometridae (*Chlorochlamys appellaria* Pearsall*, Synchlora gerularia* Hübner), Saturniidae, and the Noctuidae (*Schinia oculate* Smith) use *B. sarothroides* and *B. glutinosa* as larval hosts (Robinson et al. 2010).

**Tortoise use:** There is no information on *Baccharis* species use by tortoises.

**Propagation, production, and cultivation:** Fruits should be spread in a thin layer to dry in a warm, well-ventilated area that is protected by the wind. When dry, the pappus and other non-seed material can be removed by rubbing in between the hands or by feeding the whole inflorescence into a brush machine (Bonner and Karrfelt 2008; Young and Young 1986). Clean seeds can be stored in airtight containers between 1.7° and 4.5°C (Bonner and Karrfelt 2008). *Baccharis* seeds are nondormant, and thus require no treatment prior to germination (Baskin and Baskin 2014; Olson 1974; Young and Young 1986). Several studies (Baskin and Baskin 2014; Bonner and Karrfelt 2008; Olson 1974) recommend an alternating temperature regime of 30°/15-20°C and full light for germination of *Baccharis* L.species. A propagation study of *B. glutinosa* in which seeds were grown under the previously described conditions for 15-30 days resulted in a germination rate of 75-82%. *Baccharis glutinosa* performed well in acquiring roots on stem cuttings from wild stock, but the authors concluded that there were too few accessions for a definitive answer about its use as a technique in that experiment (Everett et al. 1978).

**Recoverability:** Although *Baccharis* spp. frequently occupy highly disturbance prone habitats such as desert washes and riparian habitats, we found no literature on the recoverability of *Baccharis* after disturbance. This taxon frequently occupies disturbance-prone washes and is small-seeded and wind-dispersed (Baldwin et al. 2002) suggesting good colonizing potential (Shryock et al. 2014).

## *Baileya* Grote spp. (Asteraceae)

**Common Name(s):** *Baileya multiradiata* Harv. & A. Gray ex torr. –desert marigold; and *B. pleniradiata* Harv. & A. Gray – woolly marigold.

**Functional group and bloom season:** Annual (*B. multiradiata*)*,* and perennial (*B. pleniradiata)* forbs. *Baileya multiradiata* blooms between April and July, and *B. pleniradiata* between March and June (Keil 2017b, 2017c).

**Distribution in Mojave/Habitat:** Found in disturbed areas such as arroyo bottoms, roadsides, outwash slopes, and sandy plains in the eastern Mojave Desert (Baldwin et al. 2002). *Baileya multiradiata* grows between 600 m and 1600 m, and *B. pleniradiata* grows below 1500 m (Baldwin et al. 2002).

**Flower color and shape:** Yellow; involucral heads of disc and ligulate florets, with a broad landing platform for pollinators.

**Pollinator use:** Pollinators of *Baileya* include *Colletes* Latreille*, Exomalopsis* Spinola*, Megachile,* and *Perdita* Smithbees(Hurd and Linsley 1975a; Griswold et al. 2006), as well as, *Calliopsis* (=*Hypomacratera) subalpinus* Cockerel (taxon authority not verified) and *Melissodes subagilis* Cockerell (Allred 1969). *Baileya multiradiata* is also used as a larval host for *Schinia miniana* Grote, the desert marigold moth (Myles and Binder 1990).

**Tortoise use:** Both species have been recorded as diet plants for desert tortoise in small amounts (<1% of diets) in the eastern Mojave Desert (Esque 1994).

**Propagation, production, and cultivation:** At the USDA Seed Extractory in Bend, Oregon, *B. pleniradiata* seed lots are processed using a Westrup Model LA-H laboratory brush machine, with a #10 mantel, set at medium speed (Barner 2009). Seeds are then air-screened using an office Clipper with a 1/16 round top screen and a 30 × 30 wire bottom screen, set at medium speed (Barner 2009). After cleaning, seeds were stored at 0.5° – 3.3°C. *Baileya* species germinate easily, which is likely due to their lack of dormancy and affinity for disturbed habitat. In a USFS germination study of Chihuahua Desert species, *B. multiradiata* germinated well (>50%) under all treatments but had the highest germination percentages when provided a 3-week warm-moist (30°C) pretreatment (Pendleton and Pendleton 2014). Salvage of adult *B. multiradiata* resulted in 38% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 30% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *Baileya* species readily recolonize disturbances such as those created by wildfire (Abella 2009) and dirt roads (Walker and Powell 1999), contributing to their high performance as restoration species. *Baileya multiradiata* re-seeds prolifically and can be a major contributor to seedling abundance on recovering burned areas (Scoles-Sciulla et al. 2011). There is some concern that *Baileya* used in restoration can preclude other species (Walker and Powell 1999). It would be useful to follow some established stands in restoration areas and observe the fates of such areas.

***Bouteloua* spp. Lag. (Graminaceae)**

**Common names:** *Bouteloua aristidoides* (Kunth) Griseb. – needle grama; *B. barbata* Lag. sixweeks grama; *B. curtipendula* (Michx.) Torr. – side-oats grama; *B. eriopoda* (Torr.) Torr. – black grama; and *B. trifida* Thurb. Ex S. Watson – three-awn grama.

**Functional group and bloom season:** *Bouteloua aristidoides* and *B. barbata* are native, warm season annual grasses that are active in August to September, and August to December; respectively (SEINet 2020). *Bouteloua curtipendula,* *B. eriopoda* are perennial native grasses blooming in May to October *B. trifida* is also a perennial with short rhizomes and blooming March to September.

**Distribution in Mojave/Habitat**: *B. aristidoides* and *B. barbata* are found on dry, rocky to sandy slopes, flats, washes, and disturbed areas below 1800 m and 1700 m, respectively (Columbus 2012a, 2012b). *Bouteloua curtipendula* and *B. eriopoda* both range between 900 m to 1900 m, and occupy dry rocky hillslopes, flats and washes (Columbus 2012c, d). *Bouteloua trifida* also occupies dry rocky, primarily calcareous slopes from 200 m to 1600 m (Columbus 2012e).

**Flower color and shape**: As grasses, all the inflorescences are green, some with reddish tinge as fruits ripen. *Bouteloua a.* var. *aristidoides* has upright inflorescences with widely separated pendant to adpressed branches each having 1 to 4 hairy spikelets with 2-7 mm awns; *B. b.* var. *barbatus* also has upright inflorescences with 2 to 8 widely spaced branches composed of 7 to 40 tightly spaced spikelets each having 2 to 7 mm awns; *B. curtipendula* has straight, upright inflorescences with 13 to 60 evenly spaced pendulus branches each comprised of 1 to 8 glabrous spikelets falling with the branch; *B. eriopoda* inflorescences are upright with 2 to 7 branches each 10 to 40 mm long with branches comprised of 1 to 8 ascending spikelets that are tightly clustered like a comb; and *B. trifida* has upright inflorescences with 1 to 7 widely spaced branches that are 10 to 35 mm long with tightly organized spikelets having 2 to 8 mm awns forming comb-shaped branches along the inflorescences (Columbus 2012e).

**Pollinator use**: All four of the grasses featured in this account are wind pollinated. All five *Bouteloua* spp. in this account are likely to be used by the larvae of the Pahaska skipper (*Hesperia pahaska* Leussler), and the orange skipperling (*Copaeodes aurantiaca* Hewitson*;* Calscape.org 2020).

**Tortoise use:** *Bouteloua barbata, B. trifida,* and *Bouteloua* sp. were noted in anecdotal feeding observations of Mojave desert tortoises.

**Propogation, production, and cultivation**: Recently, commercial venders advertised the availability of *B. aristidoides* (7 vendors), *B. curtipendula* 14 vendors), and *B. eriopoda* (3 vendors) among their supplies of seed (USDA-NRCS 2014). *Bouteloua curtipendula* was second only to *Atriplex canescens* in the number of vendors providing seeds, indicating how popular it is in restoration mixes. Most of the literature on the cultivation and use of *Bouteloua* spp. is dominated by *B. curtipendula*, followed by *B. gracilis* (not addressed because occurs above elevations commonly found in Mojave Desert), and *B. eriopoda*.Most of the information addresses these taxa outside the study region or at higher elevations and thus is not particularly useful for work in the Mojave Desert.

An experimental restoration incorporating *B. aristidoides* and *B. barbata* into a community plot design was established along the Hassayampa River, near Wickenburg, Arizona (Wolden and Stromberg 1997). After a year, plants established best when seeds were hoed into the surface in comparison with no seeding, seeding only, and seeding with hoeing and a mulch amendment.

In contrast to its common name, *B. aristidoides* can form seeds within four weeks of germination below 300 m, but within six weeks above 300 m (Went 1948). In New Mexico, *B. barbata* has a close relationship to kangaroo rats, depending on them for seed dispersal and possibly soil disturbances for germination sites (Brown and Heske 1990). Went (1948) found that *B. barbata* seeds germinated well with warm 8-hour day (27˚ C), and night (26˚ C) temperatures, but did not germinate as well with warm days and cool nights (13˚ C).

**Recoverability**: Because it is rarely found in desert tortoise habitats, it should perhaps be viewed with some skepticism of its wide use in agency seed mixes (e.g., post-fire or disturbance seeding). As annuals, *B. aristidoides* and *B. barbata* would be vulnerable to seed loss by fires, and off-site seed sources would likely be required for natural recovery from such disturbances. As perennials, *B. curtipendula, B. eriopoda*, and *B. trifida* may have some recoverability from fire disturbance. Perennial grasses are valued for their ability to reduce erosion by the establishment of diffuse root systems.

## *Chaenactis fremontii* A. Gray (Asteraceae)

**Common Names:** Fremont pincushion.

**Functional group and bloom season:** Annual forb that blooms between February and May (Morefield 2017).

**Distribution in Mojave/Habitat:** *Chaenactis fremontii* grows in open sandy/gravelly areas below 1600 m throughout the Mojave Desert and is often seen growing up through shrub canopies (Baldwin et al. 2002; Morefield 2017).

**Flower color and shape:** White; involucral heads ligulate.

**Pollinator use:**  Little information was found on pollinator visitors of *C. fremontii*. However, a congener *C. douglasii* (Hook.) Hook. & Arn. of the Intermountain West hosts a large number of bees including *Andrena* Fabricius bees, as well as bees of the Apidae *Bombus, Ceratina* Latreille*, Micranthophora* Orr), Halictidae (*Agapostemon, Lasioglossum* (=*Dialictus*), *Halictus*,andMegachilidae (*Megachile* and *Osmia*; Cane et al. 2012, Orr et al. 2018). In addition to some of those recorded by Cane et al. (2012), Carril et al. (2018) found *C. douglasii* is used by *Dianthidium* spp., *Heriades* Spinolasp*.*, *Stelis carnifex* Cockerell, *Hesperapis* Cockerell sp., *Perdita* spp*.* (two species), *Anthophora* spp. (two species), *Bombus* spp., *Ceratina* spp*.* (three species), *Hylaeus* spp*.* (two species), *Dufourea malacothris* Timberlake, *Megachile* spp. (three species), and *Ashmeadiella* Cockerell sp*ecies* (five species). These plant congeners differ little from one another morphologically, and we speculate that many pollinator species similarly use *C. fremontii*. In springtime, *C. fremontii* is often the most abundant wildflower to be seen in the lower Mojave and upper Sonoran deserts (Morefield 2017). The abundance and the likelihood that it hosts a high number of pollinator visitors make *C. fremontii* an excellent choice for creating pollinator habitat.

**Tortoise use:** *Chaenactis fremontii* is used as forage by desert tortoises in the Mojave Desert (Jennings and Berry 2015; Oftedal 2002).

**Propagation, production, and cultivation:** To clean seeds, rub dried florets on a rubber mat and separate from the chaff with a sieve (Wall and MacDonald 2009). As a desert winter annual and an Asteraceae species, *C. fremontii* likely exhibits physiological dormancy and requires a heat treatment before successful germination can occur (Baskin and Baskin 2014). The desert species *C. fremontii* and *C. stevioides* have both been propagated successfully through direct seeding (Everett and O’Brien 2012).

**Recoverability:** The tendency of *C. fremontii* to grow beneath shrubs may make it more susceptible to seed death from wildfires, as fire temperatures are considerably higher beneath shrub canopies than in the drip line or interspaces (Brooks 2002, Esque et al. 2010). The abundance of this species in the low desert and its production of small, wind-dispersed seeds (Morefield 2017) suggest that this species could rapidly colonize disturbed areas after fires. After the large fire at Joshua Tree National Park in 1999, *Chaenactis fremontii* was prolific in some burned areas, presumably from the lack of competition from the shrubs that had burned the year before (T. Esque, pers. obs.)

## *Chilopsis linearis* (Cav.) Sweet (Bignoniaceae)

**Common Name(s):** desert willow.

**Functional group and bloom season:** Shrub. This species flowers between May and September (Lohmann 2017).

**Distribution in Mojave/Habitat:** *Chilopsis linearis* commonly occurs along sandy washes below 1500 m (Baldwin et al. 2002).

**Flower color and shape:** White to pink, with purple nectar guides; trumpet-shaped

**Pollinator use:** The bees *Apis mellifera* and species of *Anthophora* and *Megachile* pollinate this species (Richardson 2004). *Chilopsis linearis* is also visited by nectar robbing *Xylocopa* bees and *Bombus sonorus* Say, the most consistently effective pollinator of this species, also robs nectar through the base of the flowers (Richardson 2004). Nectar-robbing happens when insects visit a plant and gather nectar without pollinating the flowers, either by causing stigma closure or bypassing the pollen load altogether (Richardson 2004). Several native bees of the genus *Centris* also pollinate *C. linearis* (Wilson and Carril 2016). *Chilopsis linearis* is a larval host for moths of Apatelodidae (*Olceclostera seraphica* Dyar), Geometridae (*Eucaterva variaria* Grote*,* and *Synchlora aerata* Fabricius), Pyralidae (*Satole ligniperdalis* Dyar), Saturniidae (*Automeris iris* Walker), and Sphingidae (*Manduca rustica* Fabricius; Robinson et al. 2010).

**Tortoise use:** The height of *C. linearis* (1.5 m – 7 m, Lohmann 2017) creates the possibility that tortoises may use this species as cover, but this has not been confirmed in the literature, likely due in part to its prevalence within washes and absence in upland habitats. It is also likely that the flowers would be palatable if they were available – as when they fall to the ground.

**Propagation, production, and cultivation:** At the Joshua Tree National Park Native Plant Nursery, seeds of *C. linearis* were collected in the late summer and dried in paper bags at ambient temperature for four to six weeks. After drying and cleaning, the seeds were stored in airtight containers at 7°C. Alternatively, seeds may be stored in wet sand to speed germination; however, because *C. linearis* lacks dormancy, this procedure is not strictly necessary (Young and Young 1986). To germinate, seeds were sown in a 2:1:2 mixture of sand, mulch, and perlite. Osmocote time release fertilizer was also added at a rate of 22 g/6 L. Seeds should be allowed to establish for 2-3 weeks before transplantation to larger containers (29 cm × 7.5 cm) in a growing medium of 2:1:1 sand, mulch, and perlite. After 8-12 weeks, seedlings are again transplanted into larger containers (6 L) containing the same growth substrate, moved to an outdoor growing area, and covered with 55% shadecloth. To acclimate the young plants to the outdoor climate, irrigation frequency and duration is gradually reduced over 4-8 weeks.

*C. linearis* can also be increased for outplanting by using stem cutting procedures, and it was among the best of seventeen trial species using that technique (Wieland et al. 1971).

**Recoverability:** *C. linearis* can be top killed by fire but has demonstrated moderate resprouting ability (Bock and Bock 2014; Brooks and Minnich 2006). Survival through resprouting occurred in 59% of trees in a desert willow population in Santa Cruz County, AZ after one fire; in another site that sustained two successive fires, only 49% survived as resprouts (Bock and Bock 2014).

## *Chylismia* (Nutt.ex Torr. & A. Gray) Ralm. (*=Camissonia* von Chamisso) spp. */ Eremothera* (P.H. Raven) W.L. Wagner & Hoch spp. (Onagraceae)

**Common Names:** *Chylismia brevipes* (A. Gray) – yellow cups; *C. claviformis* (Torr. & Frém.) A. Helle – brown-eyed evening primrose; *E. boothii* (Douglas). W.L. Wagner & Hoch – Booth’s evening primrose.

**Functional group and bloom season:** Annual forbs that mainly bloom in the spring (Wagner and Hoch 2017a). *Chylismia brevipes* blooms from March to May, *C. claviformis* blooms from February to May (Wagner and Hoch 2017 b, c), and *E. boothii* blooms March to June (T. Esque pers. obs).

**Distribution in Mojave/Habitat:** Species of these related genera are widespread in the Mojave Desert. *Chylismia brevipes* occurs mostly in the southern and eastern Mojave Desert, growing in dry washes in creosote scrub and Joshua tree woodland from -70 m to 1800 m (Baldwin et al. 2002). *Chylismia claviformis* grows on alluvial slopes, flats, and in creosotebush scrub between -70 m and 2000 m throughout the Mojave Desert (Baldwin et al. 2002; Wagner and Hoch 2017c).

**Flower color and shape:** Yellow or white; bowl-shaped and cruciform.

**Pollinator use:** Outcrossing occurs for 22 of the 61 known species of *Chylismia /Eremothera* (Raven 1979). Outcrossing *Chylismia* species are pollinated by at least two native bees, *Perdita celadona* Griswold and Miller and *P. vespertina* Griswold and Miller in Clark Co., NV, and many oligolectic bees of the *Andrena* (Raven 1979; Thorp and LaBerge 2005; Griswold et al. 2006). Several Subgenus *Onagrandrena* bees specialize on members of *Chylismia*, including *Andrena blaisdelli* Cockerell, *A. boronensis* Linsley and McSwain, *A. camissoniae* Linsley and McSwain, *A. chylismiae* Linsley and McSwain, *A. deserticola* Timberlake, *A. flandersi* Timberlake, *A. furva* Linsley and McSwain, *A. mojavensis* Linsley and McSwain*,* *A. nevadae* Linsley and McSwain*, A. oenotherae* Timberlake, *A. raveni* Linsley and McSwain*, A. rozeni* Linsley and McSwain, *A. rubrotincta* Linsley*,* and *A. vespertina* Linsley and McSwain(Thorp and LaBerge 2005). *Eremothera boothii* is pollinated by *Andrena rozeni* and *A. vespertina* bees (Thorp and LaBerge 2005). Raven (1979) stated that *Chylismia* are also pollinated by two species of hawkmoth.

**Tortoise use:** *Camissonia andina* and *Chylismia brevipes* were both recorded in the diets of desert tortoise in the northeastern Mojave (Esque 1994). *Chylismia claviformis* was included in an experimental native forb diet treatment for captive juvenile desert tortoises; the tortoises fed a mixed-species diet including this species thrived in comparison to juvenile tortoises fed exotic or native grass diets (Drake et al. 2016).

**Propagation, production, and cultivation:** The seeds of these species are easily cleaned by rubbing the floral material through small to medium-sized screens, then using sieves (#18-25 and #30-40; Wall and MacDonald 2009). Blower speed should not exceed 1.5. As these plants are winter annuals, they germinate under relatively cool/moist conditions, most likely around November/December, so seeding in late fall will coincide with winter rains. In studies of chaparral *Camissonia* species, *C. californica* experienced its highest germination rates when grown at 23°C (Keeley and Keeley 1987) and a dry heat treatment (150°C for 5 minutes) increased germination in *C. hirtella* (Keeley et al. 1985). Germination in *C. californica* is also stimulated by the presence of charred wood extracts (24% increase in germination as compared to control groups; Keeley and Keeley 1987).

**Recoverability:** Although typically a minor component of the annual community, *Chylismia* species density can increase after soil disturbance (Suazo et al. 2012).

***Coreopsis* (*=Leptosyne*) *bigelovii* (A. Gray) H.M. Hall**

**Common Names:** bigelow’s tickseed.

**Functional group and bloom season:** *Coreopsis bigelovii* is a winter annual blooming from February to June (Keil 2012 [as *Leptosyne*]).

**Distribution/Habitat:** *Coreopsis bigelovii* is widespread in the western Mojave Desert from Joshua Tree National Park and including Death Valley National Park (Keil 2012) and occurs outside of non-desert habitats of southern California (Calscape.org 2020). Elevational range is 150 m to 2000 m.

**Flower color and shape:** ray and disk flowers are yellow and have a typical sunflower shape (Keil 2012).

**Pollinator use:** The sunflower budmoth (*Suleima helianthana* Riley (taxonomic authority not in ITIS but in Robinson et al. 2010) and southern emerald moth (*Synchlora frondaria* Guenée in Boisduval and Guenée) likely use *C. bigelovii* as a larval host in the far west and far east of the Mojave Desert, respectively (Calscape.org 2020). The *Xanthothrix ranunculi* Edwards moth was observed in the west Mojave and may also use *C. bigelovii* (Calscape.org 2020).

**Tortoise use:** There is one anecdotal observation of this species being eaten by a wild desert tortoise.

**Propagation, production, cultivation:** This genus is widely used in cultivated gardens, and *C. bigelovii* is available commercially. The species is likely to do well as a restoration plant through cultivation practices for increasing plant materials. Seed production of perennial species is good (NativePlantNetwork.org). Protocols for growing perennial species within the genus are widely available (NativePlantNetwork.org 2020)

**Recoverability:** As an annual, the seeds of *C. bigelovii* are susceptible to fire and would likely require reintroduction from off-site to recover. This species is a good candidate for restoration work.

## *Cryptantha* Leh. Ex G. Don spp. (Boraginaceae)

**Common Names:** *Cryptantha angustifolia* (Torr.) Greene – narrow-leaved forget-me-not, *C. circumscissa* (Hook. & Arn.) I.M. Johnst.; *C. micrantha* (Torr.) I.M. Johnst. – dye cryptanth or purple root cryptanth; *C. nevadensis* A. Nelson & P.B. Kenn. – Nevada cryptanth; and *C. pterocarya* (Torr.) Greene– winged nut forget-me-not.

**Functional group and bloom season:** Annual forbs. Species generally bloom from March to May or June; some (*C. circumscissa* (Hook. & Arn.) I.M. Johnst.) flower later, from July to August (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** *Cryptantha*species are very common, grow mainly in sandy or gravelly soils, and are widespread in the Mojave Desert ecoregion (Baldwin et al. 2002). Some of the most commonly seen species are *C. circumcissa* found from 300 m to 3700 m*, C. micrantha* found growing from 200 m to 2300 m*; C. nevadensis* occurring below 2100 m*;* and *C. pterocarya* found below 2500 m (Baldwin et al. 2002).

**Flower color and shape:** Generally white; salverform/tubular; often very small.

**Pollinator use:** Several species of beeshave been collected on *Cryptantha* spp. (Carril et al. 2018). A few species of *Hoplitis* Klug bees are specialist pollinators of *Cryptantha*, having hooked hairs on their mouthparts (mandibles and clypeus) that assist with pollen removal from the narrow tubes of *Cryptantha* flowers (Wilson and Carril 2016). In south-central Utah there are 57 taxa from 5 families of native bees found using *Cryptantha pterocarya* (Carril et al. 2018). Based on that observation and similar floral anatomy, it seems likely that other *Cryptantha* spp. have many more pollinators than are currently known.

Painted lady (*Vanessa cardui* Linnaeus) butterflies use *C. angustifolia* as a larval host (Robinson et al. 2010). *Ethmia minuta* Clarke (taxonomic authority not consistent with ITIS) moths use *C. circumscissa* as a host for larvae and possibly *E. brevistriga* Clarke (taxonomy also not consistent with ITIS); however, the range of the latter is not confirmed within the Mojave Desert (Calscape.org 2020).

**Tortoise use:** *Cryptantha* species are of great importance in desert tortoise diets, and several species are used for forage across the Mojave Desert (Esque 1994; Jennings and Berry 2015). *Cryptantha micrantha* was the most abundant annual forb in tortoise diets. This annual forb comprised ~ 7% of all the bites among all plant species (and ~13% for native species) documented in Utah, Arizona, and California, although its rank is largely influenced by observations at City Creek, Utah (14,420 bites). With far fewer bites (1%), *C. nevadensis* was ranked twelfth in tortoise diets. This species inhabits gravelly sandy soils across a broad elevational range (150 m – 1800 m; Jaeger 1969) and is less restricted to sandy soils than its congener *C. micrantha* (T. Esque pers. obs.). Combining the other annual *Cryptantha* species that have similar habit (*C. virginensis*, *C. circumcissa*, *C. pterocarya*, and *C. angustifolia*), total bites equal 18,887 (9% of all species and 17% of natives) across six sites, thus highlighting the prevalence of this genus in tortoise diets.

**Propagation, production, and cultivation:** Low growing and compact the seeds are small for *C. micrantha* (0.6-1.5 mm) and *C. angustifolia* (Torr.) Greene (1.0-1.2 mm), which can be acquired by collecting whole plants and rubbing them over #25 and #45 sieves (*C. micrantha*) or #14 and #20 sieves (*C. circumcissa*) with a blower speed of 1.25 (Wall and MacDonald 2009). Larger seeds (2.5-4.5 mm) of *C. virginensis* (M.E. Jones) Payson require larger sieves for separating chaff (#12 and #16) at a higher speed of 2.0 (Wall and MacDonald 2009). Although information on seed ecology or germination requirements is largely unavailable, *C. pterocarya* seeds have physiological dormancy, and germination was optimized with cool day/night temperatures of 15°/6° C (Baskin and Baskin 2014).

**Recoverability:** Natural recovery of these species following wildfire in the northeast Mojave Desert is mixed. In burned habitat *C. circumcissa* and *C. pterocarya* generally have low production and soil seed densities compared with unburned areas. *Cryptantha micrantha* and *C. nevadensis* generally have greater recoverability except when areas repeatedly burn (L. DeFalco, unpubl. data). The congener *C. fendleri* (A. Gray) Greenehas also shown resistance to invasion by cheatgrass (Barak et al. 2015). No information is currently available on success of seeding with *Cryptantha* spp. in the Mojave and Colorado deserts.

## *Dalea* L. spp. (Fabaceae)

**Common Name(s):** *D. mollis* Benth. – hairy prairie clover; and *D. mollissima* Rybd. **–** soft prairie clover.

**Functional group and bloom season:** *D. mollis* and *D. mollissima* are herbaceous annuals that bloom from March to May (McMahon and Isely 2017 a, b).

**Distribution in Mojave/Habitat:** Both species grow below 900 m in creosote flats and in disturbed sites like roadsides and washes in the southern and eastern Mojave Desert (Baldwin et al. 2002).

**Flower color and shape:** White to purple; papilionaceous.

**Pollinator use:** *Dalea* species are widely used as pollinator host species across the United States (Cane 2006; USDA Natural Resources Conservation Service and the Xerces Society 2012). In the Mojave Desert, *D. mollis* and *D. mollissima* provide resources for bees in several genera, including *Ancylandrena* Cockerell*, Anthophora, Centris, Colletes, Eucera, Hesperapis, Martinapis* Cockerell, and *Perdita* (Hurd and Linsley 1975a; Griswold et al. 2006; Wilson and Carril 2016). Some of the *Colletes* bee species are specialists on *Dalea* spp. (Cane 2006). Both *D. mollis and D. mollissima* may be larval hosts for *Colias cesonia* Stoll, the southern dogface butterfly (Stewart et al. 2001), and *Hemileuca burnsi* J.H. Watson moths (Calscape.org 2020).

**Tortoise use:** No information could be found on desert tortoise use of *Dalea* spp.

**Propagation, production, and cultivation:** Like other Fabaceae species, *Dalea* species are physically dormant and require scarification to break seed dormancy (Baskin and Baskin 2014). After treatment of the congener, *D. aurea,* with four scarification methods (control, hot water soak at 90°C for 4 hours; mechanical scarification using the ForsbergR commercial sample scarifier; and a 1 L rock tumbler with grit, set for 2-3 hours). All seeds were immediately planted in 288-cell square deep-plug trays filled with Sunshine #1 Mix and left to germinate in a greenhouse (23°/15°C). The rock tumbler (70% germination) and hot water soak (65% germination) treatments resulted in significantly higher germination rates than that of scarification machine (10%) and control groups (33%; Dreesen and Harrington 1997).

**Recoverability:** The occurrence of *D. mollis* and *D. mollissima* in disturbed habitats (washes, roadsides) suggests that they would be successful early establishment species for restoration projects. When Abella et al. (2015c) used the perennial congener *D. pringlei* in roadside restoration of Saguaro National Park, outplanted seedlings had a 75% survival rate after one year of planting.

## *Dasyochloa* *pulchella* (Kunth) Willd. Ex Rydb. (= *Erioneuron pulchellum*) (Poaceae)

**Common Name(s):** fluffgrass.

**Functional group and bloom season:** *Dasyochloa pulchella* is a small perennial graminoid. Flowers from February to May (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** Fluffgrass grows in sandy to rocky soil on slopes and flats in desert shrubland or woodland from 300 m – 1700 m (Baldwin et al. 2002). It is more common in the eastern than western Mojave.

**Flower shape and color:** Light brown or purple, paleas hairy, organized into dense spikes.

**Pollinator use:** Fluffgrass is wind pollinated. It is a larval host for skipper butterflies, including the Pahaska skipper (*Hesperia pahaska* Leussler), the green skipper (*H. veridis* W.H. Edwards), and possibly the Uncas skipper (*H. uncas* Holland; Robinson et al. 2010).

**Tortoise use:** *D. pulchella* was eaten at two sites and composed 0.3% of desert tortoise diet plants.

**Propagation, production, and cultivation:** Fluffgrass germinates well on a 33°/27°C temperature regime under a 14 hr/10 hr light to dark cycle, and germination success is significantly increased by seed scarification and surface-sowing (Pezzani and Montaña 2006). This species is also stoloniferous and may propagate vegetatively.

**Recoverability:** Fluffgrass colonizes burned areas and other disturbed sites (Vasek 1983; Abella et al. 2007; 2009). The seeds are dispersed by harvester ants in the Chihuahuan (Whitford 1978; Gordon 1993) and Mojave deserts (L. DeFalco, pers. obs.), possibly contributing to recovery of this species in disturbed areas.

## *Descurainia pinnata* (Walter) Britton (Brassicaceae)

**Common Name(s):** pinnate tansy mustard.

**Functional group and bloom season:** *Descurainia pinnata* is an annual forb that blooms between February and July (Al-Shehbaz 2017a).

**Distribution in Mojave/Habitat:** This species colonizes a wide variety of habitats below 2500 m and grows throughout the Mojave region (Baldwin et al. 2002).

**Flower color and shape:** Yellow; cruciform.

**Pollinator use:** *Osmia* bees visit *D. pinnata* at the Nevada National Security Site (formerly Nevada Test Site, Allred 1969). *Descurainia pinnata* is also visited by *Andrena barbilabris*, *A. piperi* Viereck, *A. bruneri* Viereck and Cockerel, *A. nigricula* LaBerge and Bouseman, *Perdita morula* Timberlake, *P. duplonotata* Timberlake, *Ceratina nanula*, *Hylaeus mesillae*, a *Hylaeus* morphotype. a *Lasioglossum* morphotype, *Halictus* *tripartitus* Cockerell, and an *Osmia* morphospecies.

Pinnate tansy mustard is a larval host for butterflies in the Pieridae including: *Anthocharis cethura*; *A. pima* W.H. Edwards; the Sara orangetip butterfly(*A. sara* Lucas); *Euchloe hyantis* W.H. Edwards*; E. Olympia* W.H. Edwards;Becker’s white (*Pontia beckeri* W.H. Edwards); the checkered white(*Pontia protodice* Boisduval & Le Conte; and the western white *P. occidentalis* Reakirt; Robinson et al. 2010; Stewart et al. 2001; and Calscape.org 2020).

**Tortoise use:** Desert tortoises forage on this species in the eastern Mojave (Esque 1994). This species was fifth most abundant among diet species across the range of the tortoise and observed in the diets at four different sites, and present at additional sites across the deserts.

**Propagation, production, and cultivation:** Seeds gathered from plants in the field germinated and grew easily when directly sown for greenhouse experiments (DeFalco et al. 2003). *Descurainia pinnata* exhibits light physiological dormancy and germinates most successfully after stratification in temperatures between 5°- 20°C (Young et al. 1970). These findings are corroborated by a recent study of germination requirements of current and potential restoration species of the Colorado Plateau (Foxx and Kramer 2015). Under all three pre-treatments simulating winter conditions (12 weeks at 1.1°C, followed by germination conditions simulating early, mid, and late spring temperatures), *D. pinnata* seeds experienced germination rates of 50% or better, while treatments without winter conditions had very low germination rates (6-20%). Plants of this species produce numerous, small seeds that may make it suitable in a commercial seed increase setting.

**Recoverability:** Recoverability is unknown, but the incredibly broad distribution, habitat breadth, and prolific seed production of this species suggest that it would perform well in restoration projects.

## *Dietaria (=Machaeranthera) canescens* Pursh (Asteraceae)

**Common Names(s):** tansy-aster.

**Functional group and bloom season:** This species is an annual or herbaceous perennial, and blooms from May to June (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** *Dietaria canescens* extends into mountains of the Mojave Desert (up to 3400 m), particularly to the north and west (Baldwin et al. 2002). Subspecies *D. c.* *leucanthemifolia* Greeneoccurs in desert scrub from 1000 m to 2000 m (Baldwin et al. 2002).

**Flower color and shape:** Involucrate heads of yellow disc flowers and pale purple ray flowers.

**Pollinator use:** Pollinator studies of *D. canescens* in the Mojave Desert are lacking, but in Idaho this species is visited by sweat bees (*Halictus* spp.), green sweat bees (*Agapostemon* spp.), European honeybees (*Apis mellifera*), bee flies (Bombilidae; Tilley et al. 2014). In arid to semi-arid lands of Utah, *Dietaria canescens* was used by 41 bee species (Carril et al. 2018).

The sand aster is a larval host for owlet moths (*Cucullia dorsalis* Smith*, Heliothis phloxiphaga* Grote and Robinson*, Schinia ligeae* Smith)*,* the plume moth (*Hellinsia lacteodactylus* taxonomy not verifiable in ITIS – Chambers *in* Lotts and Naberhaus 2017)*,* and the leafroller moth (*Pelochrista bolanderana –* synonomy not found,taxonomy not provided; Robinson et al. 2010). The cabbage white butterfly (*Pieris* spp.) and the sagebrush checkerspot (*Chlosyne acastus* W. H. Edwards) also is larval hosted by *D. canescens* (Tilley et al. 2014 and Robinson et al. 2010, respectively).

**Tortoise use:** This species has not been documented as Mojave desert tortoise diet or cover.

**Propagation, production, and cultivation:** Seed chilled at 4°C for 35 days had 77% germination (Parkinson and DeBolt 2005). *Dietaria canescens* has demonstrated high field establishment and seed viability (60-90%) when grown in cultivation (Tilley 2015), although seeds are difficult to clean (Tilley et al. 2014).

**Recoverability:** In the Great Basin, this species is an early colonizer of disturbed sites, including burned areas (Koniak 1985; Tausch et al. 1995), and has been described as an effective competitor with the invasive *Bromus tectorum* (Tilley et al. 2014). This species also supports pollinators and resists heavy grazing in other Western landscapes (Hart 2001; Tilley et al. 2013). *Dietaria tanacetifolia* is recommended in seed mixes because the seed has high viability and germination tolerance, and seedlings are less affected by cheatgrass than other native species (Barak et al. 2015). *Dietaria canescens* that was present in the seed bank of semiarid grassland and shrub steppe was released from competition and increased in abundance after cheatgrass was suppressed by the pre-emergent herbicide imazapic (Elseroad and Rudd 2011).

## *Echinocereus* spp. Engelm*.* (Cactaceae)

**Common Name(s):** *Echinocereus engelmannii* (Parry ex Engelm.) Lem*.* – Engelmann’s hedgehog cactus; *E. mojavensis* (Engelm. & J.M. Bigelow) Rümpler (=*triglochidiatus; =triglochidiatus var. mojavensis* – both taxa unaccepted, but frequently used taxa) – claret-cup cactus, Mojave mound cactus.

**Functional group and bloom season:** *Echinocereus* species are stem succulent cacti that flower from May to June in the Mojave Desert (Baldwin et al. 2002).

**Habitat:** This genus grows widely throughout the Mojave and other parts of the desert southwest (Baldwin et al. 2002). Both species are found in a variety of dry habitats (Baldwin et al. 2002). *Echinocereus engelmannii* grows anywhere below 2400 m, and *E. triglochidiatus* grows between 150 m and 3000 m (Baldwin et al. 2002).

**Flower color and shape:** *Echinocereus engelmannii –* pink; funnelform to cup-shaped. *Echinocereus triglochidiatus* – red; tubular.

**Pollinator use:** *Echinocereus* are self-incompatible and require animal pollinators to reproduce (Cota 1993; Simpson and Neff 1987). Because of their large flower size and openness *Echinocereus* species are pollinated by bees of various sizes (Cota 1993; Grant and Grant 1979). This genus undoubtedly is visited by some bees in the genus *Diadasia* (J. Wilson, pers. obs.). Medium-large bees such as *Megachile gentilis* Cresson, *M. casadae* Cockerell*,* and *Apis mellifera* are more effective pollinators of these cacti than smaller bees like *Ceratina nanula,* and *Perdita* species (Grant and Grant 1979). *Echinocereus engelmannii* is principally pollinated by *Ashmeadiella opuntiae* Cockerelland *Megachile gentilis* (Grant and Grant 1979).

*Echinocereus* flowers are also visited by beetles (*Carpophilus pallipennis* Say*, Acmaeodera* sp. Eschscholtz,and *Pteleon brevicornis* Jacoby; Grant and Grant 1979), but these rarely contact the stigma and are thus less reliable pollinators (Cota 1993). The pollination ecology of *E. triglochidiatus* is unusual within its genus because it has red, tubular flowers that are pollinated by hummingbirds (Freeman et al. 1984; Grant and Grant 1967).

**Propagation, production, and cultivation:** *Echinocereus* of many species and variety are identified by the “cactus-collecting” community, and indeed some species have become very rare or nearly extirpated as a result of overzealous collecting (e.g. *Echincereus Lindsayi* in Baja Norte, Mexico). While not as well recognized for the ability to be propagated vegetatively, *Echinocereus* can re-sprout readily from properly prepared stem cuttings (T. Esque, pers. obs.). *Echinocereus engelmannii* seed germinated at a rate of 88% under conditions of 26°C and a 12hr/12hr light to dark cycle (Royal Botanic Gardens Kew 2017).

**Recoverability:** Like other cacti, *E. engelmannii* does not recover well after fire (Thomas 1991). The congener *E. fasciculatus* (Engelm. Ex B.D. Jacks.) L.D. Benson has demonstrated low resprouting potential (3% of individuals) after fire (McLaughlin and Bowers 1982). However, offsets from mature plants may be a successful means of propagating materials for restoration.

## *Encelia* Andans. spp. (Asteraceae)

**Common Name(s):** *Encelia farinosa*A. Gray ex Torr. –brittlebush, *E. frutescens* (A. Gray) A. Gray – button brittlebush.

**Functional group and bloom season:** Shrubs. *Encelia farinosa* blooms from January to June (Keil and Clark 2017a); *E. fructescens* blooms from February to May (Keil and Clark 2017b).

**Flower color and shape:** Yellow. The involucral heads of *Encelia farinosa* are composed of disc and ligulate florets, while those of *E. fructescens* lack ligulate florets. Inflorescences of both species provide pollinators with stable landing platforms.

**Distribution in Mojave/Habitat:** *Encelia farinosa* can be found on rocky slopes below 1000 m throughout the Mojave Desert (Baldwin et al. 2002). *E. fructescens* grows in disturbed areas such as roadsides, washes, and slopes below 800 m in the southern and eastern Mojave (Baldwin et al. 2002; Benson and Darrow 1981).

**Pollinator use:** Bees of genera *Anthidium, Colletes,* and *Megandrena* Cockerell pollinate *Encelia* species (Hurd and Linsley 1975a; Griswold et al. 2006). *Encelia farinosa* is also a larval host for the brittlebush moths: *Bucculatrix enceliae* Braun (Braun 1958, 1963; Robinson et al. 2010) and *Carolella willettana* Comstock (Pierce and Pool 1938).

**Tortoise use:** Despite representing <1% of cover in most undisturbed desert tortoise habitats, it is worth noting that several species in the genus *Encelia* occurring throughout the Mojave and Colorado deserts are used for cover by desert tortoises *Encelia farinosa, E. frutescens, E. actoni* Elmer*,* and *E. virginensis* A. Nelson, (Drake et al. 2015, Supplemental 2), which may make it a suitable genus for habitat restoration. *Encelia farinosa* was the seventeenth most frequently used cover species and had particularly widespread use by tortoises at five sites (Table 3) andwas considered important for desert tortoise cover at the far western extent of their range near Palm Springs, CA (Lovich et al. 2011). *Encelia frutescens* is widespread in the Sonoran and Mojave deserts (Benson and Darrow 1981) and was eaten by tortoises at City Creek, Utah in trace amounts (Table 2).

**Propagation, production, and cultivation:** Hand-harvest has been suggested as the only practical means of seed collection because *Encelia* spp. occupy areas of dry washes and rocky hillsides that were considered too difficult to access any other way (Kay et al. 1977f). However, at least *Encelia farinosa* also occupies extremely disturbed sites such as fallow livestock corrals and may be suitable for cultivation in locations that are more easily collected. Furthermore, because this genus can grow in relatively thick stands, hand collection can be very efficient. Collected floral material for *Encelia farinosa* needs to be very dry before processing using a blower, a #20 sieve, or a rubber mat with wooden block to separate chaff from achenes (Wall and MacDonald 2009). In a study of seed viability of Mojave Desert species under long-term storage conditions, *E. frutescens* and *E. virginensis* had high initial germination rates (73% and 77%, respectively) that were generally retained over ≥ 5 years of sealed storage (Kay et al. 1988). In contrast, *Encelia farinosa* had an initial low germination rate of 1%, which did not change after seven years of storage treatments (Kay et al.1988). Long-term storage (≥ 9 years) for seeds of *E. virginensis* can occur under a range of temperatures (room, 4 °C, -15 °C) with little change in germinability (Kay et al. 1984). Kay et al. (1977f, 1988) also found that optimal germination temperatures for *E. virginensis* range from 10 – 20 °C and at a depth of 1 cm. This genus exhibits physiological dormancy, so seed pretreatment could increase germination success (Baskin and Baskin 2014). Bowers (1994) described 17 mm of rainfall as the required amount of moisture for germination of *Encelia farinosa*. *Encelia farinosa* was among the best in a trial of 17 species to determine if stem cuttings provided a viable alternative to seeding (Wiedland et al. 1971). Salvage of adult *E. virginensis* resulted in 67% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 36% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *Encelia* species are successful colonizers of disturbed sites, mainly due to high rates of seed production, dispersal, and establishment. On a prescribed burn in the Sonoran Desert, *Encelia farinosa* initially sustained an 83% reduction in density post-fire, but in 9 months increased nearly eightfold (762%) above pre-fire densities due to successful seed germination and seedling establishment (Cave and Patten 1984). The congener *E. virginensis* independently establishes in recovering burned areas for decades following wildfires in the Mojave and Sonoran deserts (Lovich et al. 2011; Shryock et al. 2014). *Encelia* spp. may also resprout after disturbance, but this happens infrequently (Rogers and Steele 1980; Brown and Minnich 1986).

## *Ephedra* L. spp. (Ephedraceae)

**Common Name(s):** *E. californica* S. Watson – desert tea; *Ephedra nevadensis* S. Watson– Nevada ephedra; and *E. viridis* Coville – green ephedra.

**Functional group and bloom season:** *Ephedra* species are dioecious shrubs (male and female flowers on different plants). *Ephedra californica* blooms from March through April; *E. nevadensis* has cones from March to June; and *E. viridis* has cones from February to June (Ickert-Bond 2017).

**Distribution in Mojave/Habitat:** *Ephedra californica* can be found in creosote scrub, grassland, and chaparral below 900 m in all but the northeast portion of the MojaveDesert (Ickert-Bond 2017). *Ephedra nevadensis* grows in creosote scrub and Joshua tree woodland below 1100 m throughout the Mojave (Ickert-Bond 2017)*. Ephedra viridis* grows in creosote scrub, sagebrush scrub, and pinyon-juniper woodlands in the higher elevations of the Mojave (90 m – 2300 m; Ickert-Bond 2017).

**Flowers color and shape:** *Ephedra* are gymnosperms and do not flower, but produce dioecious, axillary cones (Ickert-Bond 2017).

**Pollinator use:** *Ephedra* species are wind-pollinated gymnosperms but are larval hosts for *Saturniidae* Boisduval moths (*Hemileuca chinatiensis* Tinkham, and *H. griffin* Tuskes; Robinson et al. 2010).

**Tortoise use:** Several species of the genus *Ephedra* were used by tortoises for cover (Table 3). *Ephedra* *nevadensis* was the third most abundant cover plant used by the Mojave desert tortoise and was used at eight of nine sites (Table 3).This species was also preferred by tortoises for cover significantly more than other species in undisturbed habitat (Nussear 2004). By combining occurrences across all *Ephedra* spp., this genus comprises (> 5%) of tortoise use at all nine sites (Table 3). *Ephedra californica* is the fifteenth most frequently used cover plant and only used for cover at Ft. Irwin, California; *E. viridis* is ranked twentififth and used at Ft. Irwin and St. George, Utah. *Ephedra* spp. were documented in tortoise diets at City Creek, Utah and Littlefield, Arizona (Table 1) but these aphyllus, evergreen shrubs are unlikely influential in tortoise diet..

**Propagation, production, and cultivation:** Initial seed germinability can be high for *E. californica* (89%), *E. nevadensis* (68%) and *E. viridis* (38%) but declines under long-term storage (≥ 9 years) even under dry sealed conditions; cold storage at -15 °C preserves germinability compared with warmer storage conditions (Kay et al. 1984). Germination for *E. nevadensis* is optimal at 20 °C at 1 cm depth (Kay et al. 1977g), and freezing temperatures may promote seed germination (Kay et al. 1988). Propagation of *E. nevadensis* may be an economical use of seed, as outplanted nursery-raised seedlings have demonstrated > 50% survival over 3.5 years (Scoles-Sciulla et al. 2015). However, seedlings may be vulnerable to small mammal herbivory. Imazapic-containing herbicide treatments used to suppress competitive exotic annual grasses have also reduced survival of outplanted *E*. *nevadensis* seedlings (Scoles-Sciulla et al. 2015). Bulk collections of seeds during mast years may be cleaned by running the material through a fanning mill equipped with a #12 top screen and a #1/12 bottom screen (Kay et al. 1977g). In trials to determine if plant materials for *Ephedra* spp. could be increased by using stem cutting from wild stock, *Ephedra* did not perform well (Everett et al. 1978), but the authors note that better handling of the materials might improve results. Salvage of adult *E. torreyana* resulted in 15% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 36% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** Although *Ephedra* spp. do not recover well when the root crown is injured, resprouting and long-term recovery is possible when fire intensity is low (Shryock et al. 2014). *Ephedra californica* does not recover as well in burned areas, compared with its congeners. The smooth, hard-coated seeds of these *Ephedra* spp. are too large for wind-dispersal and are distributed by rodents (Hollander et al. 2010). Seeds have also been found at the edge of harvester ant mounds at the Nevada National Security Site (T. Esque, pers. obs.) and may be subject to ant predation by large harvester ants (i.e., *Pogonomyrmex rugosus* Emery). Because *E. nevadensis* is a masting species (Meyer 2008) with sporadic flowering, it is not considered a good candidate for commercial production by growing parent plants, but its value in the community is worth some extra effort.

## *Chrysothamnus* spp. and *Ericameria spp.* (Asteraceae)

**Common Name(s):** *Chrysothamnus* spp*. and**Ericameria* spp. are known collectively as rabbitbrush or goldenbush. *Chrysothamnus viscidiflorus* (Hook.) Nutt. – yellow rabbitbrush*; E. laricifolia* (A. Gray) Shinners – turpentine-brush (*E. larcifolia* should not be confused with *Thamnosma montana* Torre. & Frem. – turpentine bush, a.k.a. turpentine broom); *E. linearifolia* (DC.) Urbatsch & Wussow(=*cooperi*) – interior goldenbush; *E. nauseosa* var*. hololeuca* (A. Gray) G.L. Nesom & G.I. Baird – white rabbitbrush; *E. n.* var*. mohavensis* (Greene) G.L. Nesom & G.I. Baird – Mohave rabbitbrush;and *Ericameria paniculata* (A. Gray) Rydb. – black-banded rabbitbrush.

**Functional group and bloom season:** Shrubs. For *Chrysothamnus viscidiflorus* flowering occurs July to September*; E. laricifolia* September to October; *E. linearifolia* March to June*; E. n.* var. *hololeucus* and *E. n. var. mohavensis* flower August to October*,* and *E. paniculata* June to December (Urbatsch 2012a-g).

**Distribution in Mojave/Habitat:** *Ericameria laricifolia* grows in woodlands and shrublands from 1000 m to 2000 m. *Ericameria linearifolia* is found in valleys and rocky slopes from 300 m to 2000 m (Urbatsch 2012c). *Ericameria n.* var. *mojavensis* is found in dry scrub between 400 m and 2400 m, and *E. n.* var. *hololeucus* grows in well-drained granitic or limestone soils in a slightly broader elevation range (15 m – 2500 m; Baldwin et al. 2002). *Ericameria paniculata* grows in gravel washes from 400 m to 1600 m (Urbatsch 2012g). *Chrysothamnus viscidiflorus* grows at higher elevations in desert mountains from 900 m to 4000 m.

**Flower color and shape:** Yellow; involucral heads mainly of disc florets, with sparse ligulate florets; involucral heads organized in tight panicles.

**Pollinator use:** Rabbitbrush are important because they are among the few plant taxa that provide desert pollinator nectaring sites during late summer and fall (Scheinost et al. 2010; Martin Oliver, Bureau of Land Management, Bishop Field Office, pers. comm*.*, 28 Feb 2017). In south-central Utah *Ericameria nauseosus* was ranked number one by the number of insect visitors among plants considered as bee attractants (Carril et al. 2018). At the Nevada National Security Site (formerly Nevada Test Site), *Ericameria paniculata* is associated with bees such as *Lasioglossum* *albohirtum* and *Perdita callicerata* Cockerell*;* the closely related *Chrysothamnus viscidiflorus* is associated with *Dianthidium pudicum* Cresson*, D. subparvum* Swenk*, Hylaeus asininus* Cockerell & Casad*, Lasioglossum sisymbrii* Cockerell*,* and *Melissodes subagilis* (Allred 1969). Bees of genera *Colletes* and *Perdita* also visit southwestern *Ericameria* spp. (Hurd and Linsley 1975a; Griswold et al. 2006).

Rabbitbrush provide nectar to the juba skipper (*Hesperia juba* Scudder; photo, SoCalButterflies.com), and are larval hosts for sixteen other species of Lepidopterans (Robinson et al. 2010; Scheinost et al. 2010), including the Mormon metalmark (*Apodemia mormo* Felder and Felder), *Chlosyne californica* W.G. Wright, skippers (*Hesperia* sp. Fabricius), fritillaries (*Speyeria* spp. Scudder), and the painted lady (*V. cardui*). *Ericameria nauseosa* is used by small [*Gnorimoschema octomaculell*a](https://www.nhm.ac.uk/our-science/data/hostplants/search/detail.dsml?PK_MainID=11357&PSpeciesqtype=starts+with&PGenus=Ericameria&PFamilyqtype=starts+with&sort=Family&Familyqtype=starts+with&Speciesqtype=starts+with&Genusqtype=starts+with&PGenusqtype=starts+with&beginIndex=7&listPageURL=list%2edsml%3fPSpeciesqtype%3dstarts%2bwith%26PGenus%3dEricameria%26PFamilyqtype%3dstarts%2bwith%26sort%3dFamily%26Familyqtype%3dstarts%2bwith%26Speciesqtype%3dstarts%2bwith%26Genusqtype%3dstarts%2bwith%26PGenusqtype%3dstarts%2bwith&searchPageURL=index%2edsml%3fGenusqtype%3dstarts%2bwith%26Familyqtype%3dstarts%2bwith%26PFamilyqtype%3dstarts%2bwith%26PGenusqtype%3dstarts%2bwith%26sort%3dFamily%26PSpeciesqtype%3dstarts%2bwith%26Speciesqtype%3dstarts%2bwith%26PGenus%3dEricameria) Chambers moths (taxonomic authority from Lotts and Naberhaus 2017)*,* the noctuid moths(*Schinia tertia* Grote, *S. unimacula* Smith, *S. walsinghami* H. Edwards), and the northern checkerspot butterfly (*Chlosyne* *palla* Boisduval) (Robinson et al. 2010). *Ericameria linearifolia* hosts the noctuid moths *Plagiomimicus tepperi* Morrison and *Cucullia dammersi* McDunnough. *Ericameria paniculata* is host to the noctuid moths *Schinia tertia* and *S. waslinghami*, as well as the *C. palla* butterfly. *Ericameria laricifolia* is host to the *Schinia argentifascia* Barnes and McDunnough in the Noctuidae.

**Tortoise use:** *Ericameria* spp. were used by tortoise for cover at one site. This genus is not used by desert tortoise as forage.

**Propagation, production, and cultivation:** To clean *Ericameria* seeds, gently rub dry floral material either over a rubber mat or through an appropriately sized screen and use a blower set at 1.25 to clear away chaff (Wall and MacDonald 2009). Although untreated *E. nauseosa* seeds from most sources germinate well at warm temperatures (≥ 30°C), this species experiences its highest rate of germination at 30°/15°C after fourteen days of dry storage at 2-5°C (Khan et al. 1987; Sabo et al. 1979; Rosner and Harrington 2007). This cold treatment presumably increases germination rate by breaking physiological dormancy (Baskin and Baskin 2014). It should be noted that *E. nauseosa* is a wide-ranging species, and because seed dormancy and stratification requirements vary among ecotypes, seeds from increasing altitude and latitude may need longer cold treatments to germinate successfully (Rosner and Harrington 2007). An alternative to a cold stratification treatment is a six-hour soak in water to remove inhibitors (Graham 2004a). Sabo et al. (1979) found that this species germinated better in light than in darkness, while Khan et al. (1987) found no light-related differences in germination rate. *Chrysothamnus* sp. did not root well in trials to attempt increasing plant materials from stem cuttings (Everett et al. 1978); however, the researchers noted that better material handling techniques might improve outcomes. Varieties of *E. nauseosa* are found in at least 14 nurseries in California (Calscape.org 2020). Like *E. nauseosus*, *C. viscidiflorus* is highly variable, and requires further consideration of ecotypes for matching appropriate habitats.

**Recoverability:** *Ericameria* species recover moderately well after fires. In one study, *E. laricifolia* density was significantly lower in burned than in unburned plots (116 plants/0.5 ha in unburned plots, 25 plants/0.5 ha in burned plots); however, all surviving plants had also successfully resprouted (Wilson et al. 1995). There was extensive volunteer establishment of *E. nauseosus* ssp. *hololeucus* along the second Los Angeles Aquifer (Kay 1979). *Ericameria* species have small seeds that are wind-dispersed (Royal Botanic Gardens Kew 2017), suggesting high potential for recolonization of disturbed sites (Shryock et al. 2014).

## *Eriogonum* Michx. spp. (Polygonaceae)

**Common Name(s):** This genus is known collectively as the wild buckwheats.

*Eriogonum fasciculatum* Benth. – California buckwheat; *E. inflatum* Torr. & Frém. – desert trumpet; *E. maculatum* A. Heller – red-spotted wild buckwheat*; E. thomasii* Torr. – Thomas’ buckwheat (*E. f.* var. *flavorviride* Munz & I.M. Johnst., and *E. f. polifolium* (Benth.) Torr. & Gray). Other congeners with limited pollinator information include; *E. corymbosum* Benth. – crispleaf buckwheat *E. deflexum* Benth. – skeleton buckwheat; *E. gracillimum* S. Watson - rose and white wild buckwheat; *E. pusillum* – yellow turbans; and *E. wrightii* Benth. *–* bastard sage.

**Functional group and bloom season:** Annual and perennial forbs, and shrubs. Most species are summer-blooming (Reveal and Rosatti 2017). *Eriogonum fasciculatum* is a woody shrub that flowers year-round (Reveal and Rosatti 2017); *E. inflatum* is an herbaceous perennial and flowers year-round; *E. maculatum* is an annual that flowers from April to November; and *E. thomasii* is an annual that flowers year-round (Reveal and Rosatti 2017).

**Distribution in Mojave/Habitat:** The *Eriogonum* spp. are a diverse and widespread genus with 67 species in California’s Mojave Desert (Baldwin et al. 2002). *Eriogonum fasciculatum* is common and found on dry slopes, washes, and canyons below 2300 m in sandy/gravelly soils on flats and slopes below 2000 m (Baldwin et al. 2002). *Eriogonum inflatum* grows on sandy to gravelly soil from 80 m to 1800 m. *Eriogonum thomasii* can be found growing in sandy/gravelly soils from -61 m to 1300 m, and *E. maculatum* is found in clay-dominated soils as well as sandy and gravelly flats from 100 m to 2500 m (Baldwin et al. 2002).

**Flower color and shape:** White, pink, or yellow; stellate and saucer-shaped; inflorescence is an umbel.

**Pollinator use:** *Eriogonum* spp. are larval hosts and sources of pollen and nectar to a wide variety of insect fauna (Montalvo 2004; Montalvo and Beyers 2010; Young-Mathews 2012). The most frequent native bee visitors include *Lasioglossum*, *Hylaeus, Halictus,* and *Perdita.* Other native bee genera that use *Eriogonum* are *Andrena, Ashmeadiella,* *Centris*, *Colletes, Exomalopsis, Hesperapis, Heriades, Megachile,* and *Nomia* (Adamson et al. 2014; Allred 1969; Hurd and Linsley 1975a; Griswold et al. 2006; Moldenke and Neff 1974). Wild buckwheats are also visited (and presumably pollinated) by Bombyliidae flies (*Villa, Toxophora, Geron* (taxonomy not available), *Exoprosopa,* and *Epacmus (=Leptochilus*), non-Bombyliidae flies in the *Tachinidae* (*Paradidyma* sp. Brauer and Bergenstamm.), wasps (*Vespula* Thomson*, Philanthus* Fabricius, *Oxybelus* Latreille*, Eucerceris* Cresson, *Isodontia* Patton), and Coleoptera beetles (*Mordella* Linnaeus; Moldenke and Neff 1974).

*E. fasciculatum* hosts moths represented by five families including: Geometridae (*Chlorochlamus appellaria* Pearsall, blackberry looper moth – *Chlorochlamys chloroleucaria* Guenée in Boisduval and Guenée, *Nemoria leptalea* Ferguson, *Pero macdunnoughi* Cassino and Swett*,* the wavy-lined emerald moth – *Synchlora aerata,*  *Gloveria gargamelle* Strecker (MPG), and *Gloveria medusa* Strecker (MPG);Noctuidae (*Dichagyris variabilis* Grote, *Aplectoides condita* Guenée, *Triocnemis saporis* Grote, *Toripalpus trabalis* Grote(taxonomic authority not confirmed), Burns’ buckmoth – *Hemileuca burnsi* J.H. Watson, electra buckmoth – *Hemileuca electra* W.G. Wright, and Neumo’gen's Buckmoth – *Hemileuca neumoegeni* H. Edwards); Sesiidae (clear-winged moths) *Synanthedon polygoni* Edwards, *Artyrotaenia citrana* Fernald; Saturniidae Boisduval; and Tortricidae (Adamson et al. 2014; Robinson et al. 2010; Stewart et al. 2001). Powell and Hogue (1979) also stated that California desert buckwheats host the Nevada buck moth (*Hemileuca nevadensis* Stretch). *Eriogonum inflatum* is also a host plant for moths of the Gelechiidae; Noctuidae (*Triocnemis saporis*, and *Synanthedon polygoni* Edwards); and Sesiidae (Robinson et al. 2010; Stewart et al. 2001).

Butterflies that use *E. fasciculatum* include the ‘blues’ and ‘hairstreaks’ of the Lycaenidae: Bramble hairstreak, blue copper (*Chalceria heteronea* Boisduval), Acmon blue butterfly (*Plebejus acmon)* and thelupine blue (*P. lupini* Boisduval); the Bernardino blue (*Euphilotes bernardino* W. Barnes and McDunnough) and other varieties of that species, and a complex of metalmark butterflies with species flying in spring and fall (*Apodemia virgulti* Behr and *A. mormo*; respectively; Robinson et al. 2010; D. Walker, SoCalButterflies.org). The dainty sulphur (*Nathalis iole* Boisduval), common buckeye (*Junonia coenia* Hübner *(=grisea*)), and gray hairstreak (*Strymon melinus* Hübner) also nectar on *E. fasciculatum* as do many other butterfly species (photos, D. Walker, SoCalButterflies.com accessed 7 Dec 2019). Butterflies that use *E. inflatum* include the gossamer-winged butterflies such as *Chionodes dammersi* Keifer (CoL), and square-spotted blues (*Euphilotes* *battoides* Behr; Robinson et al. 2010). *Eriogonum corymbosum* Benth. host the Mormon metalmark butterfly (*Apodemia mormo*), Sheridan’s hairstreak (*Callophrys sheridanii* W. H. Edwards), western dotted blue butterfly (*Euphilotes battoides*), Pacific dotted-blue butterfly (*Euphilotes* *enoptes* Boisduval), and the Acmon blue (*Plebejus acmon*) (Robinson et al. 2010)*.* *Eriogonum deflexum* is used by the Mormon metalmark butterfly (*A. mormo*). *Eriogonum wrightii* is also a host to the Mormon metalmark (*A. mormo*), the Bramble hairstreak (*Callophrys dumetorum*), pacific blue-dotted hairstreak (*Euphilotes enoptes*), *Plebejus acmon*, and the veined blue butterfly *Plebejus (=Icaricia) neurona* Skinner (Robinson et al. 2010).

**Tortoise use:** Four species of this genus (*E. fasciculatum, E. inflatum, E. maculatum,* and *E*. *thomasii*) are used in desert tortoise diets in the northeastern Mojave Desert (Esque 1994). *Eriogonum fasciculatum* was used for cover at three sites, and *E. inflatum* at two sites, although the latter does not provide deep shade (Table 3).

**Propagation, production, and cultivation:** Many desert *Eriogonum* species have low seed set (Wall and McDonald 2009). Seeds are separated from the floral involucres by rubbing material through a screen (#16 – 35) then clearing away the chaff with a blower (Wall and McDonald 2009). Some *Eriogonum* species have physiological dormancy (*E. fasciculatum*) while others are nondormant (*E. abertanium* Torr.; Baskin and Baskin 2014), but species of this genus generally tend to store well (Kay et al. 1988). Emery (1964) found that several species, including *E. fasciculatum*, germinate without pretreatment, although it is recommended that seeds be stored at temperatures of 0.5°-3.3°C (Barner 2007). Kay (1984) found that *E. fasciculatum* germinates best at 15°C. Salvage of adult *E. inflatum* resulted in 28% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 27% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *E. fasciculatum* grows in fire-adapted chaparral habitat, where many shrub species resprout after fires (Caprio 1994), and *E. wrightii* Torr. *ex* Benth. has been classified as a fire-tolerant re-sprouter (Caprio 1994). In a fire study on vegetation communities in the Tonto National Forest, *E. fasciculatum* had no resprouts or new seedlings on burned plots a year after a fire (Wilson et al. 1995); however, in desert environments this is not an unlikely outcome for a perennial species after such a short time period.

## *Euphorbia* L. *spp.* (Euphorbiaceae)

**Common Name (s):** *Euphorbia albomarginata* Torr. & A. Gray – rattlesnake sandmat; *E. micromera* Boiss. ex Engelm. – Sonoran sandmat; and *E. parryi* Engelm. – Parry’s spurge.

**Functional group and bloom season:** The genus *Euphorbia* are comprised of annual and perennial forbs. *Euphorbia albomarginata* is an herbaceous perennial blooming April to November; *E. micromera* is an annual blooming April to June and possibly again in September through December; and *E. parryi* blooms May to June (Keil et al. 2017).

**Distribution in Mojave/Habitat:** *Euphorbia albomarginata* grows in open places and slopes in sandy/gravelly soil below 2300 m and is widespread throughout the Mojave Desert (Baldwin et al. 2002). *Euphorbia micromera* is found in flats, washes, and bajadas between 152 m and 1524 m, and *E. parryi* grows on sand dunes below 700 m (Baldwin et al. 2002).

**Flower color and shape:** The flowers of *Euphorbia* are characterized by the presence of a cyathium, an aggregation of the male and female flowers that is surrounded by a petaloid floral envelope. Both the male and female flowers are highly reduced, with the males composed of a single anther, filament, and pedicel, and the female flowers of a pedicel and a prominent, three-parted ovary. Cyathia greatly differ among *Euphorbia* species, with some that are larger and more flower-like (e.g., *E. albomarginata*) and some that are very small, without well-developed petaloid features (e.g., *E. micromera*). As its name suggests, the color of the *E. albomarginata* flower is mostly white with a rusty-red center.

**Pollinator use:** Some Euphorbias have a mat-forming growth habit and large cyathia that are ideal for effective “mess and soil” pollination, in which pollen is distributed from male to female flower parts by the movement of insects walking over the plant (Ehrenfeld 1979). *Euphorbia albomarginata* attracts a considerable number of pollinator species, ranging through the orders Apoidea (bees), Diptera (flies), and Coleoptera (beetles; Ehrenfeld 1979; Wilson and Carril 2016). *Euphorbia parryi* is visited by *Lasioglossum clematisellum* Cockerell, *Neolarra cockerelli* Crawford,and *Perdita dilecta* Timberlake bees (Carril et al. 2018). The dainty Sulphur (*Nathalis iole*) butterfly nectars on *E. albomarginata* (photos– SoCalButterflies.com accessed 7 Dec 2019).

**Tortoise use:** *Euphorbia albomarginata* was the ninth most heavily used diet species and found in diets at four sites including southern Nevada, the east and west Mojave Desert, and the Colorado Desert (Table 2). *Euphorbia micromera* is also found in diets of tortoises in the northeast Mojave Desert, as well as *E. parryi* (Esque 1994).

**Propagation, production, and cultivation:** Little information exists on *Euphorbia* seed ecology and germination biology. Small seed size and short or prostrate nature make seed collection of *Euphorbia* spp. challenging. It is possible that *Euphorbia parryi* disperses its seeds ballistically (Ehrenfeld 1979); seed collection must be pre-planned accordingly. In a study of germination requirements for Colorado Desert species, *E. micromera,* a summer annual, germinated successfully when seeded in flats and kept in a 27°/26°C diurnal temperature regime (Juhren et al. 1956; Gutterman 1994). Clean the seeds by rubbing dried floral parts over an appropriately sized screen (Wall and MacDonald 2009).

**Recoverability:** The tendency of *E. albomarginata* to grow in disturbed areas and its vegetative growth pattern may help it establish after fires. Furthermore, the mat–forming growth pattern may be beneficial to reduce rain splatter and additional erosion in burned areas. However, we found no studies documenting this species in burned areas.

## *Festuca (=Vulpia) octoflora* Walter(Poaceae)

**Common Name(s):** sixweeks fescue.

**Functional group and bloom season:** Sixweeks fescue is a short annual grass that flowers from March to June (Smith and Aiken 2017).

**Distribution in Mojave/Habitat:** *Festuca octoflora* grows in sandy soils along washes, hills, and in chaparral below 2000 m; it occurs throughout the Mojave Desert (Baldwin et al. 2002).

**Flowers color and shape:** The flowers are organized into a panicle of tight spikelets; the florets are awned (Smith and Aiken 2017).

**Pollinator use:** Like other grasses, *F. octoflora* is wind pollinated. We found no information on its use as a larval host plant in the Mojave Desert: however, other *Festuca* species including some found in the USA are larval hosts to Lepidoptera (Robinson et al. 2010).

**Tortoise use:** *Festuca octoflora* was the fifteenth most abundant among diet species, and this species is widely used as it was found in diets at four sites across the desert. However, juvenile desert tortoises fed diets of only *F. octoflora* did not grow as well as those fed a mixed diet of *F. octoflora* and native forbs (Drake et al. 2016), suggesting the importance of providing a diversity of herbaceous plant taxa when restoring tortoise habitats.

**Propagation, production, and cultivation:** Horticulturalists at the Kew Royal Botanic Gardens found that *F. octoflora* germinates best at 20°C (Royal Botanic Gardens Kew 2017).

**Recoverability:** Sixweeks fescue sometimes recovers well from soil disturbance (Suazo et al. 2012) as well as low-intensity fires, like those used in prescribed fire (Cave and Patten 1984). Increase in abundance in response to herbicide treatments suggests it may be a suitable restoration species in severely degraded habitat (Steers and Allen 2010).

***Grayia spinosa* (Hook.) Moq.**

**Common Name:** spiny hopsage.

**Functional group and bloom season:** This is a long lived woody shrub blooming March through June.

**Distribution in Mojave/Habitat:** Spiny hopsage is distributed broadly throughout the intermountain western United States, and within the Mojave Desert (SEINet.org 2020). *Grayia spinosa* occupy sandy, to gravelly to cobbly soils inupper bajadas to valley bottom in desert shrub communities at elevations from 33 m to 2900 m (Wetherwax and Wilken 2012).

**Flowers color and shape:** The staminate flowers are green, and the pistillate flowers have a pink bract that enlarges and grows deeper in color after pollination.

**Pollinator use:** *Grayia spinosa* is a larval host to the *Perizoma custodiata* Buenee in Boisduval and Guenee moth (Calscape.org 2020).

**Tortoise use:** *Graya spinosa* was observed one time anecdotal as food for a Mojave desert tortoises, and was used for cover four times at one site.

**Propagation, production, and cultivation:** This species has received a surprising amount of attention in the literature.*Grayia spinosa* can be propagated from seed, stem cuttings from wild plants, or stems cuttings from nursery stock (Wieland et al. 1971; Everett et al. 1978; Shaw 1992). Growing *G. spinosa* from seed can be successful (Shaw 1992). Best germination and establishment results were found in association with cool moist growing conditions similar to those in the fall or early winter seasons. There was low germination in early and late spring, likely associated with low precipitation. Seedbeds with roughened conditions had better germination success than those in compacted seedbeds.

*G. spinosa* and 17 other desert species on the ecotone between the Mojave Desert and Great Basin were propagated from field collected stem cuttings or from cuttings from glasshouse grown seedlings that were chilled to 4˚ C prior to tissue collections (Wieland et al. 1971). Stems were rooted in vermiculite and subjected to five environmental treatments including: a mist house; lath house; glasshouse; bottom-heated glasshouse which was open to outside air (low humidity); and closed bottom- heated glasshouse (high humidity). Ambient temperatures for each treatment ranged from daytime temperatures 20 ˚ to 30˚ C, and nighttime 10 ˚ to 20 ˚ C (Wieland et al. 1971). The most successful stem cuttings were treated with 0.3% IBA in talc matrix (Hormidon 2 treatment) and grown in vermiculite under humid conditions (Wieland et al. 1971).

Everett et al. (1978) used the same rooting hormone as Wieland et al. (1971) with *G. spinosa* and 54 other desert shrub species. They experimented on the rooting ability of six different phenological stages of wild collected materials, four types of cutting material (softwood, semi-hardwood, hardwood, and root shoots), and did not use subsurface heating in the treatments (Everett et al. 1978). *Grayia spinosa* was very responsive to stem propagation, and cuttings of semi-hardwood from vegetatively productive or reproductively active plants had the best rooting success (Everett et al. 1978). Results also varied by accession: large stock within 3 to 12 weeks of planting were comparable to plants that would take 6 months to develop from seed. Comparison of the root to shoot ratio between stem-propagated and seed-propagated ensures that the rapidly grown cuttings have sufficient root development to meet the rigors of desert conditions.

**Recoverability:** *G. spinosa* can resprout readily after fire and thus is recommended for aridland reclamation, and cheatgrass remediation (Sanderson and Stutz 1994). *Grayia spinosa* also has mild to moderate soil salinity tolerance (Sanderson and Stutz 1994). While it is recommended for restoration, it may be killed by excessive heat during wildfires (Webb et al. 2003).

***Gutierrezia* Lag. spp. (Asteraceae)**

**Common Name(s):** *Gutierrezia microcephala* (DC.) A. Gray – sticky snakeweed; *G. sarothrae* (PUrsh) Britton & Rusby – broom snakeweed.

**Functional group and bloom season:** *Gutierrezia microcephala* flowers from July to November, and *G. sarothrae* flowers from May to October.

**Distribution in Mojave/Habitat:** *Gutierrezia microcephala* is distributed broadly across the Mojave, Sonoran, and Chihuahuan deserts and beyond in the western USA and Mexico (SEINet 2020). Sticky snakeweed occurs on sandy to gravelly soils on bajadas and montane slopes frequently in disturbed areas with an elevational range from700 to 2500 m. *Gutierrezia microcephala* blooms from July through December (SEINet 2020).

*G. sarothrae* is more broadly distributed than *G. microcephala* west of the Great Plains from Sinaloa, Mexico to the Canada border. It inhabits open rocky slopes from 50 m to 2900 m elevation, and flowers from July through November (SEINet 2020).

**Flowers color and shape:** Flowers of *G. microcephala* and *G. sarothrae* are yellow (Keil and Lane 2012).

**Pollinator use:** While several Lepidopteran spp. may use the *Gutierrezia* spp., the range of *G. microcephala* and *G. sarothrae* are sufficiently large that the moths use *Gutierrezia,* but they do so outside the Mojave Desert. However, *Cucullia pulla* Grote moths, and dusty raisin moths (*Ephestiodes gilvescentella* taxonomy not ITIS) likely use both species.

Carril et al. (2018) found 104 taxa of native bees using *G. sarothrae*, and an additional 4 species using *G. microcephala*.

**Tortoise use:** *Gutierrezia* sp. was observed in bite counts at one site. *Gutierrezia sarothrae, G. microcephala* and *Gutierrezia* sp. were used infrequently for cover by Mojave desert tortoises at three sites.

**Propagation, production, and cultivation:** *Gutierrezia* spp. are broadly considered increasers on disturbed lands for ~ 100 years. Arizona Flora (Kearney and Peebles 1960) described *Gutierrezia sarothrae* as “worthless” and ‘not even good to reduce soil erosion’. In a more recent publications *G. sarothrae* was referred to as a “poisonous half-shrub” (Jacoby et al. 1982)*.* Most of what we know about *Guttierrezia* biology comes from research designed to understand vulnerabilities in its life history characteristics in order to eradicate it from western landscapes. Campbell and Bomberger (1934) provided an alternative view nearly a century ago when they stated, “Many ranchmen believe that *Gutierrezia* will crowd out the valuable forage grasses on the range. This opinion results from failure to recognize over-utilization and ignoring the fact that on grass ranges, the unpalatable *Gutierrezia* plants are subject to little foliage removal by cattle, while the palatable grasses, when overutilized, sometimes are eaten to within a half inch of the soil surface”. Current views are shifting in regard to the role *Gutierrezia* spp. may play in landscape ecology. Given the environmental and social challenges of restoration in the Mojave Desert, some resource managers currently take a stance that any native is better than non-natives, and although *Gutierrezia* monocultures are not the management goal, it may take some time to return to resilient long-lived natives. *Gutierrezia* spp. still may reduce wind and water erosion in the short-term restoration processes, and more attention should be given to understanding ecosystem function in this regard.

Neither of the *Gutierrezia* spp. are palatable to livestock, and G. *sarothrae* is considered toxic. Although native, *Gutierrezia* spp. are characterized as aggressive invading species – but in fact there is evidence that *G. microcephala* seedlings do not compete well with perennial bunchgrasses (Thacker et al. 2009). Percent germination of *G. sarothrae* was very low to zero at temperatures ≤ 10 ˚C, or > 32.2 ˚C, and when mannitol induced water stress was at or below -0.24 MPa (i.e. zero germination at -1.2 MPa; Kruse 1970). *Gutierrezia sarothrae* seeds had germination rates of > 50 % when mannitol induced water stress was low (i.e., values of ≥ -0.24 MPa), and as high as 90 % with zero water stress (e.g. using distilled water at 0 MPa; Kruse 1979). At temperatures of 60 ˚C and 70 ˚C, *G. sarothrae* took less than 6 days to germinate and as few as 4.6 days under the lowest water stress conditions (i.e. > 0.012 MPa). *Gutierrezia sarothrae* can grow outside these tolerances but may require >10 days to germinate at the highest tolerable water stress levels (i.e. -0.24 MPa). Salvage of adult *G. sarothrae* resulted in 50% survival after 12 months of care in a nursery; surviving *G. sarothrae* were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 25% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *Gutierrezia microcephala* is an early successional species and increases after disturbances such as overgrazing, fire, and drought, but may not compete well with grasses. *Gutierrezia sarothrae* has demonstrated remarkable resilience despite a century of efforts to destroy it. That says a lot about its resilience. Experiments designed to quantify the difference in soil loss from bare ground compared to overgrazed pasture and since recovered by *Guttierrezia* spp. with its shallow fibrous roots may bear interesting results.

## *Hilaria (=Pleuraphis*) *rigida* (Thurb.) Benth. ex Scribn.(Poaceae)

**Common Name(s):** big galleta.

**Functional group and bloom season:** *Hilaria rigida* is a common late season perennial grass that may flower throughout the year (Columbus 2012f).

**Distribution in Mojave/Habitat:** Big galleta grows in sandy to rocky soil in flats, washes, sand dunes, and scrublands in the southern and eastern Mojave Desert (Columbus 2012f).

**Flowers color and shape:** The inflorescence of *H. rigida* is a spike of highly pubescent spikelets.

**Pollinator use:** Like other grasses, *H. rigida* is wind-pollinated, and we found no information on this species’ use as a larval host plant in the USA. However, a relative of *H. rigida*, *H. cenchroides*, is used by larvae of the silkmoth, *Hemileuca oliviae* Cockerell (Robinson et al. 2010).

**Tortoise use:** This perennial grass was the thirteenth most abundant plant and was observed in diets at six sites demonstrating its ecological breadth across the deserts. Perennial grasses may be more important in tortoise diets than previously appreciated (Esque et al. 2014).

**Propagation, production, and cultivation:** Initial germinability of mature seed germinated at 15 °C was low (16%), and germinability of seeds declines dramatically beyond one year of storage even under room or cooler temperatures (Kay et al. 1988). Seedling establishment of *H. rigida* is enhanced by ensuring seed is placed below the soil surface and in combination with supplemental irrigation (Winkel et al. 1995 a, b). Salvage of adult *H. rigida* resulted in 41% survival after 12 months of care in a nursery; surviving *H. rigida* were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 14% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** The dense clumps of coarse stemmed *H. rigida* can stabilize loose soils and windblown sand (Calscape.org 2020).*Hilaria rigida* is currently the focus of a multi-collaborator project designed to develop seed transfer zone maps for managers and practitioners and to increase native plant materials for habitat restoration ([https://www.usgs.gov/centers/werc/science/native-plant-materials-ecological-restoration-degraded-drylands](file:///D:\Meetings%20and%20Manuscripts\RESTORATION\MOJAVE%20DESERT%20PREFERRED%20SEED%20LIST%20(PSL)\Mojave%20PSL%20formatted%20for%20journal\FNL%20PSL%20FOR%20Journal\can%20https:\www.usgs.gov\centers\werc\science\native-plant-materials-ecological-restoration-degraded-drylands), accessed October 24, 2018). In those studies of this perennial grass, tillers attached to roots were collected from adult plants in its natural habitat and successfully propagated new genetically identical plants for common garden experiments, thus indicating a potential species and viable method for production.

## *Krameria* L. spp*.* (Krameriaceae)

**Common Name(s):** *Krameria bicolor* S. Watson *(=grayi) -* white ratany*;* *K. erecta* Schult. (=*K. parvifolia) -* range ratany*.*

**Functional group and bloom season:** Shrubs. *Krameria bicolor* flowers from April to May, *K. erecta* has a slightly longer flowering duration, lasting from March to May (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** *Krameria erecta* grows on dry, rocky ridges and slopes up to 1200 m (Baldwin et al. 2002). *Krameria bicolor* is found in similar habitats but prefers lime soils and grows up to 1400 m in elevation (Baldwin et al. 2002).

**Flower color and shape:** Deep purple to red; stellate and saucer shaped. The sepals are large and petal-like, while the petals themselves are modified into an upper “claw” and two lower appendages that surround the stamens and pistil.

**Pollinator use:** The flowers of *Krameria* species produce no nectar, but rather fixed oils that are rich in free beta-acetoxy fatty acids (Simpson and Neff 1987, Carneiro et al. 2015). The primary pollinator visitors of *Krameria* are bees of the *Centris* genus, which mix the oils with pollen of co-occurring species (*Larrea tridentata* (DC.) Coville, and species of *Parkinsonia* L., *Olneya* A. Gray, *Senna* Mill., and *Prosopis* L.) into ‘loaves’ to feed their larvae (Simpson and Neff 1987). Virtually all pollination of *Krameria* is done by female *Centris*, with occasional visits from bees of *Lasioglossum*, and *Exomalopsis genera,* and the Halictidae, and Anthophoridae (Simpson and Neff 1987). *Krameria* species are larval hosts for moths of families Gelchiidae, Noctuidae (*Oxycnemis fusimacula* Smith), and Saturniidae (*Hemileuca chinatiensis* Tinkham), and Lycaenidae butterflies (*Apodemia mormo*) (Robinson et al. 2010).

**Tortoise use:** White ratany (*K. bicolor*, formerly *K. grayi*) was the tenth most frequently used cover plant by tortoises (1.26%, Table 3) and was eaten by tortoises at five sites including along the Colorado River in Nevada, the southeast Mojave Desert, and most of the Colorado Desert in California (Table 2). *Krameria* spp. are among the very few woody shrubs to be included as tortoise diet species in the Mojave Desert: *K. erecta* was fourteenth most abundant and found at two sites in the northeast Mojave Desert, southern Nevada (Table 2) and southern California (P.A. Medica, USGS, *pers. comm*., 2018). Tortoises may climb entirely off the ground into the shrubs to gain access and eat the purple flowers (Esque 1994, P.A. Medica, USGS, *pers. comm*., 2018). Its congener, *K. erecta*, is more widespread in the western Mojave Desert and occurs in the western and northern portions of the Colorado Desert in California (Benson and Darrow 1981). *Krameria erecta* is also a diet species for desert tortoise: it occurred in more than 2,000 bites (>2% of natives) and was documented in the diet of tortoises at Arden, Nevada; City Creek, Utah; and Littlefield, Arizona (Supplemental 2).

**Propagation, production, and cultivation:** *Krameria* species are rooted hemiparasites, and they have documented associations with *Larrea tridentata, Ambrosia dumosa, Lycium andersonii, Encelia farinosa, Ephedra antisyphilitica, Menodora scabra, Parkinsonia aculeata, P. microphylla, Prosopis velutina*, *Zizyphus parryi,* and *Vachellia constricta* (MacDougal and Cannon 1910). Despite their hemiparasite habit, they do not require a host to germinate their seeds (Baskin and Baskin 2014). Very little is known about germination ecology and establishment success of *Krameria*. Optimal germination for the congener *K*. la*nceolata* Torr. occurred at 24°C (Musselman and Mann 1977). The hooked spines that cover *Krameria* spp. fruits may make them easier to gather by seed collectors (H. Dial, Plant Materials Center, *pers. comm*., 2018). Simpson (1989) also documented vegetative reproduction of *Krameria* via rhizomes, which could be used as an alternative propagation method if seed collection falls short or seeds have low viability.

**Recoverability**: Low resprouting ability following wildfire is characteristic of *K. bicolor* in the Sonoran and Mojave deserts (Rogers and Steele 1980; Abella 2009). High levels of pre-dispersal seed parasitism by moth larvae (Gelechiidae) could hinder seed collection efforts of *Krameria* (Simpson 1989)

## *Larrea tridentata* (DC.) Coville(Zygophyllaceae)

**Common Name(s):** creosotebush.

**Functional group and bloom season:** Shrub. Flowers primarily from February to April, and any time after adequate rainfall (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** Widespread and common below 1000 m throughout the Mojave Desert (Baldwin et al. 2002).

**Flower color and shape:** Yellow; stellate.

**Pollinator use:** *Larrea tridentata* is among the most widely pollinator-visited species in the Mojave Desert ecoregion (Hurd and Lindsley 1975 a, b; Minckley et al. 1999; Minckley et al. 2000). At least 90 species of bees use *Larrea tridentata* as a pollen resource and this guild spans several genera and includes 22 oligolectic bee species (Hurd and Linsley 1975a). The majority of these species use *Larrea tridentata* during its spring bloom, but 39 species also attend the summer-fall bloom, when it occurs, and 8 species are restricted to the late-season bloom (Hurd and Linsley 1975a). Many other potential pollinating insects are associated with *Larrea tridentata* including species from six families of Coleoptera, seven families of Diptera, and Hymenopterans including Chrysididae, Tiphiidae, Scoliidae, Vespidae, and Sphecidae (Hurd and Linsley 1975b). The specialist moth *Thyridopteryx meadii* Edwards (nomenclature from <https://www.nhm.ac.uk/our-science/data/lepindex/advanced/list/?snoc=meadi&genus=thyridopteryx> Accessed 4 March 2020) uses the leaves of *Larrea tridentata* for egg casing material (Powell and Hogue 1979). This use of the leaves contributes substantially to seed loss due to predation by the larvae of the creosotebush bagworm (Boyd and Brum 1983). At least three other species of Lepidopterans use *Larrea* in the USA (*Digrammia colorata* Grote, *Agapema galbina* Clemens*, Sphingicampa heiligbrodti* Harvey; Robinson et al. 2010).

**Tortoise use:** *Larrea tridentata* was used at all sites we evaluated and was most frequently used for cover among all plant species (over 41% of the tortoise occurrences beneath this evergreen shrub). *Larrea tridentata* is ubiquitous in undisturbed low elevation sites and tortoises encounter it so regularly that its use for cover is widespread (Table 3), but it is not a major diet species (Table 2).

**Propagation, production, and cultivation:** Bulk seeds collected and hulled by hand yield the best germinability compared with mechanical means (Kay et al. 1977d). Initial germinability of seed is low (< 10%) but retains some germinability in long-term (≥ 9 yrs) storage at room temperature or cold conditions (Kay et al. 1984, 1988). This species can be germinated for propagation by simulating late summer/early fall rainfall period (25°C, Kay et al. 1988), which can be simulated by placing a permeable bag of seeds in the holding tank of a commode for 24 hours where the water is refreshed with every flush or when soil temperatures are above 15°C (Barbour 1968). Direct seeding before the onset of warm summer/fall rains may increase establishment success, although seeds need to be sown or lightly harrowed to cover them with soil to protect them from seed harvesters that are typically active during this time (DeFalco et al. 2012). Seedling emergence is enhanced when seed is planted and covered with gravel mulch, which warms the seeds and promotes germination (K. Ostler, Nevada Test Site *pers. comm*., 2015). Establishment may be increased when the seedlings sprout under nurse plants such as *Ambrosia* *dumosa* (McAuliffe 1988). The seeds can be cleaned by gently rubbing the fruits over #10-12 screen or a rubber mat (Wall and MacDonald 2009).

**Recoverability**: Creosotebush can recover well from surface disturbances, such as being run over by vehicles, if the root crown is not destroyed. However, multiple such disturbances will cause mortality. *Larrea tridentata* doesnot recover well after high intensity wildfire that injures the root crown (Alford et al. 2005; Brooks and Minnich 2006; Shryock et al. 2014). In a review of post-fire plant recovery by Abella (2009), creosote bush populations in burned areas had low (3% - 7%) to moderate (18%, 37%) resprouting rates. Salvage of adult *Larrea* resulted in 48% survival after 12 months of care in a nursery; surviving *Larrea* were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 53% survival 27 months after transplanting (Abella et al. 2015b). Additional experiments transplanting salvaged plants around solar energy production facilities are ongoing; however, results are not published at this time.

## *Lasthenia* spp. (Asteraceae)

**Common Name(s):** *Lasthenia californica* Lindl. - California goldfields; *L. gracilis* (DC.) Greene - common goldfields.

**Functional group and bloom season:** Annual. *Lasthenia californica* and *L. gracilis* bloom from February to June (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** Both species are restricted to the west Mojave Desert and occur in many habitat types below 1500 m (Chan and Ornduff 2012).

**Flower color and shape:** Yellow; involucral heads of disc and ray florets.

**Pollinator use:** Goldfields in central California are pollinated by specialist Andrenid bees (Thorp and Leong 1998) and butterflies (Murphy 1984). A Noctuidae moth (*Heliothodes diminuta* Grote) uses *L. californicus* as a larval host in southern California, but their use has not been confirmed in the Mojave Desert (Robinson et al. 2010).

**Tortoise use:** Although abundant at many sites in the west Mojave Desert these species were not recorded in the diets of desert tortoises (Jennings and Berry 2015).

**Propagation, production, and cultivation:** *Lasthenia* species establish and propagate from seed easily, usually germinating within 5-15 days (Everett and O’Brien 2012). Seeds must be protected from birds but given full sun (Everett and O’Brien 2012). *Lasthenia californica* seeds had 100% germination within two weeks at 21°C with 16 hours of light; seedlings were kept at 18.3°C for three weeks until they were ready to transplant (Walker 2013).

**Recoverability:** *L. californica* was reduced by fires in the Sonoran Desert, but populations in burned areas may increase in density and biomass within a year after fires (Cave and Patten 1984). This species also increases after fire in vernal pool environments in northern and central California (Pollak and Kan 1998).

## *Lepidium* spp. (Brassicaceae)

**Common Name(s):** *Lepidium flavum* Torr. – yellow pepperweed*; L. fremontii* S. Watson – desert pepperweed*;* and *L. lasiocarpum* Nutt. – hairypod pepperweed.

**Functional group and bloom season:** *Lepidium flavum* is an annual that flowers from March to June*; L. fremontii* is a short lived, herbaceous perennial that flowers from March to June; *L. lasiocarpum* is an annual plant that flowers from March to June (Al-Shehbaz 2017 b, c).

**Distribution in Mojave/Habitat:** *Lepidium flavum* grows in sandy or alkaline soils in creosote scrub below 1400 m, mainly in the western Mojave Desert (Baldwin et al. 2002). *Lepidium lasiocarpum* is found in disturbed areas below 600 m throughout the Mojave Desert (Baldwin et al. 2002). *Lepidium fremontii* grows in sandy washes, on barren knolls, and in gravelly soils below 160 m (Baldwin et al. 2002).

**Flower color and shape:** Yellow or white; cruciform; organized in racemes.

**Pollinator use:** The congener *L. montanum* Nutt. is a recommended pollinator species in the state of Nevada (Eldredge et al. 2013). *Lepidium* species are used by greater than 70 species of native bees at Grand Staircase-Escalante National Monument in south-central Utah (Carril et al. 2018). The annual *Lepidium* spp. are likely self-pollinated (Snell and Aarssen 2005). However, *L. flavum* is used by the native bee *Andrena mohavensis* Ribble and *L. fremontii* may similarly be important to pollinators. *Pontia protodice* and *P. occiddentalis* Reakirt, the checkered and western white butterflies, respectively, use *Lepidium* species as larval host plants (Robinson et al. 2010; Stewart et al. 2001).

**Tortoise use:** *Lepidium lasiocarpum* is the tenth most abundant species in diets and found in diets at three sites from the northeast Mojave Desert to the Colorado Desert (Table 2). *Lepidium fremontii* was used as cover at one site (Table 3).

**Propagation, production, and cultivation:** *L. lasiocarpum* has been found to germinate best at 25°C (Barton 1936; Capon and Van Asdall 1967) and with water equivalent to ≥15 mm of rainfall (Freas and Kemp 1983). At the Joshua Tree National Park Native Plant Nursery in Twentynine Palms, California, *L. fremontii* seeds are collected in late summer after the pods dehisced (Graham 2004b). The seeds may be dried in paper bags for 4-6 weeks, then stored in airtight containers at 7°C. Seeds can be pre-treated with a two-hour soak in water to remove any inhibitors (and break physiological dormancy) and then sown in open flats in a 2:1:2 mix of sand, mulch, and perlite. After a 2-3-week establishment period, seedlings are transplanted into pots with the same soil mixture. At 8-12 weeks, the seedlings may be transplanted into larger PVC containers (37.5 cm × 15 cm) filled with the same medium and a dose of Osmocote time release fertilizer (22g/6L). The plants may then be moved to an outdoor growing compound and covered with a 55% shade cloth until October. To acclimate the young plants to the outdoor climate, irrigation frequency and duration is gradually reduced over 4 – 8 weeks.

**Recoverability:** Little information is available on the recoverability and restoration potential of *Lepidium* species. The tendency of *L. lasiocarpum* to inhabit disturbed areas suggests that they may perform well as pioneer species in restoration communities.

## *Lupinus* spp. (Fabaceae)

**Common Name(s):** *Lupinus arizonicus* (S. Watson) S. Watson*-* Arizona lupine; *L. brevicaulis* S. Watson– shortstem lupine; *L. concinnus* J. Agardh– bajada lupine, elegant lupine; *L. odoratus* A. Heller*-* Mojave lupine; *L. shockleyi* S. Watson – purple desert lupine; *L. sparsiflorus–*Benth. *-* Coulter’s lupine.

**Functional group and bloom season:** Mojave Desert lupines are primarily annual forbs that flower from March to May (Baldwin et al. 2002; Sholars 2017).

**Distribution in Mojave/Habitat:** Mojave Desert lupines generally grow in sandy, open areas at low elevation (< 2000 m). *Lupinus shockleyi* grows below 1200 m (Sholars and Riggins 2012). Several lupines (*L. arizonicus, L. brevicaulis, L. concinnus,* and *L. sparsiflorus*) can be found in disturbed areas like washes, roadsides (Wainwright 1978; Baldwin et al. 2002), although there are few studies that report lupines in burned desert areas.

**Flower color and shape:** Pink to deep purple to blue, with white or yellow banner spots; papilionaceous.In *L. arizonicus, L. odoratus,* and *L*. *sparsiflorus,* the banner spots darken red to purple after pollination, alerting insects that pollination has already occurred (Wainwright 1978).

**Pollinator use:** Bees are the principal pollinators of desert lupines. Bees of the *Anthophora* genera visit *L. odoratus* (Hurd and Linsley 1975a). *Lupinus arizonicus* and *L. sparsiflorus* are pollinated by digger bees (*Anthophora*), bumble bees (*Bombus*), *Centris rhodopus* Cockerell, *Andrena* (Andrenidae), *Anthidium*, honeybees (*Apis mellifera*), and *Osmia* (Megachilidae; Wainwright 1979). Other bee visitors to southwestern *Lupinus* species include *Halictus tripartitus*, *Ashmeadiella* spp*., Megachile* spp., and *Eucera* spp. (Allred 1969; Wilson and Carril et al. 2018).

Desert lupines are also important larval hosts for many Lepidopterans. *Lupinus arizonicus* hosts larvae of several owlet moths (Noctuidae) including four well-known agricultural pests: the corn earworm (*Helicoverpa zea* Boddie), the tobacco budworm (*Heliothis virescens* Fabricius), the beet armyworm (*Spodoptera exigua* Hübner), and the cabbage looper (*Trichoplusia ni* Hübner; Robinson et al. 2010). Lupine congeners in the Sonoran Desert (*L. argenteus* Pursh*, L. sericeus* Pursh*,* and *L. succulentus* Douglas × K. Koch) are oviposition hosts for various Arizona butterflies, particularly sulphurs/hairstreaks (Lycaenidae Leach), blues, and duskywings (Hesperidae Latreille; Stewart et al. 2001).

**Tortoise use:** *Lupinus concinnus* and *L. odoratus* were both used as tortoise diet plants at one site composing 0.4% and 0.1% of bites, respectively. *Lupinus odoratus* also occurs in tortoise diets in the western Mojave Desert (Jennings and Berry 2015). *Lupinus sparsiflorus* is an important spring diet species for Sonoran desert tortoises: in a scat analysis study in the Pichaco Mountains, it was the most abundant diet plant (26% of diets; Vaughan 1984).

**Propagation, production, and cultivation:** Lupine seeds are easily cleaned by allowing the fruits to dry and dehisce in paper bags (Wall and MacDonald 2009). As the seed pods dry, the pods snap open, audibly, projecting the seeds some distance (T. Esque, pers. obs.). Low elevation desert lupines generally germinate well at 15°C - 20°C, and germination is improved by seed scarification (Royal Botanic Gardens Kew 2017). Bajada lupine (*L. concinnus*) is predominantly self-fertile with high germinability (Wiens 1984). Juhren et al. (1956) recorded annual lupines germinating in May at day/night temperatures of 19°/4°C in response to 12 mm of rainfall.

**Recoverability:** One soil disturbance study (Suazo et al. 2012) found no difference between density of *Lupinus* spp. between disturbed and undisturbed sites, suggesting that while desert lupines can grow on disturbed sites, they do not necessarily prefer them. *Lupinus* density did, however, slightly increase in disturbed plots paired with a water addition treatment (Suazo et al. 2012), suggesting that lupines can successfully colonize disturbed areas if provided adequate resources. *Lupinus arizonicus* commonly grows in roadsides, and some other species grow in washes. Lupines in other systems are good colonizers, for example, on Mt. Lassen and Mt. St. Helens (J. Perkins – Mojave Desert Restoration Program Coordinator, BLM – CA, pers. comm., 2019). The range of *L. concinnus* extends into chaparral, where this species has been recorded in burned areas (Vogl and Schorr 1972). However, there are no reports of fire recovery of this species in low elevation desert. The relatively large seeds of desert lupines may be dispersed by rodents (Vander Wall 1990).

***Lycium* spp. (Solanaceae)**

**Common Name(s):** *Lycium andersonii* A. Gray – Anderson’s boxthorn; *L. cooperi* A. Gray – Cooper’s boxthorn; *L. pallidum* Miers – pale boxthorn.

**Functional group and bloom season:** Shrubs, 0.5 m to 3 m tall. All three species flower from March to May (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** *Lycium andersonii* grows on gravelly/rocky slopes and in washes below 1900 m throughout the Mojave Desert (Baldwin et al. 2002). *Lycium cooperi* is found on sandy/rocky flats and in washes below 2000 m (Baldwin et al. 2002). *Lycium pallidum* grows in sandy/rocky soil in flats, washes, and on slopes below 1200 m (Baldwin et al. 2002).

**Flower color and shape:** White to purple; tubular.

**Pollinator use:** *Lycium andersonii* and *L. cooperi* are recommended as spring pollinator habitat species (M. Oliver, pers. comm., BLM – CA, Bishop Field Office, 28 Feb 2017). *Lycium* spp. are pollinated by bees of the *Anthophorula* Provencher (=*Synhalonia;* Hurd and Linsley 1975a). *Lycium* species also host sphingid moth larvae (*Manduca quinquemaculatus* Haworth*, M. sexta* Linnaeus; Robinson et al. 2010).

**Tortoise use:** *Lycium* *andersonii* was the fifth most abundantly used cover plant taxon by desert tortoises and was used at seven of nine sites surveyed. *Lycium pallidum* (pale wolfberry) was the most highly selected cover species for a sample of ~100 Mojave desert tortoises at the Yucca Mountain project at the Department of Energy, Nevada National Security Site (formerly Nevada Test Site; K. Ostler, Nevada Test Site, *pers. comm*., 2016). *Lycium andersonii* (along with *Larrea tridentata* and *Ambrosia dumosa*) were the only species used for cover by tortoises at all eight sites (Table 3).

**Propagation, production, and cultivation:** Collecting berries of *L. andersonii* for use in re-vegetation is a difficult process due to the fleshy fruit that can mold easily with storage (Kay et al. 1977e), and seeds are difficult to germinate and grow (K. Oster, Nevada National Security Site, *pers. comm*., 2016). Initial germinability of field-collected *L. andersonii* seed is low (< 10% at 15 °C) and optimally germinates at 20 °C (Kay et al. 1988). Dry, sealed storage of seeds at room temperature results in better long-term germinability (≤ 9 years) than at storage temperatures of 4°C and -15 °C (Kay et al. 1984). Stem cuttings of these species dipped into Hormodin 2 powder (0.3% indole-3-butyric acid in talc) and placed in vermiculite root easily and may provide an alternative to propagation from seed (Wieland et al. 1971). The seeds can be cleaned by maceration through a food mill or a #25 sieve (Wall and MacDonald 2009). Once the pulp is dry, fruits can be run through a sieve once more to separate the seed and chaff with a blower set at 1.75 (Wall and MacDonald 2009).

**Recoverability:** The Bishop, CA BLM Field Office has recommended *L. andersonii* as a potential restoration species (M. Oliver, BLM-CA, *pers. comm*., Feb. 28, 2017). However, this species does not recover well following fire, only re-sprouting after low intensity fires that do not destroy the root crown (Shryock et al. 2014). Moderate rates of resprouting in *Lycium* (21% of population) occurred following fires in south-central Arizona (Rogers and Steele 1980). *Lycium* species have large seeds that are animal-dispersed, which may challenge re-seeding efforts, but increases the probability for their migration into disturbed sites.

## *Malacothrix* spp. (Asteraceae)

**Common Name(s):** *Malacothrix glabrata* D.C– Eaton - desert dandelion; *Malacothrix coulteri* Harv. & A. Gray – snake’s head; *M. sonchoides* (Nutt.) Torr. & A. Gray – sowthistle desert dandelion.

**Functional group and bloom season:** *Malacothrix* spp. discussed hereare herbaceous annuals. *Malacothrix coulteri* flowers from March to May; *M. glabrata* flowers from March to June; and *M. sonchoides* flowers April to June (Davis 2012a, b, c).

**Distribution in Mojave/Habitat:** *Malacothrix coulteri* occurs mostly in the western Mojave Desert, and grows in sandy, open areas below 1500 m (Davis 2012a). *Malacothrix glabrata* is widespread throughout the Mojave Desert and can be found below 2000 m growing beneath shrubs or in open areas of sandy/gravelly soil (Davis 2012b). *Malacothrix sonchoides* grows on fine sandy soils or dunes in shrublands and Joshua tree woodlands below 1400 m (Davis 2012c).

**Flower color and shape:** Yellow; involucral heads of ligulate florets.

**Pollinator use:** *Malacothrix glabrata* is associated with the bees *Anthophora urbana, Ceratina nanula, Lasioglossum hyalinum* Crawford*, Hesperapis wilmattae* Cockerell, and bees of genus *Colletes* (Allred 1969; Hurd and Linsley 1975a). In south-central Utah, *Malacothrix sonchoides* Torr. & A. Gray hosts eight species of native bees (Carril et al. 2018). *Malacothrix glabrata* and *M. sonchoides* also are likely hosts for the larvae of moths like *Autographa californica* Speyerand *Heliolonche pictipennis* Grote (Robinson et al. 2010; Calscape.org 2020).

**Tortoise use:** *M. coulteri* and *M. glabrata* were recorded in tortoise diets in the western Mojave Desert (Jennings and Berry 2015). In a study on the effects of diet plants on tortoise health, *M. californica* mixed with other native forb speciessignificantly increased survival and overall health of juvenile desert tortoises compared with those fed a diet of annual invasive (*Bromus madritensis*) or native grasses (*Festuca octoflora*; Drake et al. 2016). *Malacothrix glabrata* has higher digestibility for tortoises compared with native or invasive grasses (Nagy et al. 1998), and juvenile and adult tortoises fed single-species diets, including *M. glabrata*, gained more minerals from forbs compared with invasive or native grass diets (Hazard et al. 2010).

**Propagation, production, and cultivation:** Harvested fruits are spread in a thin layer in a warm, well-ventilated area to dry. Once dry, pappus and other debris is removed by rubbing the seeds over a screen or a rubber mat (Wall and MacDonald 2009). Little information is available on the propagation and seed storage of *Malacothrix* species. As a member of Asteraceae, if this plant undergoes dormancy, it would likely be physiological in nature. To break physiological dormancy, appropriate pretreatment conditions are needed including a combination of temperature and moisture requirements (Baskin and Baskin 2014). For desert winter annuals, a pretreatment simulating hot, dry summer conditions, followed by a germination environment simulating the cooler, wetter conditions of winter can increase successful germination. In the Colorado Desert, winter annuals germinated on washed sand in flats under a temperature regime of 18°/8° (day and night; respectively), while summer annuals did not (Juhren et al. 1956; Gutterman 1994). The congener *M. fendleri* exhibited highest germination (66%) without warm or cold stratification treatments (i.e., 10°/20°C and 12 hr light/dark cycle for six weeks after pretreatment), suggesting that this genus is nondormant (Pendleton and Pendleton 2014). Seed increase has been attempted with *Malacothrix* sp. by placing weed matting material around the shoots and across open spaces (H. Dial – USDA, Natural Resources Conservation Service, pers. comm,, 2017). However, the seed was still difficult to collect because as it ripened the winged achenes had a predisposition to disperse on the slightest breeze. Bagging the flower heads may be necessary to capture a large proportion of the ripening seeds.

**Recoverability:** We found no published information onthe response of *Malacothrix* to fire disturbance, however, *Malaxothrix* flowered profusely in burned areas after 1999 fires at Joshua Tree National Park (T. Esque, pers. obs.). This genus may increase after mechanical soil disturbance in the Mojave (Suazo et al. 2012).

## *Mentzelia* spp. (Loasaceae)

**Common Name(s):** *Mentzelia affinis* Greene – yellow comet; *Mentzelia albicaulis* (Douglas ex Hook.) Douglas ex Torr. & A. Gray - whitestem blazingstar; *M. involucrata* S. Watson – whitebract blazing star*; M. laevicaulis* (Hook.) Torr. & A. Gray – smooth-stemmed blazing; *M. longiloba* J. Darl. – long lobed blazing star; *M. longiloba* J. Darl. Kartesz (=*M. longiloba*) – Adonis blazingstar;and *M. tricuspis* A. Gray – desert blazingstar.

**Functional group and bloom season:** *Mentzelia affinis* is an annual blooming from April to May; *M. albicaulis* is an annual and blooms from March to July; *M. involucrata* is an annual flowering January to May; *M. laevicaulis* is an herbaceous perennial that blooms from May to October; *M. longiloba* is a biennial or herbaceous perennial that blooms from March to June; and *M. tricuspis* is an annual that blooms March to May (Brokaw et al. 2012a, b, c, d, e, and f; respectively).

**Distribution in Mojave/Habitat:** *Mentzelia affinis* grows on rocky soils below 1200 m*. Mentzelia albicaulis* inhabits a variety of desert habitats including sand dunes, bajadas, and washes in creosotebush to woodland habitats at elevations less than 2300 m. *Mentzelia laevicaulis* lives in sandy to rocky slopes, washes and roadcuts below 2900 m. *Mentzelia involucrate* occupies bajadas, steep slopes and washes in creosotebush scrub below 900 m. *Mentzelia multiflora longiloba* lives on sandy flats in creosotebush scrub below 800 m*. Mentzelia tricuspis* sandy and gravelly slopes and washes from 150 m to 1280 m(Baldwin et al. 2002)*.*

**Flower color and shape:** White to yellow; stellate, saucer or bowl-shaped

**Pollinator use:** Visitors to *Mentzelia* species include bees, butterflies, and moths (Mee et al. 2003). Bees of genera *Agapostemon, Bombus, Lasioglossum, Martinapis, Megandrena,* and *Perdita* pollinate *Mentzelia* spp. (Hurd and Linsely 1975a; Griswold et al. 2006). In south-central Utah, *Mentzelia albicaulis*, also found in the Mojave Desert, is visited by several native bees including *Andrena utahensis* LaBerge, *A. nigricula* LaBerge and Bouseman, *Perdita holoxantha* Timberlake, *Anthophora petrophila* Cockerell, *Agapostem angelicus* Cockerell, *A.* *texanus* Cresson, and *Hoplitis zuni* Parker (Carril et al. 2018). *Mentzelia involucrata* is pollinated by *Xeralictus bicuspidariae* Snelling and Stage bees, and these bees also pollinate a similar-looking species and tortoise food, the ghostflower (*Mohavea confertifolia* (Benth.) A. Helle). The ghostflower mimics the blazing star and also mimics the female bee, thereby attracting male *X. bicuspidariae* bees ([https://entmuseum.ucr.edu/bug\_spotlight/posted%20Images-pages/–3.htm](https://entmuseum.ucr.edu/bug_spotlight/posted%20Images-pages/33.htm) - Accessed 23 Mar 2020).

*Mentzelia laevicaulis* is pollinated by the two-tailed swallowtail (*Papilio multicaudata* W. F. Kirby) and the white-lined sphinx moth (*Hyles lineata*; Caldwell 2014). *Mentzelia laevicaulis* is a larval host plant for the moths *Protogygia album* Harvey, *Anoncia leucoritis* Meyrick*,* and *A. psepsa* Hodges (taxonomy from<https://www.discoverlife.org/mp/20q?search=Anoncia%20leucoritis>, accessed 24 Mar 2020; taxonomy from<https://www.discoverlife.org/mp/20q?search=Anoncia+psepsa>, accessed 24 March 2020; respectively), and the gray hairstreak butterfly (*Strymon melinus*; Robinson et al. 2010).

**Tortoise use:** Several species of *Mentzelia* were recorded in the diets of desert tortoise in the western Mojave Desert, including *M. albicaulis, M. involucrata* S. Watson*, M. multiflora longiloba* J. Darl. Kartesz*,* *M. affinis*, and *M. tricuspis* A. Gray (Jennings and Berry 2015).

**Propagation, production, and cultivation:** Seeds are cleaned by rubbing them through a medium-gauge screen or allowing the fruits to dehisce in paper bags (Wall and MacDonald 2009). Seed planting should occur in November or December using drill-seeding methods at a rate of 6 kg percent live seed/ha at a depth of 1.3-0.6 cm (Pavek 2011). Studies of germination suggest that the physiological dormancy of *Mentzelia* species is fairly persistent and requires extended pretreatment to break. In a study of Chihuahua Desert, *M. albicaulis* experienced low germination (< 10%) across all treatments (5°C moist stratification for three weeks, 30°C stratification for three weeks, and no stratification) but germinated best under the cold-moist stratification treatment (Pendleton and Pendleton 2014). Fresh seeds cold-moist stratified at 5°C for 12 weeks resulted in 49% germination (Pendleton and Pendleton 2014). In another study *M. laevicaulis* seeds from Emery County, Utah only germinated in treatments that imposed 12 weeks of winter conditions (Kramer and Foxx 2016). Of these, nearly 100% of viable seeds germinated after a winter/early spring treatment (12 weeks at 1.1°C, then 4 weeks at 52°F/1.1°C), while 75% germinated after a winter/mid-spring treatment (12 weeks at 1.1°C, then 59°F/41°F), and only 25% after a winter/late spring treatment (12 weeks at 1.1°C, then 68°F/50°F). Treatments without winter conditions experienced no germination.

**Recoverability:** Disturbance responses of *Mentzelia* species are mixed. In one study of the effects of soil disturbance in the Mojave Desert, *Mentzelia* density significantly decreased in response to disturbance, and only moderately recovered with water additions (Suazo et al. 2012). However, *M. albicaulis* increased in response to nuclear detonation tests (e.g., fire and soil disturbance) at Yucca Flat, Nevada (Rickard and Shields 1963).

## *Mirabilis* spp. (Nyctaginaceae)

**Common Name (s):** *Mirabilis laevis* (Benth.) Curran(= *M. bigelovii*) – desert wishbone-bush; *M. multiflora* (Torr.) A. Gray – wild four o’clock.

**Functional group and bloom season:** Herbaceous perennials.*Mirabilis laevis* flowers from February to June; *M. multiflora* flowers from May to August (Murdock 2012 b, c).

**Distribution in Mojave/Habitat:** *Mirabilis laevis* grows throughout the Mojave Desert in rocky areas below 2300 m (Baldwin et al. 2002). *Mirabilis multiflora* is less widespread in this ecoregion, occurring mainly in the northeastern portion. It can be found in sandy/gravelly soils below 2500 m (Baldwin et al. 2002).

**Flower color and shape:** *Mirabilis laevis* has variable flower colors from magenta to white (Murdock 2012b), and *M. multiflora* are magenta(Murdock 2012c). Inflorescence is generally an umbel-like cluster with one flower per axil. The flower of *M. multiflora* is narrowly funnel shaped.

**Pollinator use:** *Mirabilis multiflora* is recommended as a host plant for pollinator species in Nevada (Eldredge et al. 2013), but the specific pollinator species served by this plant were not specified. *Mirabilis laevis* is a larval host to *Lithariapteryx jubarella* Comstock moths; however, this moth species’ range is relatively small in the desert compared to the range of the plant (Calscape.org 2020).*Mirabilis multiflora* is a confirmed larval host for both the *Lithariapteryx jubarella* Comstock moth and the *L. abroniaeella* Chambers moth (Calscape.org 2020; taxonomic authority for neither species confirmed by ITIS), but neither species has many confirmatory sightings. According to the HOSTS database, *Mirabilis multiflora* is a host species for *Satyrium favonius* J.E. Smith butterfliesandHeliodinidae moths(Robinson et al. 2010), although the former is not known from the region according to Lotts and Naberhaus (2017). *Mirabilis multiflora* is also important to nocturnal pollinators such as the white-lined sphinx moth (*Hyles lineata*) for which the plant provides nectar for the adults and food for the larvae (Hodges 1995; Robinson et al. 2010). *Hyles lineata* larvae may be eruptive in some years and observed crossing desert roads in great numbers (T. Esque, pers. obs.).

**Tortoise use:** *Mirabilis laevis* has been reported in tortoise diets in the northeast and western Mojave Desert (Esque 1994, Jennings and Berry 2015; respectively). Wishbone bush - *M. laevis* var. *villosa (*Kellog) Spellenb. (originally published as *M. bigelovii in* Jennings 1993*)* was the eighth most abundant species in diets and was observed in diets at one location in the west Mojave Desert (Jennings and Berry 2015). The congener *M. multiflora* occurred in diets in the northeast Mojave, and the variety *pubescens*, originally identified as *M. multiflora* var. *pubescens* S. Watson *(=froebelli)* by Burge and Bradley (1976) occurred in diets in southern Nevada.

**Propagation, production, and cultivation:** This group forms large tubers that may be conducive to vegetative propagation (Decker 2005; Huaman et al. 1995). Nut-like fruits of *M. laevis* can be collected and processed by rubbing material over medium screen or #12 sieve to separate fruit from stems and seed from fruit with the blower speed at 1.75 or higher to separate out hollow seeds, which can be a high percentage of the seed lot (Wall and MacDonald 2009). Germination of *Mirabilis* is highly inhibited by the seed coat (L. Eisenberg, USDA-National Forest Service, *pers. comm*., 2018). Soaking the seeds in water and removing the coat entirely, chilling the seed overnight (4°C), then lightly covering the seeds with a damp substrate has resulted in high germination and survival rate in *Mirabilis* (Decker 2005; L. Eisenberg, USDA-National Forest Service, pers. comm., 2018). Several species of *Mirabilis*, including *M. laevis* and *M. multiflora*, are already in commercial production and available from at least 10 retail vendors (Calscape.org 2020).

**Recoverability:** This genus tends to have large seeds that provision developing seedlings and likely are dispersed by small mammals into disturbed areas. Rodent-mediated dispersal may have been the case in a fire study near Phoenix, AZ, in which *M. laevis* colonized burned areas where it was not recorded in pre-fire vegetation assessments (Cave and Patten 1984). The large, tuberous underground roots of *Mirabilis* may help these plants survive fire injury (Huaman et al. 1995). *Mirabilis laevis* (=*M. multiflora*) has demonstrated tolerance to saline soils (Zollinger et al. 2007).

## *Muhlenbergia porteri* Scribn. X Beal (Poaceae)

**Common Name(s):** Bush muhly.

**Functional group and bloom season:** Perennial graminoid. This species flowers between June and October (Peterson 2017).

**Distribution in Mojave/Habitat:** *Muhlenbergia porteri* grows in a variety of habitats, including rocky slopes, cliffs, dry arroyos, and flats. It frequently grows beneath shrubs, presumably in association with fertile islands and protected from large herbivores; however, in the absence of heavy grazing it also grows as a large free-standing grassy clump. It occurs most abundantly in the eastern Mojave between 610 and 1680 m (Baldwin et al. 2002).

**Flower color and shape:** Purple, with conspicuous awns; much reduced; organized in an open panicle.

**Pollinator use:** *Muhlenbergia porteri* is pollinated by wind rather than insects but is a host species for larvae of the range caterpillar moth (*Hemileuca oliviae*; Packard and Cockerell 1914; Robinson et al. 2010).

**Tortoise use:** *Muhlenbergia porteri* was ranked seventh among bite counts but was observed eaten by tortoises in the Ivanpah Valley (Avery 1998). It was suspected to have been important to tortoises in other places such as the Beaver Dam Slope, Utah (Woodbury and Hardy 1948).

**Propagation, production, and cultivation:** *Muhlenbergia porteri* seed is non-dormant and has high rates of germination when grown under an alternating temperature regime of 30°/17°C (Ashby and Hellmers 1955). Knipe and Herbel (1960) also found that germination success of *M.*  *porteri* decreases by 25 – 50% when plants are moisture-stressed at or below -1.52 MPa. *Muhlenbergia* *porteri* has been transplanted successfully from its habitat to 1 gal pots for a native plant salvage project (Craig and Abella 2008). To clean seeds, the stalks are stripped so the florets can be rubbed through a small-sized screen or shaken through #35 sieve (Wall and MacDonald 2009).

**Recoverability:** The recovery of *M. porteri* following wildfire is not documented, but Roundy and Jordan (1988) documented that this grass recovers well from top-kill disturbance such as over-grazing, but poorly from disturbance of the root crown. These findings suggest that this grass would recover well from fires that are not severe enough to damage below-ground tissues. *Muhlenbergia porteri* is highly palatable to livestock and wildlife (Seegmiller et al. 1990, Whitfield and Anderson 1938, Abella 2008,) and is also valued as a cover species for the prevention of soil erosion (Whitfield and Anderson 1938).

## *Nicotiana* spp.(Solanaceae)

**Common name(s):** *Nicotiana attenuata* Torr. ex S. Watson *-* coyote tobacco; *N. obtusifolia* M. Martens & Galeotti *-* desert tobacco.

**Functional group and bloom season:** *Nicotiana attenuata* is an annual that flowers from May to October (Baldwin et al. 2002); *N. obtusifolia* a facultative perennial and blooms mainly from March to June (Wells 1959).

**Distribution in Mojave/Habitat:** *N. obtusifolia* occurs mainly in low-elevation (< 1600 m) creosote bush scrub but can also be found in blackbrush communities where its primary habitats are calcareous bedrock outcrops, talus slopes, and desert washes (Wells 1959). *Nicotiana attenuata* occurs at higher elevations (200 m to 2800 m) on open, well-drained slopes, and is commonly seen in disturbed sites such as roadsides (Baldwin et al. 2002).

**Flower color and shape:** White, tubular

**Pollinator use:** Researchers have recorded a wide variety of pollinator visitors to *Nicotiana attenuata,* including hummingbirds (*Archilochus alexandri* Bourcier & Mulsant and *Selasphorus* Swainsonspp.), sphingid moths (*Hyles lineata, Manduca* spp.), and syrphid flies (*Eupeodes fumipennis* Thomson (=*Metasyrphus, =Syrphus venablesi)*; Aigner and Scott 2002; Wells 1959). *Nicotiana obtusifolia* is also a facultative outcrossing species with only an intermediate level of reliance on pollinators (Adler et al. 2012). Pollination information for *N. obtusifolia* is limited, but its floral syndrome (white flowers with a short tube) suggests pollination by short-tongued bees, and possibly sphingid moths (McCarthy et al. 2016). *Nicotiana obtusifolia* is a larval host for the sphingid moths *Manduca sexta* and *M. quinquemaculatus;* however, Jassbi et al. (2010) found that the *Nicotiana attenuata* is a better food source for *Manduca* larvae, as its tissues contain lower concentrations of certain antiherbivore secondary metabolites (hydroxygeranyllinallol diterpenoid glycosides).

**Tortoise use:** Our analysis of desert tortoise bite counts, scat analysis, and telemetry data yielded no record of tortoises using *Nicotiana* spp. as food or cover.

**Propagation, production, and cultivation:** Seeds of both *Nicotiana* species germinate well at 21°C, and *N. obtusifolia* will germinate in temperatures up to 35°C (Wells 1959). *Nicotiana attenuata* seeds require cold stratification below 4°C. Wells (1959) obtained 91% germination from this species after three days of cold stratification.

**Recoverability:** *Nicotiana attenuata* is one of the first species to colonize burned areas in pinyon-juniper woodlands, chaparral, and Great Basin Desert habitats (Wells 1959; Aigner and Scott 2002; Baldwin et al. 1994; Waitman et al. 2009), and some First Nations purposefully burn areas in order to cultivate that species (Aigner and Scott 2002; Preston and Baldwin 1999). *Nicotiana obtusifolia* is adapted to frequently disturbed habitats (Wells 1959) but is not associated with post-fire communities, and its seeds lack the smoke-triggered germination mechanism that occur in *Nicotiana attenuata* (Preston and Baldwin 1999). However, some researchers have reported *Nicotiana* colonization of burned areas in Mojave Desert shrublands (L. DeFalco, T. Esque – USGS, Martin Oliver and J. Perkins – USDI-BLM, pers. obs.). Thus, more information is required to understand the role of this species for restoration in the Mojave Desert.

## *Oenothera* spp. (Onagraceae)

**Common Name(s):** *O. cespitosa* Nutt. – fragrant evening primrose*; Oenothera deltoides* Torr. & Frém. – basket evening primrose; *O. pallida* Lindl. – pale evening primrose; and *O. primiveris* A. Gray – desert evening primrose.

**Functional group and bloom season:** *O. cespitosa* is an herbaceous perennial blooming March to July; *O. deltoides* is an annual blooming February to March; *O. pallida* blooms May to September; *O. primiveris* is an annual flowering from March to May(Kea and Peebles 1960).

**Distribution in Mojave/Habitat:** *O. cespitosa* grows on bajadas across the Mojave Desert (Baldwin et al. 2002). *Oenothera deltoides* can be found in dunes and other sandy areas below 1100 m (Baldwin et al. 2002)*, O. pallida* grows in sandy soils on dry flats and slopes between 1067 m and 2286 m in the northeast Mojave (SEINet)*, O. primiveris* is found on sandy flats, low hills, dune margins, and arroyos from 30 m to 1400 m.

**Flower color and shape:** *Oenothera cespitosa*, *O. deltoides, and O. pallida –*- white (or pink in older flowers); *O. primiveris* – yellow; cruciform and saucer to bowl-shaped.

**Pollinator use:** The pollen grains of *Oenothera* species possess exceptionally long, webby viscin threads (Thorp and LaBerge 2005). Some insects are specialized to collect the pollen grains such as hawkmoths (Sphingidae) and certain species of Andrenidae bees, including *Andrena anograe* Cockerell*, A. linsleyana* Thorp*, A. linsleyi* Timberlake*,* and *A. stagei* Linsley and MacSwain (Thorp and LaBerge 2005). Female *Andrena* bees gather the large, triangular pollen grains of evening primroses using specialized hair brushes on their legs (Powell and Hogue 1979).Their dark integuments enhance their ability to absorb radiant energy, allowing them to stay active during crepuscular periods when *Oenothera* species flower (Thorp and LaBerge 2005). Associations between *O. californica* (S. Watson) S. Watson and the bees *Anthophora urbana* and *Perdita fallugia* Timberlake were documented at the Nevada National Security Site (Allred 1969). However, neither of these bees are among the specialist subgenus described by Thorp and LaBerge (2005), and these bees likely do not possess the necessary foreleg morphology to collect *Oenothera* pollen effectively.

Evening primroses are extensively used as larval host plants by several Lepidopteran families and in the US, including owlet moths (Noctuidae) and hawkmoths (Sphingidae; Robinson et al. 2010).

**Tortoise use:** *Oenothera deltoides, O. pallida,* and *O. primiveris* were recorded in the diets of desert tortoises in the northeastern Mojave Desert (Esque 1994). *Oenothera* spp., were eaten with gusto when tortoises located them during feeding observations, and a term borrowed from range sciences to describe these plants for tortoises is ‘ice cream plants’ (Esque 1994).

**Propagation, production, and cultivation:** To clean seeds, capsules can be opened with pliers or a scalpel and gently rubbed over a medium screen (Wall and MacDonald 2009). The seeds are relatively soft, so this must be done carefully. Other *Oenothera* species (*O. biennis* L. and *O. issleri* no taxonomy found) can resprout from axillary buds or adventitious buds on roots (Martinkova et al. 2004), suggesting propagation from tissue may be possible. Seed germination responses can vary widely among *Oenothera* species. In a germination experiment using *O. cespitosa* in the Chihuahuan Desert (also occurs in the Mojave Desert), seeds achieved a 93% germination rate after a three-week warm-moist stratification treatment at 30°C and germinated moderately well (47%) with no pretreatment (Pendleton and Pendleton 2014). However, in the same experiment, *O. albicaulis* Purshhad very low germination (4%) across all treatment groups (5°C moist stratification for three weeks, 30°C stratification for three weeks, and no stratification) and did not improve under a prolonged stratification treatment (5°C for 12 weeks). Among 123 species of *Oenothera,* fifty-seven are outcrossing, with most of this diversity existing in western North America (Raven 1979).

**Recoverability:** We found no information on the use of *Oenothera* spp. in restoration in the Mojave Desert, but the occurrence of evening primroses in habitats such as washes and roadsides suggests that they would colonize disturbed areas well. The lignified “birdcages” left by *O. deltoides* may help disperse seeds by aiding movement on the sand dunes and other unstable structures on which this species occurs. The seed pods of *O. deltoides* curtail dehiscence until they are moistened with water (Martínez-Berdeja et al. 2015) ensuring successful seedling establishment. Perhaps the addition of captive propagated ‘bird cages’ could be incorporated into a natural timed-release of seeds that would help protect the seeds from granivores until appropriate germination conditions were met.

## *Opuntia basilaris* Engelm. and J.M. Bigelow (Cactaceae)

**Common Name(s):** beavertail prickly pear cactus.

**Functional group and bloom season:** Perennial succulent with pancake shaped segments. *Opuntia basilaris* flowers from March to June (Parfitt 2017).

**Distribution in Mojave/Habitat:** *Opuntia* *basilaris* is very common in the Mojave Desert and occurs from desertscrub to pinyon-juniper woodland between 150 m and 2200 m (Baldwin et al. 2002).

**Flower color and shape:** Pink; bowl-shaped.

**Pollinator use:** *Opuntia basilaris* is a pollinator host for numerous bees, including those of genera *Agapostemon, Anthophora, Ceratina, Diadasia, Lithurgis* Berthold(=*Lithurgopsis*)*, Megandrena,* and *Melissodes* (Grant and Grant 1979; Griswold et al. 2006). Grant and Grant (1979) also recorded visits to *O. basilaris* by the sap beetle (*Carpophilus pallipennis*); however, it should be noted that these beetle species are not nearly as effective pollinators as the bee species. *Opuntia basilaris* is also a host species for the moth *Dyotopasta yumaella* Kearfott(Robinson et al. 2010).

**Tortoise use:** Although*O. basilaris* is not a frequently used diet species for desert tortoise (ranked forty-fifth), it is widely used (three sites) and can be important forage during drought years when annual forage species are in short supply (Turner et al. 1984; Esque et al. 2014). Furthermore, other North American tortoise species use other *Opuntia* spp. when available, but too much *Opuntia* in the diet may present physiological problems (Hellgren et al. 2000).

**Propagation, production, and cultivation:** Seeds are cleaned by rubbing dried fruits over a medium screen, then hand-sorting the seeds from the chaff (Wall and MacDonald 2009). If the fruits are too hard to put through a screen, pulse them in a blender and dry the pulp thoroughly (Wall and MacDonald 2009). Potter et al. (1984) found that seeds of three *Opuntia* species (*O. discata* Griffiths*, O.* X *edwardsii* V.E. Grant & K.A. Grant*,* and [*Opuntia engelmannii* var. *lindheimeri*](https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=195321) (Engelm.) B.D. Parfitt & Pinkava) all experienced optimal germination at 30°C after receiving a 30-60-minute scarification procedure (via concentrated sulfuric acid). *Opuntia* species have been widely cultivated for food in Mexico and the US by separating the nodes of parent plants and placing them in the ground. *Opuntia basilaris* can also be vegetatively propagated for xeric landscaping and natural areas where it can be highly successful (T. Esque, pers. obs.). Salvage of adult *O. basilaris* resulted in 100% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 93% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** Like most cacti, *O. basilaris* does not recover well following intense fire and is often killed by fire injury (Esque et al. 2004, Brooks and Minnich 2006; Shryock et al. 2014; Thomas 1991). However, some resprouting can occur with low intensity fire (L. DeFalco, unpubl. data). They have large seeds that are not wind-dispersed, but are likely rodent-dispersed, and seedlings take a long time to mature (Royal Botanic Gardens Kew 2017). In a study of vegetative communities in seven paired burned and unburned sites, *O. basilaris* decreased in all sites in which it occurred (Steers and Allen 2011).

***Pappostipa speciosa* (= *Stipa*) (Trin. & Rupra.) Romasch.**

**Common Name(s):** desert needle grass.

**Functional group and bloom season:** perennial bunchgrass blooming in April to July (Columbus et al. 2012).

**Distribution in Mojave/Habitat:** *Pappostipa speciosa* is broadly distributed throughout the Mojave Desert and southwestern US.It occurs ondry bajadas and gentle to steep rocky slopes from 580 m to 700 m (SEINet 2020).

**Flower color and shape:** Inflorescence is green to gold as it cures. The inflorescence is a 10 to 15 cm long spike partly enclosed within a sheath. There are single long awns that are 35 mm to 40 mm long that is bent once and subtended by many shorter hairs.

**Pollinator use:** It is possible that *Hesperia juba*, *H. nevada* Scudder, and *H. uncas* W.H. Edwards butterfly larvae use *P. speciosa*, because this group uses grasses in the western US.

**Tortoise use:** *Pappostipa speciosa* is not recorded in Mojave desert tortoise diets.

**Propagation, production, and cultivation:** *Pappostipa speciosa* was grown in a nursery for restoration projects at Zion National Park, in Springdale, Utah (Decker 2003a). Fully matured seeds are hand collected and stored in sealed containers and kept at 4 – 16 ºC. Seeds are naturally cold stratified and kept damp during fall months after directly being sown into a 1.5:1:1:2 soil mixture of vermiculite, sterile sand, turface, and peat; a balanced NPK nutrient ratio is occasionally incorporated in the soil mix. Seedlings are grown in a shadehouse from March through October for fall planting and irrigated to nearly dry to hardening the plants while they are grown and before they are outplanted.

**Recoverability:** *Pappostipa speciosa* can persist after fire, with sufficient inputs of precipitation (Webb et al. 2003). *Pappostipa speciosa* is also an important plant in temperature regions of Patagonia, in South America and there are far more publications with information about recovery of the species down there, than in the Mojave Desert. Publications focus primarily on responses of vegetation to grazing and fire as two primary disturbances in that area (e.g. Guadalupe et al. 2013).

## *Parkinsonia* spp. (Fabaceae)

**Common Name(s):** *Parkinsonia florida* (A. Gray) S. Watson *–* blue palo verde; *P. microphylla* Torr*.* – foothill paloverde.

**Functional group and bloom season:** Trees, growing up to 8 m (*P. microphylla*) or 12 m tall (*P. florida*; Shreve and Wiggins 1964). *Parkinsonia* species generally flower between April and May (Wojciechowski 2017).

**Distribution in Mojave/Habitat:** *Parkinsonia microphylla* grows in washes, floodplains, and canyons in the southern Mojave and the Sonoran/Colorado deserts. *P. floridum* grows in the Sonoran/Colorado Desert of southern California (Baldwin et al. 2002).

**Flower color and shape:** Yellow; cruciform and saucer shaped.

**Pollinator use:** These species are beneficial to desert pollinators, particularly bees, but are uncommon in the Mojave Desert and found mainly along riparian areas in the Mojave-Sonoran ecotone and further south. *Parkinsonia* species are primarily pollinated by *Centris* bees, particularly *C. pallida* Fox, to which they provide pollen and nectar resources that complement the oil provisions these bees collect from *Krameria* spp. (Simpson and Neff 1987). Leafcutting bees (*Anthidium, Megachile*)*,* plasterer bees (*Colletes*)*,* and Apidae (*Anthophora, Martinapis*)also pollinate *Parkinsonia* trees (Hurd and Linsley 1975a). Palo verdes also host several moths of family Saturniidae, particularly *Syssphinx* species (Robinson et al. 2010).

Both palo verdes are recommended as pollinator habitat in the southwestern deserts (USDA Natural Resources Conservation Service and the Xerces Society 2012), but when re-vegetating disturbed Mojave Desert shrublands, these tree species may be uncommon in adjacent undisturbed habitats.

**Tortoise use:** While the data that were available for this study did not indicate use by tortoises, tortoises certainly use them as a shade resource in regions where tortoises and *Parkinsonia* co-exist. This is true for places like the Chemehuevi Valley in San Bernardino County, and on the bajadas near Glamis in Imperial County, California. The understory along desert washes where *Parkinsonia* grow provides a diversity of plant materials that tortoises use in the Sonoran Desert (Van Devender et al. 2002, Esque et al. 2014). The fallen flowers of *Parkinsonia* would also be available as forage.

**Propagation, production, and cultivation:** *Parkinsonia* species easily cross-pollinate, so great care must be taken to correctly identify specimens and select sites in which only one species occurs. *Parkinsonia florida* can be distinguished from *P. microphylla* post-seed set by its tendency to retain its seed pods late into the summer; this trait also makes it easier to collect pods from *P. florida* before granivory occurs. Once seed pods hit the ground, a variety of invertebrate seed predators infest fruits and make seeds unavailable for regenerating new plants (McAuliffe 1988). After collecting fruits, seeds are shelled and stored in air- and water-tight containers at ambient temperature. Like many other Fabaceae species, *Parkinsonia* seeds are physically dormant due to a hard seed coat (Baskin and Baskin 2014). Dormancy can be broken in multiple ways, including scarification (Everitt 1983), wet heat treatments (5 seconds at 100°C; Teketay 1996), and percussion (Mondoni et al. 2013). Optimal germination of *P. aculeata* is at 25°C regardless of light conditions (Everitt (1983b). Kleffner (2001) grew *Parkinsonia* outdoors, under either 68% shadecloth or in full sun, planted at a depth two times their diameter in a 50/50 local soil/wood mulch mix. Plants were thinned and transplanted (if needed) after one month of growth, and outplanted after one year.

**Recoverability:** In burned areas, *Parkinsonia* species generally sustain high amounts of shoot-kill from which they may or may not recover (Alford et al. 2005; Esque et al. 2013; Shryock et al. 2015). *Parkinsonia microphylla* has demonstrated only moderate resprouting capability. In one study, 25% of *P. microphylla* individuals resprouted after fire (McLaughlin and Bowers 1982), while another study recorded post-fire resprouting in 13% of individuals (Rogers and Steele 1980). Caged and watered seedlings of *P. microphylla* resulted in high plant survival (84%) two years after planting (Abella et al. 2015c). Re-planting treatments were tested in highly eroded desert land in the Sonoran Desert. Inoculation by growth-promoting bacteria, native arbuscular mycorrhizal fungi, and compost had little effect on survival and growth for *P. microphylla* or *P. florida* after 30 months (Bashan et al. 2012).

## *Penstemon spp.* (Plantaginaceae)

**Common Name(s):** *Penstemon eatonii* A. Gray – Eaton’s firecracker penstemon; *P. palmeri* A. Gray - Palmer’s penstemon; *P. parryi* (A. Gray) A. Gray – Parry’s penstemon; and *Penstemon pseudospectabilis* M.E. Jones - showy penstemon.

**Functional group and bloom season**: All four of these *Penstemon* are sub-shrubs and short-lived perennials with wand-like inflorescences. *Penstemon eatonii* blooms April to June (SEINet 2020); *P. palmeri* flowers from May to June (Baldwin et al. 2002); *P. parryi* blooms February through May *(SEINet 2020); P. pseudospectabilis* blooms from March to May (Baldwin et al. 2002).

**Distribution in Mojave Desert/Habitat:** *Penstemon eatonii* has a patchy distribution in the Mojave Desert mostly associated with plateaus and mountain ranges, such as Pine Valley Mountain in Utah, the Spring Mountains of Nevada, and New York and San Bernardino mountains in California, where it inhabits rocky slopes and canyons from 1000 m to >1600 m (SEINet 2020). *Penstemon palmeri* inhabits creosotebush scrub to pinyon-juniper woodland, growing in washes, canyon floors, and along roadsides from 1100 m - 2300 m (Baldwin et al. 2002). *P. parryi* has extremely limited range in the Mojave Desert only occurring near St. George, Utah (SEINet 2020), where it grows in the Navajo sandstone canyons and hillsides from 700 m to 1200 m in elevation (T. Esque, pers. obs.). *Penstemon pseudospectabilis* is strongly distributed in the Sonoran Desert of Arizona and grading into the eastern Mojave Desert through Utah, Nevada and eastern California toward the Baker Sink. It grows in rocky washes, canyons, and creosote scrub from 100 m to 1400 m (Wetherwax and Holmgren 2012).

**Flower color and shape:** *P. eatonii* has a scarlet red corolla that is the narrowest among those discussed here. *Penstemon palmeri* are purple to pink on a lighter background, with distinct nectar guides, and vestibular (having a wide opening – presumably to accommodate bees; Wilson et al. 2004). *P. parry* is day-glow pink with a narrower flower than *P. pseudospectabilis*. The flowers of *P. pseudospectabilis* are variable ranging from combination pink and white to pink to solid bright red with a tubular to trumpet shape. They are slightly globose, more similarly to *P. palmeri* in overall form.

**Pollinator use:** Bees are the principal pollinators of many penstemons (Lange and Scott 1999), and *P. palmeri* is strongly adapted to pollination by large-bodied bees. *Anthophora urbana* uses this species in south-central Utah (Carril et al. 2018). Besides being purple and vestibular, it is the only odoriferous penstemon, emitting an intoxicatingly sweet scent that is attractive to bees (Thomson et al. 2000; Wilson et al. 2004). Nectaring *Bombus, Xylocopa*, and various anthophorine bees pollinate this species (Wilson et al. 2004). At the Nevada National Security Site (formerly Nevada Test Site), the bees *Ashmeadiella australis* Cockerell*, Lasioglossum hyalinum, L. incompletum* Crawford, and *L. nevadense* visit Palmer’s penstemon (Allred 1969). Bee visitors to other *Penstemon* spp. at the site include *Lasioglossum incompletum, L. microlepoides, Halictus tripartitus*, and *Lasioglossum sisymbrii* (Allred 1969). *Penstemon palmeri* is not known to be visited by hummingbirds (Thomson et al. 2000), although it seems unlikely they would not visit on occasion.

While*P. pseudospectabilis* is also capable of self-pollination (Lange and Scott 1999), this species, as well as *P. parryi* and *P. eatonii,* have relationships with many pollinators. There is an evolutionary trend among *Penstemon* species from bee toward bird pollination, which manifests with an increasingly narrower, redder corolla, greater production of nectar sugar, and the loss of the exserted lower lip (Castellanos et al. 2004; Wilson et al. 2004). *Penstemon pseudospectabilis* is pollinated by *Anthophora, Bombus*, and *Osmia*, as well as honeybees (*Apis mellifera*), cactus bees (*Lasioglossum spp.*) and sweat bees (*Halictus spp.*; Lange and Scott 1999; Lange et al. 2000). *Penstemon pseudospectabilis* traits are at the center of the pollination syndrome spectrum and are visited by hummingbirds as well as bees (Lange and Scott 1999). Closer to the hummingbird end of the bee-to-hummingbird pollinator spectrum, *P. eatonii* also hosts a great variety of bee pollinators. Carril et al. (2018) documented 51 native bee species across 20 genera that visited *P. eatonii*.

In the Mojave Desert, the most notable bird visitor to *Penstemon* is Costa’s hummingbird (*Calypte costae* Bourcier; Crosswhite and Crosswhite 1982; Lange and Scott 1999), which breeds in desertscrub and wash habitat (Austin 1970; Blake 1984; Szaro and Jakle 1985). Other resident hummingbird visitors to *Penstemon* include the black-chinned (*Archilochus alexandri*), and Anna’s (*Calypte anna* Lesson) but also broad-tailed (*Selasphorus platycercus* Swainson), rufous (*Selasphorus rufus* Gmelin), and broad-billed hummingbirds (*Cynanthus latirostris* Swainson). *Calypte costae*, *C. anna*, and *Archilochus alexandri* all breed in the Mojave Desert (although *C. anna* are probably limited mostly to suburban areas), but other hummingbirds use flowering species in xeririparian habitat as food sources during their migrations (Crosswhite and Crosswhite 1982; Freeman et al. 1984; Lange and Scott 1999; Lange et al. 2000; and T. Esque, pers. obs. for breeding *C. anna* and *A. alexandri*).

The *Penstemon* are also likely larval hosts to some Lepidopterans including the common buckeye butterfly (*Junonia coenia* (Hübner), the variable checkerspot (*Euphydryas chalcedona* E. Doubleday), Edith’s checkerspot (*E. editha* Boisduval), and the *Archirhoe neomexicana* Hulst moth (Calscape.org 2020).

**Tortoise use:** We have found no information on the use of *Penstemons* by desert tortoise as either cover or forage. This species is consumed by wildlife in the Great Basin (Stevens and Monsen 1988), and it is possible that tortoises consume the herbaceous seedlings and juvenile plants when encountered.

**Propagation, production, and cultivation:** *Penstemon* species are spring-blooming and generally germinate well between 15°-20°C (Royal Botanic Gardens Kew 2017; Raeber and Lee 1991). Pretreatment with gibberellic acid also seems to greatly benefit germination of *Penstemon* seeds. *Penstemon pseudospectabilis* germinated to 94% when imbibed on agar with gibberellic acid (GA3) for 8 weeks at 0° C and grown on a medium of 1% agar + 250 mg/l gibberellic acid GA3 at 20° C, 8/16 light and dark (Royal Botanic Gardens Kew 2017). All of the *Penstemon* are sold at many nurseries across the Mojave Desert and commercial growers cultivate them because they are highly valued for their spectacular floral displays and ability to attract pollinators.

Seeds of *P. palmeri* stored in warehouse conditions maintained 80% germinability for five years, which gradually decreased to 50% after fifteen years of storage (Stevens et al. 1981). Optimal germination conditions for *P. palmeri* are 15°C under a 12-hour photoperiod (Kitchen and Meyer 1992). Seeds that are heat-treated (30°C) have lower light requirements for germination (Kitchen and Meyer 1992). Imbibition of a gibberellic acid solution (250 mg/L) also effectively breaks dormancy in *P. palmeri* seeds (Kitchen and Meyer 1992). *Penstemon palmeri* has demonstrated seasonally bimodal germination, with some seedlings emerging in fall and some in spring; this pattern can manifest even among seeds from the same cohort (Kitchen and Meyer 1992).

There has been concern among desert resource managers in Nevada about outcrossing between *Penstemon* species (Lara Kobelt, BLM, Southern Nevada District Office, pers. comm., 2020). The rare *Penstemon bicolor* var. *bicolor* can outcross with both its relative *– P. b.* var*. roseus*, and also with *P. palmeri*. If outplanted too closely, these varieties and species can outcross. Avoiding these sorts of unintended consequences of restoration activities is a fundamental tenant of this work by practitioners. Such outcomes should always be considered in the planning stages of restoration projects.

**Recoverability:** Caprio (1994) classified *P. parryi* as a species responding well to fire disturbance. Likewise, *P. spectabilis* has demonstrated the ability to re-sprout after low-intensity fires (Schmalbach et al. 2007). Once established, most *Penstemon* readily self-seed, thus increasing their likelihood of resilience after initial restoration investment. All these *Penstemon* can be found growing in roadside riparian habitats.

*P. palmeri* is commonly used in mine restoration (Richards et al. 1998) but does not compete well with cheatgrass (*Bromus tectorum*) compared with other native plant species (*Acmispon humistratus, Cryptantha fendleri* (A. Gray) Greene*,* and *Machaeranthera tanacetifolia* (Kunth) Nees) in the Great Basin (Barak et al. 2015). *Penstemon palmeri* species also may be sensitive to re-introduction to disturbances with saline soils (Zollinger et al. 20017) but demonstrates some tolerance to zinc contamination associated with mining, agriculture, and waste disposal (Paschke et al. 2005). *Penstemon palmeri* colonizes burned areas (Brooks and Matchett 2003) and roadsides, and successfully establishes when hand-sown in disturbed sites (Walker and Powell 1999). However, seedling establishment associated with nurse plants may be necessary in some disturbed habitats (Poulos et al. 2014).

## *Plantago* spp. (Plantaginaceae)

**Common Name(s):** *Plantago ovata* Forsk (= *P. insularis*) - desert indianwheat; *P. patagonica* Jacq. – woolly plantain.

**Functional group and bloom season:** Both species are herbaceous annuals. *Plantago ovata* flowers from February to April, and *P. patagonica* from April to August (Rosati 2012).

**Distribution in Mojave/Habitat:** *Plantago ovata* Forskk*.* has a broad geographic range and grows in sandy/gravelly soils in creosote bush scrub to Joshua tree woodlands below 1400 m (Baldwin et al. 2002). *Plantago patagonica* is found at higher elevations (500 m – 2200 m) in pinyon/juniper and Joshua tree woodland, chaparral, and on grassy slopes (Baldwin et al. 2002).

**Flower color and shape:** White to brown; much reduced; organized in a spike.

**Pollinator use:** *Plantago patagonica* is an obligate inbreeding species, and thus not beneficial to pollinators (Sharma 1993, 1999). *Plantago ovata* can outbreed but is wind pollinated rather than animal pollinated (Sharma 1993). *Plantago ovata* is a larval host to the Edith’s checkerspot butterfly (*Euphydryas editha* Boisduval; Robinson et al. 2010).

**Tortoise use:** This species, along with its congener *P. ovata*, are diet plants of desert tortoise (Esque 1994; Esque et al. 2014; Drake et al. 2016). With three percent of total bites (Table 2), *P. ovata* was the fourth most abundant diet item and used at five sites.

**Propagation, production, and cultivation:** Seed collection is best achieved by collecting mature whole plants of *Plantago* spp. Seed easily dehisces from capsules into collection bags, and seed and chaff can be sifted through # 16 sieve with a blower set at 1.5 speed for processing (Wall and MacDonald 2009). Adondakis and Venable (2004) found that *P. patagonica* demonstrated its highest germination rate (64%) when propagated following a dry/hot treatment lasting from June to September, then under temperature regimes mimicking early winter growing conditions (December treatment: 18°/3°C, 10.25 hrs daylight). The pre-germination treatment consisted of placing mesh bags of seed directly on the ground beneath a transparent tent to shield them from the rain. This species also has a portion of seeds that remain dormant: although the highest germination rate was 64%, when ungerminated seeds were tested, ≥94% of seeds among the cohort were still viable. Another study found that *P. ovata* has optimal germination at 15°C, regardless of light conditions (Hammouda and Bakr 1969). When wetted, the seeds exude a sticky gelatin-like mass that acts as a seed adhesive as it dries to rocks (Baldwin et al. 2002). This mucilaginous layer may protect the seeds from granivory and/or enhance germination by prolonging moisture surrounding seeds.

**Recoverability:** *Plantago* species tend to have a notable presence in desert seed banks where they occur (Holzapfel et al. 1993; DeFalco et al. 2005) and germinate easily following winter rains (Adondakis and Venable 2004). *Plantago* is reduced in the seed bank following fire (Esque et al. 2010) but may recover within a couple of years after fire if the seed bank builds up after re-colonization and germination conditions are met, particularly above-average precipitation (Cave and Patten 1984). On rare occasions, this species may fuel wildfires late in the season by creating continuity of flammable vegetation between sparsely dispersed shrubs (Esque et al. 2013). Protection of seeds from predators, such as through pelletizing seed or fencing areas where seeds are broadcast, increases establishment of *Plantago ovata* (Abella et al. 2015a).

## *Psorothamnus* spp. (Fabaceae)

**Common Name(s):** *Psorothamnus arborescens* (A. Gray) Barneby – Mojave indigo-bush; *P. fremontii* (Torr. ex Gray) Barneby – Fremont’s dalea; *P. spinosus* (A. Gray) Barneby– smoke tree.

**Functional group and bloom season:** *P. arborescens* and *P. fremontii* are woody shrubs. Both species flower between April and May (Wojciechowski and Isely 2012a, b). *Psorothamnus spinosus* is a shrubby tree flowering June to July (Wojciechowski and Isely 2012c).

**Distribution in Mojave/Habitat:** *P. arborescens* is most prevalent in the southwestern Mojave Desert growing in desert areas between 400 m and 800 m (Baldwin et al. 2002). *Psorothamnus fremontii* is found throughout the Mojave in granite soils, volcanic slopes, flats, and canyons between 150 m and 1350 m (Wojciechowski and Isely 2012a, b, c). *Psorothamnus spinosus* is a Colorado Desert species growing at elevations <400m where it is associated with desert washes.

**Flower color and shape:** All three species have deep purple-blue inflorescences; papilionaceous.

**Pollinator use:** *Psorothamnus* species are pollinated by bees of genera *Ancylandrena*, *Megandrena,* and *Perdita* (Allred 1969; Griswold et al. 2006; Wilson and Carril 2016). In south-central Utah *P*. *fremontii* was used by *Agapostemon* *angelicus* Cockerell, *Anthophora* *urbana*, *Anclyandrena timberlakei* Zavortink, *Ashmeadiella cazieri* Michener, *A. bucconis* Say *A. cactorum* Cockerell, *A. cubiceps* Cresson, *A. gilletei* Titus, *A. meliloti* Cockerell, *A. xenomastax* Michener, three *Ashmeadiella* morphotypes, *Anthidium cockerelli* Schwarz, *Ceratina apacheorum* Daly, *Colletes larreae*, *C. phaceliae*, *C. slevini*, a *Colletes* morphotype, *Diadasia lutzi* Lutzi, *Hexepeolus rhodogyne*, *Hoplitis grinnelli* Cockerell, *H. paroselae* Michener, a *Hoplitis* morphotype, a *Hylaeus morphotype*, *Lasioglossum sp.*, *L. albohirtum*, *L. pulveris* Cockerell, three *Lasioglossum* morphotypes, *Megachile prosopidis* Cockerell, *M. montivaga* Cresson, *Perdita aridella* Timberlake, three *Perdita* morphospecies, and the honeybee (*Apis mellifera*; Carril et al. 2018).

Both shrub species host the desert moth *Hemileuca burnsi*. *Psorothamnus fremontii* hosts and provides nectar for the Ceraunus blue butterfly (*Hemiargus ceraunus* Fabricius; Robinson et al. 2010), and the painted lady butterfly (Caldwell 2014). *Psorothamnus spinosus* provides nectar to the desert metalmark butterfly (*Apodemia mejicanus deserti* W. Barnes and McDunnough; Caldwell 2014).

**Tortoise use:**  *Psorothamnus fremontii* makes up 1% of use for cover by tortoises, or the twelth most frequently used taxon, and was used at two sites. *Psorothamnus arborescens* might also be used as a cover species. There are no reports of desert tortoise foraging on plants of this genus (Table 2).

**Propagation, production, and cultivation:** Germinability of mature seeds is generally stable under long-term storage with initial germinability ranging from 22% (*P. spinosus* (A. Gray) Barneby), 41% (*P. fremontii*), 58% (*P. emoryi* (A. Gray) Rybd*.*), and 90% (*P. schotii* ); *P. polydenius* (Torr.) Rybd. had 2% germinability but increased over time with storage (Kay et al. 1988). *Psorothamnus* species exhibitphysical dormancy, which can be broken via scarification treatments. A study of *P. fremontii* found that three days of scarification treatment using a rock tumbler (1-L capacity, tumbled with 100 g of 10-15 mm and 75 g of coarse carborundum grit at a rotation rate of 60 rpm) resulted in greater germination speed and slightly greater total germination than a hot water soak treatment and a control group (Dreesen and Harrington 1997). Seeds of *P. schotii* are large (5.0-8.0 mm) and require a large screen with heavy paddle to remove pods from stems (Wall and MacDonald 2009). When cleaning seeds, if pods do not dehisce easily, rub over a medium screen or #6 sieve while using a blower with speed 3.0-4.0 to clear away the chaff (Wall and MacDonald 2009). Salvage of adult *P. fremontii* resulted in 40% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 14% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** Percent cover and density of *P. arborescens* was lower in two-year-old burned areas than it was in a paired unburned area, but density of this species was higher on a 24-year-old burned site than it was on an adjacent unburned site (Steers and Allen 2011). These results suggest that although *Psorothamnus* species can recover well from fire disturbance, several years or decades may be required before populations are restored to their original state.

## *Salvia* spp. (Laminaceae)

**Common Name(s):** *Salvia columbariae* Benth*.* – chia; *S. dorrii* (Kellogg) Abrams – desert purple sage; *S. mohavensis* Green – Mohave sage.

**Functional group and bloom season:** *Salvia columbariae* is an herbaceous annual that flowers from March to June (Averett 2017a). *Salvia dorrii* and *S. mojavensis* are woody shrubs that flower from April to July (Averett 2017b) and March-October, (Averett 2012), respectively.

**Distribution in Mojave/Habitat:** *S. columbariae* can be found in dry, disturbed sites below 2500 m (Averett 2017a)*. Salvia dorii* grows on dry flats and slopes between 450 m and 3200 m (Averett 2017b). *Salvia mohavensis* grows on dry rocky slopes in blackbrush to pinyon/juniper woodlands from 300 m to 1500 m (Averett 2012).

**Flower color and shape:** Blue; labiate

**Pollinator use:** Bees of several genera visit *Salvia* species, including *Anthophora, Ashmeadiella, Anthophorula (=Synhalonia),* and *Tetraloniella* Ashmead (Hurd and Linsley 1975a; Wilson and Carril 2016). The white-lined sphinx moth nectars on *Salvia* spp. (Caldwell 2014). The California patch (Chlosyne californica)and checkerspot (*Euphydryas* Scudder sp.) butterflies use *Salvia* in Clark County, Nevada (Caldwell 2014). The BLM in California (Bishop Field Office) also recommends *S. dorrii* as a host for spring pollinators (M. Oliver, pers. comm., 28 Feb 2017).

Approximately 18 % of the *Salvia* spp. in the southwestern US are bird pollinated (Wester and Classen-Bockhoff 2011). While the floral morphology of many *Salvia* spp. appears to have evolved for bee pollination, many are also fly pollinated (Celep et al. 2014). *Salvia columbariae* is also a larval host species for the *Pyrausta dapalis* Grote (taxonomic authority remains unverified) moth (Robinson et al. 2010). In chaparral habitat on the edge of the western Mojave, Costa’s hummingbirds (*Calypte costae*) – also native to Mojave Desert habitats – are highly dependent on *Salvia* flowers (Stiles 1976) and were seen nesting in shrubby *Salvia eremostachya* Jeps. (Duncan and Esque 1986), a plant similar in growth form to *S. dorii*. Hummingbirds are likely not an effective pollinator of this genus based on the short corolla tube, wide corolla opening, and exserted anthers of *Salvia* spp., but they frequently nectar on *Salvia* spp. (Stiles 1976).

**Tortoise use:** Mojave desert tortoises used *Salvia* sp. as a cover species, butwe found no data describing desert tortoise use of *Salvia* species for forage.

**Propagation, production, and cultivation:** To clean seeds, simply leave floral stems to dry in paper bags; if any seeds remain in the involucres, rub floral whorls through a medium-sized screen (Wall and MacDonald 2009). Germination of *S. columbariae* has been well-studied in comparison with its congener *S. dorrii*, likely because of the importance of *S. columbariae* as a crop plant. Optimal germination occurs at 20°C (Capon and Van Asdall 1967). Germination responses of *S. columbariae* vary among populations with respect to temperature and precipitation (Capon et al. 1978) and may be stimulated by smoke and charred wood treatments (Keeley 1984; Fotheringham et al. 1995). Baskin and Baskin (2002) found that seed germination increased by 43% when grown in media containing charred wood extracts.

The shrubby *Salvia* (*S. dorrii*, and *S. mojavensis*) are valued in cultivation for xeriscaping. *Salvia dorrii* performed well in a study of 47 woody shrubs– propagated from stem cuttings of wild stock (Everett et al. 1978).

**Recoverability:** The preference of *S. columbariae* for disturbed areas, such as desert washes, and charcoal-stimulated germination suggests that it would rapidly colonize burned areas.

## *Sphaeralcea ambigua* A. Gray(Malvaceae)

**Common Name(s):** desert globemallow.

**Functional group and bloom season:** Herbaceousperennial/sub-shrub. This species blooms throughout the year in response to precipitation, but flowers most heavily from February to May (Wolf and Evancho 2016).

**Distribution in Mojave/Habitat:** Desert globemallow is a common species in desert scrub habitats from 150 m to 2500 m (Baldwin et al. 2002).

**Flower color and shape:** Red to orange; bowl-shaped.

**Pollinator use:** The wide range of *Sphaeralcea* *ambigua* and its prolific blooms make it an excellent plant for enhancing pollinator habitat (Carril et al. 2018). *Diadasia diminuta* Cresson and *Calliopsis* *subalpina* Cockerell bees are *Sphaeralcea* specialists (Carril et al. 2018). *Sphaeralcea* species of the Mojave Desert are visited by several other native bees, including *Melissodes subagilis, Perdita arcuate* Fox, *Triepeolus helianthi* Robertson (Allred 1969) and the *Exomalopsis, Megandrena,* and *Anthophorula* genera (Hurd and Linsely 1975a; Griswold et al. 2006). *Sphaeralcea* are also visited by many flies and small beetles that were not identified to species (G. Tyree, pers. obs.).

*Sphaeralcea ambigua* is also a larval host for native butterflies, including the northern white-skipper (*Heliopetes ericetorum* Boisduval)*,* white checkered skipper (*Pyrgus (=Burnsius) albescens* Plötz), common checkered skipper (*Pyrgus communis* Grote)*,* small checkered skipper *(Pyrgus scriptura* Boisduval), gray hairstreak *(Strymon melinus*)*,* and west coast lady(*Vanessa annabella* W.D. Field; Stewart et al. 2001; Wolf and Evancho 2016).

**Tortoise use:** *Sphaeralcea ambigua* ranked seventh as a cover species across five sites (Table 3). *Sphaeralcea* *ambigua* is used by desert tortoise for cover and forage (Esque 1994, Drake et al. 2015). *Sphaeralcea ambigua* inhabits disturbed areas such as burned areas, washes, and roadsides (Walker and Powell 1999) and typically is less common in undisturbed low elevation shrublands. This pattern likely explains why this species was fifty-fifth on the diet list yet was observed as a widespread diet item at four of the ten undisturbed sites (Arden, Nevada; lower Grand Canyon, Arizona; City Creek, Utah; and Littlefield, Arizona; Table 2). Although our analysis of diets does not reflect this as a significant species in undisturbed habitats, *S. ambigua* is among those species that are palatable to tortoises, and adult tortoises have been observed feeding on this species in areas that were hand seeded with a native seed mix containing *S. ambigua* (L. DeFalco, pers. obs.). Captive tortoises gained weight when fed *S. ambigua*, in comparison to a diet of the invasive grass *Schismus* spp. (Barboza 1995). The species may provide sustenance in years when annuals fail (Hansen et al. 1976). This species is an important short-term cover for tortoises following fires until long-lived shrub species re-establish (Drake et al. 2015).

**Propagation, production, and cultivation:** Mature seeds of *S. ambigua* have low initial germinability (< 10%), can increase in germinability after dry, sealed storage, but decrease in germinability beyond 2.5 years (Kay et al. 1988). Germinability can be significantly increased through mechanical scarification with a fine grit sand-paper to abrade the seed coat (L. DeFalco, pers. comm.). Seeds are small (1.5-2.0 mm), and mature schizocarps collected by hand can be rubbed over #12 sieve to break up segments and release seeds while keeping the blower speed at 2.0-2.25 to separate the high percentage of sterile from filled seeds (Wall and MacDonald 2009). Salvage of adult *S. ambigua* resulted in 61% survival after 12 months of care in a nursery; surviving plants were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 50% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** Following large wildfires in the Mojave Desert, *S. ambigua* can dramatically increase in abundance and remain a major component of vegetation for decades (Abella et al. 2009; Drake et al. 2015; Shryock et al. 2014). *Sphaeralcea* species are used widely in restoration due to their broad distributions, and their abundance along disturbed roadside habitat where they are easily accessible to seed collectors. In burned areas in the Upper Sonoran, *S. ambigua* was initially greatly reduced post-fire, but surviving plants recovered, and new plants reinvaded burned sites within one year (Cave and Patten 1984). A caveat of using this species in restorations is that it is short-lived, with a lifespan of 2-5 years (Drake et al. 2015). The seeds of this species are dispersed by granivores such as ants (DeFalco et al. 2009), which may assist reinvasion of this species in disturbed landscapes. The seeds of *S. ambigua* are dispersed rapidly after ripening, with few retained in the schizocarp (Martínez-Berdeja et al. 2015). This strategy may promote animal-assisted seed dispersal. Pelletizing *S. ambigua* seeds or fencing seeded areas did not increase seedling establishment (Abella et al. 2015a).

## *Stanleya pinnata* Greene (Brassicaceae)

**Common Name(s):** Prince’s plume.

**Functional group and bloom season:** Herbaceous perennial /subshrub. *Stanleya pinnata* flowers between April and September (Al-Shehbaz 2012).

**Distribution in Mojave/Habitat:** This species grows in a variety of habitats (flats, slopes, canyons, woodlands, dunes) below 2896 m throughout the Mojave Desert (Al-Shehbaz 2012).

**Flower color and shape:** Yellow; cruciform; arranged in a large and showy raceme, anthers are conspicuously exserted.

**Pollinator use:** Allred (1969) recorded bees of a dozen genera visiting *Stanleya pinnata*, including *Agapostemon texanus*, *Anthophora californica* Cresson, *A. urbana, Bombus morrisoni* Cresson*, Centris rhodopus, Colletes eulophid* Robertson*, C. hyalinus* Provancher*, Calliopsis subalpina, Diadasia diminuta, D. lutzi, Lasioglossum albohirtum* Crawford, *L. sisymbrii, Melissodes subagilis, Tetralonia* Spinola sp.,  *Xeromelecta californica* Cresson*,* and *Xylocopa californica* Cresson. Later studies documented visits from bees of genera *Ancylandrena* and *Perdita* (Hurd and Linsely 1975a; Griswold et al. 2006).

*S. pinnata* is also a larval host for the Becker’s white butterfly *(Pontia beckeri*), the checkered white (*P. protodice*), the spring white (*P. sisymbrii* Boisduval), the pearly marble butterfly *(Echloe hyantis* W.H. Edwards), and Sara’s orangetip (*Anthocharis sara* Lucas*;* Robinson et al. 2010; Stewart et al. 2001). The BLM, California (Bishop Field Office) recommends *S. pinnata* as a host for summer pollinators (M. Oliver, *pers. comm*., Feb. 28, 2017).

**Tortoise use:** There is no information on whether *S. pinnata* is used by desert tortoise, perhaps due to its uncommon occurrence in intact upland creosotebush-bursage shrublands.

**Propagation, production, and cultivation:** Kay et al. (1988) found that seed germination for *S. pinnata* ssp. *inyoensis* was high (90% at best), storability was rated “excellent”, and no special storage conditions were required. *Stanleya pinnata* ssp. *pinnata* has a similarly high germination rate (92% at best), but only “fair” storability. Emery (1964) also noted that the seeds of *S. pinnata* and *S. elata* M.E. Jones germinate without pretreatment.

**Recoverability:** We found no information regarding the use of *S. pinnata* in Mojave Desert restorations, or the response of this species to fire disturbance.

## *Stephanomeria* spp. (Asteraceae)

**Common Name(s):** *Stephanomeria exigua* Nutt. – wire lettuce*, S. parryi* A. Gray – Parry’s wire lettuce; *Stephanomeria pauciflora* (Torr.) A. Nelson – few flower wire-lettuce.

**Functional group and bloom season:** *Stephanomeria exigua* is an annualflowering from April to July; *S. parryi* flowers from May to June, and *S. pauciflora* from March to November (Gottlieb 2012a, b, c).

**Distribution in Mojave/Habitat:** *Stephanomeria exigua* grows in disturbed areas of desertscrub below 2000 m, while *S. parryi* grows along sandy/gravelly slopes between 680 m and 2000 m, and *S. pauciflora* can be found on dry flats below 2400 m (Baldwin et al. 2002).

**Flower color and shape:** White to pink; involucral heads of ligulate flowers; somewhat salverform.

**Pollinator use:** *Stephanomeria* species are pollinated by bees of genera *Anthidiellum* Cockerell*, Ashmeadiella,* and *Perdita* (Hurd and Linsely 1975a; Griswold et al. 2006). *Stephanomeria pauciflora* and *S. exigua* are also larval hosts for owlet moths (*Cucullia basipuncta* Barnes and McDunnough*, C. eulepis* Grote*, Schinia scarletina* Smith; Robinson et al. 2010).

**Tortoise use:** *Stephanomeria exigua* (annual) was the second-most used species in tortoise diets and used at three sites (Supplement 2). *Stephanomeria parryi* (herbaceous perennial) was used at one site and composed 0.1% of bites, and *S. pauciflora* (subshrub) was used at two sites and composed <0.1% of bites (Supplemental 2). This species was not documented as a cover species for tortoises.

**Propagation, production, and cultivation:** Seeds from achenes can be separated from inflorescences by gently rubbing flower heads on a rubber mat with a padded wood block to remove some of the pappus and break down chaff with a blower speed set at 1.5 (Wall and MacDonald 2009). *Stephanomeria pauciflora* seed has low initial germination (< 10%), but dry, sealed storage increased germinability, particularly at room temperature (70%) compared with cold storage, up to three years but then declined thereafter (Kay et al. 1988). It has been suggested through discussion with restoration practitioners that *Stephanomeria* are not good candidates because the seeds are hard to collect and handle, and most of the collected seed has low viability. However, their propensity to re-invade burned areas supports its importance as a restoration species, and its lower yield may be overcome by using the limited field reproduction for seed increase under nursery conditions. Salvage of adult *S. pauciflora* resulted in 42% survival after 12 months of care in a nursery; surviving *Larrea* were transplanted to a disturbed roadside at Lake Mead National Recreation Area resulting in 47% survival 27 months after transplanting (Abella et al. 2015b).

**Recoverability:** *Stephanomeria* spp. may rapidly reinvade disturbed areas through reseeding (Cave and Patten 1984). The light, wind-blown seeds of *Stephanomeria* spp. may promote their distribution in disturbed areas, assisting the recovery of this species after fire (Cave and Patten 1984).

## *Stipa (=Oryzopsis, = Achnatherum) hymenoides* Roem. & Shult. (Poaceae)

**Common Name(s):** Indian ricegrass, sand ricegrass.

**Functional group and bloom season:** *Stipa hymenoides* is a perennial grass that flowers from April to July (Baldwin et al. 2002).

**Distribution in Mojave/Habitat:** Indian ricegrass grows in desert scrub, sagebrush scrub, blackbrush shrubland, and pinyon-juniper woodlands in sandy soils throughout the Mojave Desert (Baldwin et al. 2002).

**Flowers color and shape:** The inflorescence of *S. hymenoides* is an open panicle of sparse, terminal spikelets. The seeds are conspicuously downy upon maturity.

**Pollinator use:** *Stipa hymenoides* is wind-pollinated, and we found no information on the use of this species as a larval host.

**Tortoise use:** This perennial grass was the seventh most abundant species in tortoise diets and was observed in diets at five different sites spanning the Mojave and into the Colorado deserts. This species is also important in the diets of granivorous rodents (Longland and Bateman 1998). However, this species has low digestibility for tortoises compared with forbs (Nagy et al. 1998), and juvenile and adult tortoises fed single-species diets, including *S. hymenoides*, lost more minerals compared with native forb diets (Hazard et al. 2010).

**Propagation, production, and cultivation:** Seeds can be obtained by collecting and rubbing mature inflorescences on a rubber mat repeatedly to remove florets from spikelets and separate awns with the blower speed at 1.5 (Wall and MacDonald 2009). This is a large-seeded perennial grass, for which two cultivars, Nezpar and Paloma, have been developed, but remain untested in restoration trials within the Mojave Desert. *Stipa hymenoides* establishment in the Mojave Desert is enhanced by seed bed treatments that place seeds below the soil surface in combination with supplemental irrigation (Winkel et al. 1995b, Ott et al. 2011). Scatterhoarding by heteromyid rodents can assist dispersal of *S. hymenoides* onto burned areas (Longland et al. 1995). In the Great Basin Desert, diversionary seeding of millet (*Panicum miliaceum* L.) in combination with *S. hymenoides* was successfully used to reduce seed predation by rodents because the rodents are satiated by the inexpensive millet (Longland and Ostoja 2013). Trials of these methods are currently underway in the Mojave Desert using heat-killed millet (L. DeFalco, unpubl. data). *Stipa hymenoides* can also be propagated from off-shoots (H. Dial, NRCS – pers. comm.).

*S. hymenoides* grows readily from field collected tillers with attached root, and this can be a good way of establishing stock plants, as well as materials for outplanting (LAD, *unpubl. data*).

**Recoverability:** *Stipa hymenoides* has a long history of use in restorations in the Great Basin (Cook and Child 1971; Wright 1985; Thompson et al. 2006) and has been described as an important species in burned areas (Barney and Frischknecht 1974). However, persistence of seeded *S. hymenoides* in restoration areas can be limited (Ott et al. 2011).

***Xylorhiza tortifolia* (Torr. & Gray) Greene**   
**Common Name(s):** Mohave woodyaster.  
**Functional group and bloom season:** *Xylorhiza tortifolia* is a subshrub that blooms from March to May, and sometimes again in October (Baldwin et al. 2002).   
**Distribution in Sonoran/Habitat:** *Xylorhiza tortifolia* can be found in rocky soils on desert slopes and in canyons from 240 m - 2000 m (Baldwin et al. 2002).   
**Flower color and shape:** The involucral heads are composed of both ray and disc flowers and offer wide landing platforms to insect visitors. The disc flowers are yellow, and the rays are white to pale purple.   
**Pollinator use:** Carril et al. (2018) listed 11 taxa of native bees found on *Xylorhiza* sp. and *Xylorhiza tortifolia* at Grand Staircase-Escalante National Monument in south-central Utah including: *Andrena linsleyana* Thorp, *Anthophora petrophila*, an *Anthophora* morphospecies, *Ashmeadiella cactorum* Cockerell, *Ashmeadiella gilletei*, *Ashmeadiella xenomastax*, a *Hesperapis* morphospecies, a *Hylaeus* morphospecies, *Lasioglossum sisymbrii*, *Perdita aridella*, *P. morula*, and a *Perdita* morphospecies. *Xylorhiza tortifolia* is a larval host for owlet moths (Noctuidae: *Cucullia intermedia* Speyer*, Schinia ligeae*) and the brush-footed butterfly *Agathymus* (=*Charidryas) neumoegeni* (Robinson et al. 2010).   
**Tortoise use:** *Xylorhiza tortifolia* was used rarely as cover by desert tortoise at two sites (Supplement 3) but was not recorded in diets.   
**Propagation, production, and cultivation:** There was no loss in viability of *X. tortifolia* seeds after 7.5 years of storage at 4°C or -15°C (Kay et al. 1988). *Xylorhiza tortifolia* germinates well at a range of temperature conditions (10°, 15°, 20°C) at an 8 hr/16 hr light and dark cycle (Royal Botanic Gardens Kew 2017). This species is often propagated by local nurseries in southern Nevada for use in horticultural settings. *X. tortifolia* is widely used in desert pollinator gardens, and this species is fairly easy to find among nurseries and commercial growers. Nurseries at national parks (Joshua Tree National Park and Lake Mead National Recreation Area) and Nevada Division of Forestry are experienced in propagating this species. The Mojave Desert Land Trust ([www.mdlt.org](http://www.mdlt.org), Accessed 2 February 2021, TCE) sells *X. tortifolia* seeds as part of their native plant restoration nursery program; they provide guidance on the relatively easy success with this species if planted under the correct conditions.

**Recoverability:**  *X. tortifolia* was among 24 plants involved in a mine restoration project at the Silver Bell Mine in Joshua Tree National Park in 1993. *Xylorhiza tortifolia* was among 6 species that had >90 % survival during preliminary trials (Rodgers 1994).

## *Yucca* spp.(Asparagaceae)

**Common Name(s):** *Y. baccata* Torr. banana yucca; *Yucca brevifolia* Engelm. – western Joshua tree; *Y. jaegeriana* (McKelvey) L.E. Lenz – eastern Joshua tree; *Y. schidigera* Roezl. ex Ortgies - Mojave yucca; *Y. utahensis (*McKelvey) Reveal - Utah yucca*.*

**Functional group and bloom season:** Leaf succulents. *Yucca baccata*, *Y. brevifolia* and *Y. jaegeriana* flower May to June (Hess 2012a, b); *Y. schidigera* flowers April to May, and *Y. utahensis* flower from April to August (Hess 2012c).

**Distribution in Mojave/Habitat:** *Yucca brevifolia, Y. jaegeriana*, and *Y. schidigera* are the most common of five native yucca species normally found in desert tortoise habitats. *Yucca brevifolia* recently was split into *Y. jaegeriana* and *Y. brevifolia*, yet currently overlap in distribution within Lincoln Co., Nevada (Rowlands 1978). All five yuccasare found along desert slopes and flats below 2500 m (Baldwin et al. 2002). *Yucca utahensis* grows on desert hillsides and in canyons in the northeast Mojave Desert from 700 m – 2000 m (SEINet).

**Flower color and shape:** White or cream; bowl-shaped

**Pollinator use:** The symbiotic relationship between *Yucca* species and small Prodoxidae moths is one of the most famous examples of obligate mutualisms in the natural world (Pellmyr 2003). In these symbiotic relationships the moths are dependent on the yucca for a place to lay their eggs and the larvae consume a portion of the developing seeds. The yuccas are entirely dependent on the moths for pollination. *Yucca brevifolia* - the eastern Joshua tree is pollinated by *Tegeticula antithetica* Pellmyr, and *Yucca jaegerana* – the western Joshua tree is pollinated by *Tegeticula synthetica* Riley (the authority of neither moth species was verified by ITIS). Some of the other Prodoxidae related to the pollinators are ‘bogus’ moths that consume the yucca seeds without providing the pollination service (Pellmyr 2003; Pellmyr et al. 1996). Females of the pollinators have specialized tentacle mouthparts found only among these moths for collecting pollen from *Yucca* flowers. While *Yucca* species rely on these moths for pollination, the cost they pay for this service is a portion of their seeds, which the larvae feed upon as they develop (Pellmyr et al. 1996). There is no concrete evidence for successful pollination of yuccas by insect fauna other than yucca moths; however, the fresh inflorescences and fruits of yucca plants are a smorgasboard of insect life representing many different groups and a very important part of desert communities where they exist. Pre-reproductive Joshua trees are larval hosts to the yucca giant skipper (*Megathymus yuccae* Boisduval and Le Conte) whose larve eat the stems and roots of the young Joshua trees from the inside out, leaving a thumb-sized hole in the stem and webbing all over.

**Tortoise use:** *Yucca* flowers may occasionally be eaten by tortoises as they fall to the ground but are not significant diet taxa. *Yuccas* provide important habitat structure (Miller and Stebbins 1963) providing high-quality shade for desert wildlife (Snyder 2014). Tortoises use several *Yucca* species for cover, including *Y. brevifolia, Y. jaegeriana, Y. schidigera,* and *Y. utahensis* (Esque 1994; Drake et al. 2015). *Yucca schidigera* and *Y. brevifolia* were the fourth and eighth plant species, respectively, most frequently used for cover by desert tortoises in our analyses. Furthermore, *Y. schidigera* was used by tortoises at six of nine study areas, while *Y. brevifolia* was used at four study areas. These species are used as a greater proportion of cover sites than their availability in habitats, indicating that tortoise seek them out as shelter because they provide high quality, deep shade during spring through fall.

**Propagation, production, and cultivation:** *Y. brevifolia* seeds maintain high germinability (80-97%) during short-term storage (< 5 years) during dry, sealed conditions at room temperature or 4 °C (Kay et al. 1984; Kay et al. 1988; Reynolds et al. 2012). Storage at lower temperatures (-15 °C) can slightly decrease germinability of *Y. brevifolia* seeds in long term storage (≥ 9 years; Kay et al. 1984). *Yucca schidigera* seeds also have high initial germinability (67% at 15 °C). For example, germinability of *Y. schidigera* seeds increased to 96% when stored at room or cool temperatures over a period of three years (Kay et al. 1988). Studies of *Yucca* germination (*Y. baccata, Y. brevifolia, Y. elata* Engelm*., Y. schidigera,* and *Y. whipplei*) indicate that species generally germinate best in temperatures between 20° – 25°C, and that some (*Y. baccata, Y. brevifolia,* and *Y. elata*) experience higher germination rates under dark conditions (McCleary and Wagner 1973; Keeley and Tufenkians 1984; Keeley and Meyers 1985).

*Yucca schidigera* and *Y. brevifolia* transplant readily as young plants. However, small (< 25 cm, up to 1 m) pre-reproductive transplants are highly vulnerable to mammalian herbivores (Esque et al. 2015) and should be provided protective structures such as cages, or nurse plants. Growth rates for *Y. brevifolia* are slow at ~3 cm /year (Comanor and Clark 2000, Gilliland et al. 2006, Esque et al. 2015), and trees as much as 1 m tall are usually still pre-reproductive and can be over 30 years old (Esque et al. 2015). They may require 50 – 70 years to reach reproductive size in the northeast Mojave Desert. Thus, commercial production of seed is not feasible, but also unnecessary because of the abundance of seed available during episodic mast years. Mature fruits collected from *Y. brevifolia* can be belt harvested and passed one time through a fanning mill equipped with a #26 top screen and a #14 bottom screen, which removes the spongy, indehiscent fruit parts and seed that is damaged or aborted due to yucca moths (Kay et al. 1977a).

The large seeds of the desert yuccas are primarily dispersed by rodents such as kangaroo rats (*Dipodomys* Gray spp.), deer mice (*Peromyscus* Gloger spp.), and ground squirrels *Spermophilus* F. Cuvier and *Xerospermophilus* Merriam sp.), but woodrats *Neotoma* Say and Ord spp. are considered yucca seed predators because they do not use surface caches for seeds (Vander Wall et al. 2006, Waitman et al. 2012).

**Recoverability:** *Yucca* spp. can recover from fire with typically greater resprouting in *Y. schidigera* than *Y. brevifolia* (Abella 2009). Furthermore, relatively mesic conditions may be necessary during recovery of *Y. brevifolia*, and drought conditions can lead to high direct mortality or indirectly as herbivores destroy the roots, shoots and periderm (DeFalco et al. 2010). Seedlings of *Y. brevifolia* (and possibly *Y. schidigera*) benefit from nurse plants that provide protection during germination and establishment (Brittingham and Walker 2000). Thus, burned areas – particularly those that have burned multiple times – provide stark conditions for natural *Y. brevifolia* recruitment thereby complicating re-establishment of this species (DeFalco et al. 2010).

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