RANCHO SANTA ANA BOTANIC GARDEN OCCASIONAL PUBLICATIONS

NUMBER 15

A CONSERVATION PLAN FOR *CALOCHORTUS OBISPOENSIS* (SAN LUIS MARIPOSA LILY; LILIACEAE)

MELISSA A. JOHNSON

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1.0 EXECUTIVE SUMMARY

Calochortus obispoensis Lemmon is a bulbiferous herb endemic to serpentine substrates in the Santa Lucia Mountains of San Luis Obispo (SLO) County, California. This species is currently listed by the California Native Plant Society as a 1B.2 taxon, indicating that it is considered "fairly endangered" in California (CNPS 2015). At the state level the species is listed as "very imperiled" (S2.1), while at the global level the species is considered "imperiled" (G2). Despite these classifications indicating a high level of concern for survival of this species, *C. obispoensis* is not listed under the state or federal Endangered Species Acts (ESAs). Habitat destruction and herbivory are likely the most important threats to address for the continued survival of this species. Thirty-one occurrences of *C. obispoensis* are documented; however, all are restricted to the western portion of SLO County, an area where development has continued to spread rapidly as a result of a growing human population.

2.0 SCOPE AND PURPOSE

This conservation plan was undertaken for *C. obispoensis* due to its small range size, high degree of habitat specificity, and low local abundance. The purpose of this plan is to present a compilation of all relevant data for *C. obispoensis*, identify potential threats to populations, and identify immediate conservation actions to ensure its persistence. This document will serve as a guide for landowners, federal, state, and local agencies, conservation organizations, interested parties, and researchers who are committed or obliged to the preservation of this unique species.

3.0 METHODS

Field surveys were conducted in June 2015 in an attempt to locate *C. obispoensis* populations in SLO County based on data compiled from museum specimens databased in California herbaria (Consortium of California Herbaria 2015) and the California Natural Diversity Database (CNDDB) RareFind plant database (2015). Six populations were located in my 2015 surveys. Several parameters were recorded for each of the six populations including the number of individuals per population, floral visitors and potential pollinators, associated plant species, habitat characteristics, and potential threats. One voucher specimen was collected from each population. These were mounted and deposited in the herbarium at Rancho Santa Ana Botanic Garden (RSA-POM). Information gained from my 2015 surveys was also transmitted to the California Department of Fish and Wildlife for incorporation into the CNDDB. In addition, fresh leaf material was collected from three sites and dried in silica for use in future genetic analyses.

4.0 BACKGROUND

4.1 *Species Description*

Calochortus obispoensis is a bulbiferous herb in the Liliaceae family. The bulb coat is fibrous, a characteristic that is uncommon in the genus. The slender, generally branching flowering stems are 30–60 cm long. The solitary basal leaf is linear, 20–30 cm in length, long-tapered, channeled, and senesces prior to anthesis. Two cauline leaves (cauline referring to their position on the flower stalks) are 4–12 cm long, and are reduced in size toward the leaf apex and inrolled upward. The inflorescence bears 1–9 erect flowers, each of which exhibit the "cat's ear" floral form characterized by small spreading petals densely covered in trichomes (Fig. 1).

Each flower has three reflexed sepals 10–30 mm long that are lanceolate to acuminate in shape. Petals (3) are 10–20 mm long and are yellow to deep orange in color, usually more darkly colored towards the petal tip. Petals are usually broadly lanceolate or more rarely ovate. Each petal has an adaxial central tuft of coarse yellow to orange trichomes, a marginal fringe of yellow to orange trichomes, and an apical tuft of dark trichomes. The nectary near the base of each petal is round and glabrous, sometimes depressed, and hidden by dense slender hairs with fused bases. Stamens (6) are comprised of a slender filament and a dark red-brown anther. The single style bears three stigmas. Fruits are 3-chambered linear capsules, 3–4 cm in length and angular, with the tip being long-tapered. Seeds are irregularly shaped, with a fine net-like coat and are light yellow to brown in color. Cytologically, the species has a diploid chromosome number of $n = 9$ (Cave 1970).

Fig. 1. Cat's ear floral form exhibited by *Calochortus obispoensis.* Note the two small beetles crawling on the stamens, as well as evidence of herbivory to the branching stem directly above the flower.

4.2 *Taxonomy and Evolutionary History*

Calochortus Pursh is a genus of 67 species with its center of diversity in California and a range that extends from California north to Oregon, Washington, and British Columbia in Canada, east to Montana, the Dakotas, takes in the intervening states of Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico, and continues south into Mexico and Guatemala (Ownbey 1940; Munz and Keck 1959; Fiedler and Ness 1993; Fiedler and Zebell 2012). Although there have been numerous early revisions of the genus (Baker 1874; Watson 1878; Purdy 1901; Painter 1911; Abrams 1923; Jepson 1923), Ownbey's (1940) monograph of the genus was the first thorough taxonomic treatment of the group. Based on morphology, cytology, and geographic distribution he recognized three sections and 12 subsections comprising a total of 57 species and 13 varieties. Sections were largely defined by single morphological characters: *Calochortus* with winged capsules, *Mariposa* with the basal leaf senescing at anthesis, and *Cyclobothra* with fibrous-reticulate bulb coats. Ness' (1989) treatment of the group used scanning electron microscopy to examine seed morphology of 37 species of *Calochortus.* This study described seed morphologies characteristic of sections *Calochortus* and *Mariposa* but was unable to distinguish section *Cyclobothra* based on seed features. Ness suggested that *Cyclobothra* may be polyphyletic and that further study was needed to determine whether species within this section warranted transfer to other sections within the genus.

The first study to examine *Calochortus* using molecular phylogenetics was conducted by Patterson and Givnish (2002). In this study, the *rbc*L and *ndh*F chloroplast gene regions were used to infer East Asian *Tricyrtis* as sister to *Calochortus*, and an initial divergence of *Calochortus* ca. 7.3 ± 0.9 million years ago. A follow-up study by Patterson and Givnish (2004) examined relationships among 62 species of *Calochortus* using maximum parsimony and three chloroplast gene regions (*trn*T-*trn*F, *psb*A-*trn*H, and *rpl*16). Results relevant to the conservation plan presented here suggest that: (1) section *Calochortus* is monophyletic, while *Mariposa* is paraphyletic, and *Cyclobothra* is polyphyletic; (2) *Calochortus* evolved in the California Floristic Province, most likely in the Coast Ranges; (3) clades correspond to seven geographically cohesive groups; (4) the cat's ear floral form is apomorphic and evolved independently in the Bay Area, Pacific Northwest, San Diego, and Central Mexico clades; (5) the ancestral diploid chromosome number is $n = 9$; and (6) 18 species are serpentine tolerant, a recently derived trait that evolved at least seven times in the genus. A more recent molecular study using AFLP markers showed strong support for a sister relationship between *C. obispoensis* and *C. fimbriatus* H.P. McDonald [as *C. weedii* Alph.Wood var. *vestus* Purdy], a non-serpentine endemic within section *Cyclobothra* (Peak 2012).

While these earlier studies presented a first-look at the evolutionary history of genus *Calochortus*, several of the conclusions from Patterson and Givnish (2004) are questionable. For example, while the authors indicate that clades are geographically cohesive, species from different geographic regions are distributed across the phylogeny, with the only cohesive clade being Central Mexico. Additionally, the independent evolution of the various floral forms and serpentine tolerance multiple times across the phylogeny is a highly un-parsimonious interpretation. Studies that incorporate more rigorous analytical methods for evaluating phylogenetic data (e.g., maximum likelihood and Bayesian inference), as well as improved model-based approaches for inferring ancestral areas (e.g., BioGeoBEARS) and ancestral states are therefore needed. Also, the use of chloroplast markers alone is insufficient for resolving this taxonomically difficult group, such that the development of low-copy nuclear markers is warranted.

Fig. 2. Pollinators of *Calochortus obispoensis* are generalists, and include butterflies, bees, and beetles. Left: *Hesperia* sp., center: *Apis mellifera*, and right: *Bombus occidentalis*.

4.3 *Biology and Ecology*

Calochortus obispoensis flowers between May and July and produces fruits between June and August. After flowering and leaf senescence, the bulb goes dormant until it re-sprouts the following year. The basal leaf appears shortly after the winter rains, which is followed by establishment of a simple root system. The single basal leaf is the main photosynthetic organ of the plant, thereby determining the growth and reproduction of each individual (Fiedler 1987). Plants are slow growing, and age to reproductive maturity is unknown. Successful reproductive years may be followed by years of dormancy or a non-reproductive state in which only the basal leaf is present, demonstrating the irregular nature of reproduction in this group. This species is self-compatible, although a pollinator exclusion study by Fiedler (1987) suggested that autogamy is limited, such that plants are highly out-crossed. *Calochortus obispoensis* appears to attract several non-specialist bees (*Apis mellifera*, *Bombus occidentalis*; M. Johnson, pers. obs.), butterflies (*Hesperia* sp.; M. Johnson, pers. obs.), and beetles (M. Johnson, pers. obs.; Fig. 1, 2). Bees, butterflies, and beetles are typical generalist pollinators of other *Calochortus* species (Jokerst 1981; Dilley et al. 2000).

Seeds of *C. obispoensis* weigh 1.54 mg on average (Fiedler 1987) and lack any obvious dispersal mechanism (e.g., fleshy tissue, adhesives, wings; Fig. 3). In addition, fruits are capsular and borne close to the ground. Given these characteristics, seed dispersal is thought to be quite limited: Bullock (1976) found that *Calochortus* seeds moved no more than 1.4 meters downhill after a chaparral fire. Germination follows the onset of the rainy season in mid-December, with each germinant forming a small bulb that moves down through the soil via droppers (new bulbs that form at the end of a stolon; Fiedler 1987). As the plant gets larger it forms contractile roots (Rimbach 1902) until the bulb reaches a depth of ca. 10 cm, after which it ceases root production (Fiedler 1987). Vegetative reproduction via bulbils has been described in section *Calochortus* (Ownbey 1940), but little is known about vegetative reproduction by members of section *Cyclobothra*. It is estimated that the life span of these plants is likely more than ten years (Fiedler 1987).

4.4 *Habitat*

Calochortus obispoensis is an edaphic endemic that is narrowly restricted to open, dry, serpentine substrates in chaparral, coastal scrub, and valley/foothill grassland habitats (Fiedler 1985; Fig. 4). Serpentine soils are formed by the weathering of ultramafic rocks (rocks produced beneath the ocean floor by hydrothermal alteration), which are typified by low levels of silica and calcium and relatively high amounts of magnesium and iron. Serpentine soils also contain high levels of the heavy metals nickel, chromium, cobalt, and copper. In California, serpentine and related rocks are distributed in numerous discontinuous masses, covering 1100 square miles (roughly 1% of the land area) from the Oregon-California border to as far south as Santa Barbara County (Kruckeberg 1985). However, these outcrops are largely restricted to the Coast Ranges and the Sierra Nevada foothills. The combination of heavy metals and a low Ca : Mg ratio that is characteristic of serpentine soils is toxic to most plants, but *C. obispoensis* survives in this habitat. In a study of heavy metal accumulation in serpentine endemics, *C. obispoensis* was found to possess high levels of nickel and copper in both leaves and bulbs, but not at levels high enough for the plants to be considered hyper-accumulators, in contrast to many other ultramafic endemics (Fiedler 1985).

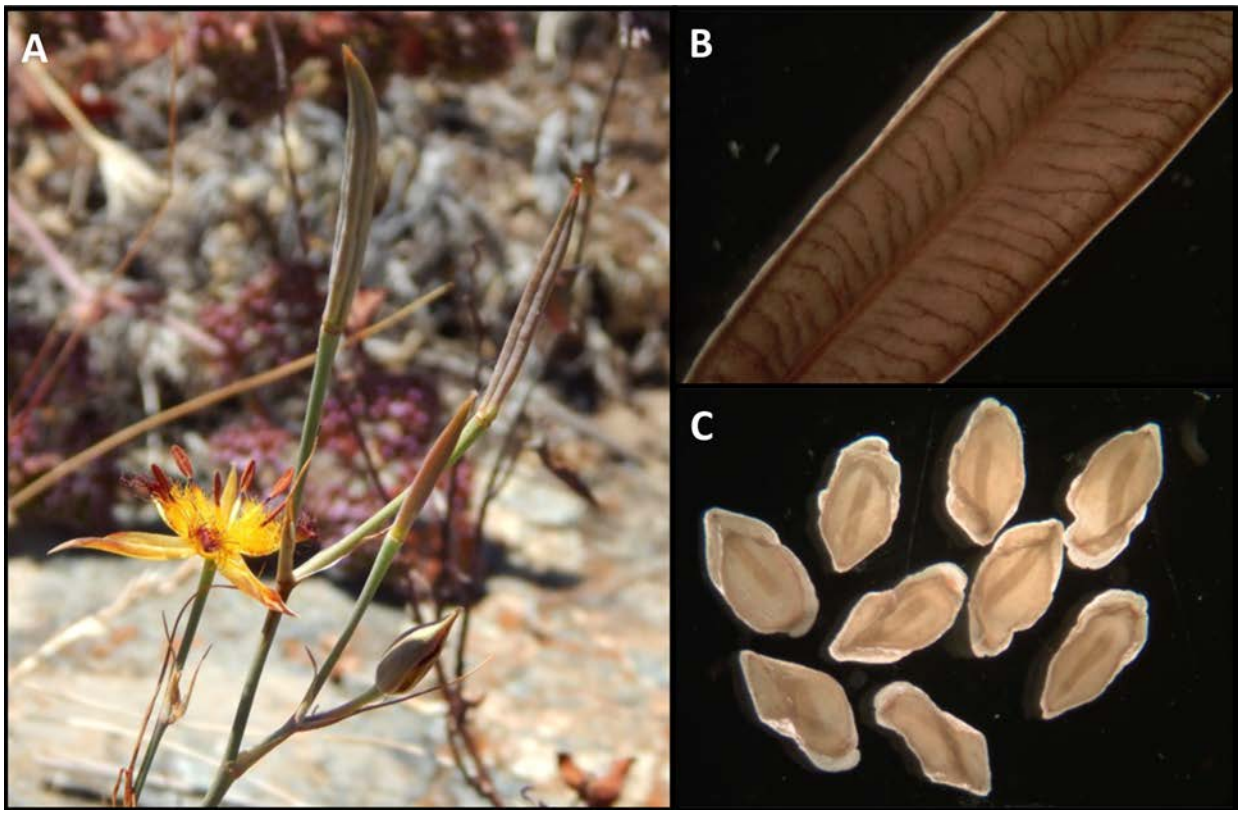

Fig. 3. Capsules and seeds of *Calochortus obispoensis.* (A) Three-chambered linear capsules; (B) close-up of the capsule showing the striate surface morphology; (C) tan, mostly flat, seeds.

Populations of *C. obispoensis* occur at sites ranging in elevation between 100 m and 500 m. Rainfall in this region averages 50 cm (22 inches) annually (Holland and Keil 1995). Most precipitation falls in the winter months, while summer months are typically dry, giving the area a Mediterranean climate. The serpentine soils of SLO County host numerous endemic plant taxa, many of which are rare. Commonly associated species include *Agrostis hooveri* Swallen (Hoover's bent grass), *Arctostaphylos obispoensis* Eastw. (serpentine manzanita), *Astragalus curtipes* A. Gray (Morro milkvetch), *Calystegia macrostegia* (Greene) Brummitt subsp. *cyclostegia* (House) Brummitt (island morning glory), *Carex obispoensis* Stacey (San Luis Obispo sedge), *Ceanothus cuneatus* (Hook.) Nutt. (wedgeleaf ceanothus), *Chorizanthe breweri* S. Watson (Brewer's spineflower), *Chorizanthe palmeri* S. Watson (Palmer's spineflower), *Cirsium fontinale* (Greene) Jeps. var. *obispoense* J.T. Howell (Chorro Creek bog thistle), *Dudleya abramsii* Rose subsp. *murina* (Eastw.) Moran (San Luis Obispo dudleya), *Eriogonum fasciculatum* Benth. (California buckwheat), *Eschscholzia californica* Cham. (California poppy), *Hesperoyucca whipplei* (Torr.) Trel. (chaparral yucca), *Layia jonesii* A. Gray (Jones' tidytips), *Lomatium parvifolium* (Hook. & Arn.) Jeps. (coastal biscuitroot), *Monardella palmeri* A. Gray (Palmer's monardella), *Quercus agrifolia* Née (coast live oak), *Quercus durata* Jeps. (leather oak), *Stipa pulchra* Hitchc. (purple needlegrass), and *Sanicula hoffmannii* (Munz) R.H. Shan & Constance (Hoffmann's snakeroot). *Calochortus clavatus* var. *clavatus* S. Watson (clubhair mariposa) and *C. albus* (Benth.) Douglas ex Benth. (white fairy lantern) are serpentine-tolerant species that were observed to be growing sympatrically with *C. obispoensis* populations at two sites in my 2015 surveys. Two other *Calochortus* species, *C. argillosus* (Hoover) Zebell & P.L. Fiedl. (San Luis Obispo clay mariposa) and *C. simulans* (Hoover) Munz (San Luis Obispo mariposa), are known to occur in SLO County (Fig. 5).

4.5 *Distribution and Abundance*

Calochortus obispoensis occurs as isolated populations on serpentine soils in the Santa Lucia Mountains of SLO County, California (Fiedler 1985). This species persists mainly in the western portion of SLO County, with the majority of populations in the direct vicinity of San Luis Obispo city (Fig. 6; note that

Fig. 4. *Calochortus obispoensis* habitat: *C. obispoensis* is restricted to serpentine substrates in chaparral, coastal scrub, and valley/foothill grassland habitats.

Fig. 5. Species of *Calochortus* found growing near *C. obispoensis* in San Luis Obispo County: *C. simulans* (not shown), *C. argillosus* (left), *C. clavatus* var. *clavatus* (middle), and *C. albus* (right). Note that these differ in floral morphology from *C. obispoensis*, having the "mariposa" (*C. argillosus*, *C. simulans*, and *C. clavatus* var. *clavatus*) and "fairy lantern" (*C. albus*) floral forms.

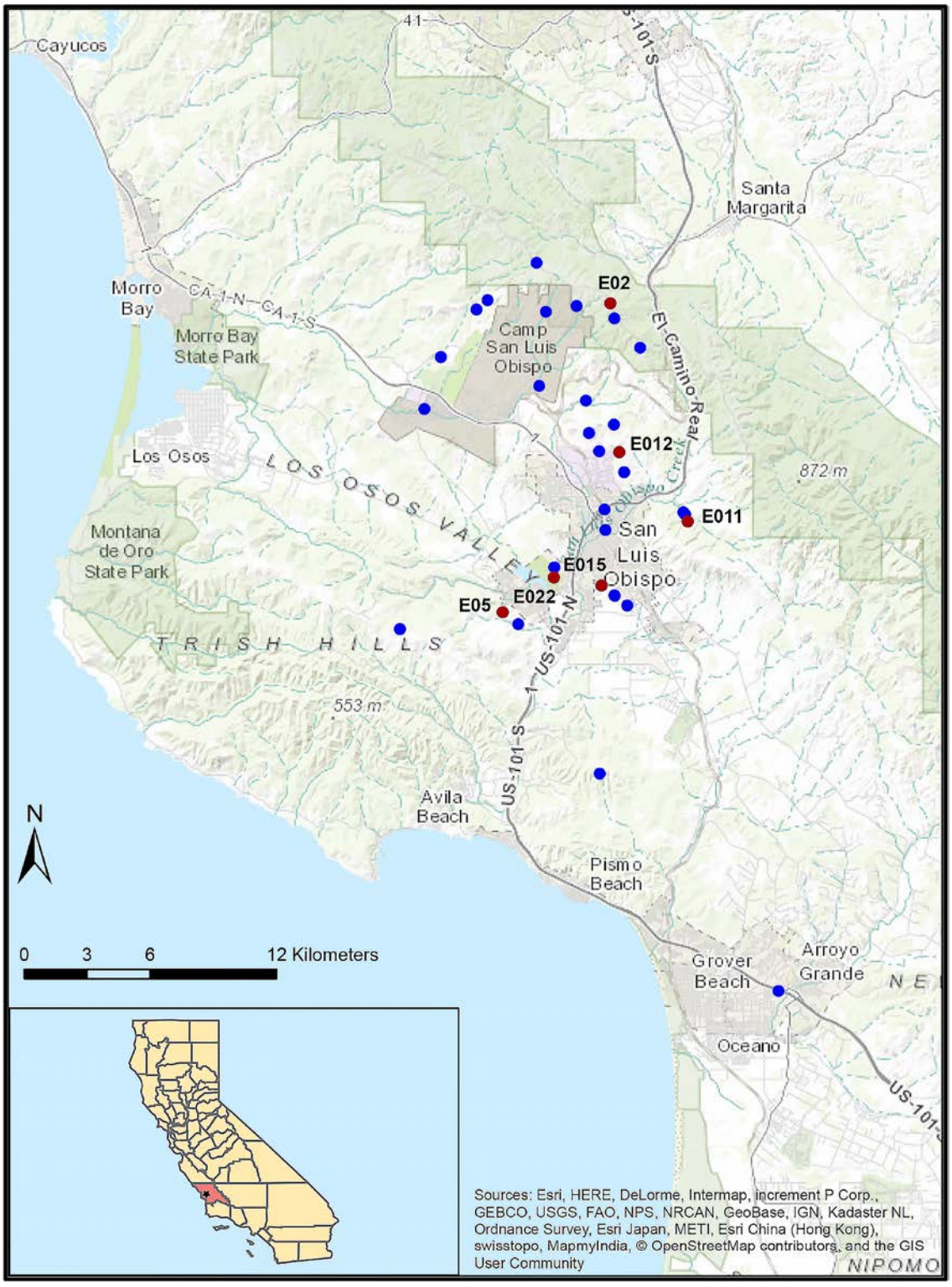

Fig. 6. Distribution map for *Calochortus obispoensis* in San Luis Obispo County, California. Red dots indicate occurrences surveyed in June 2015 whereas blue dots indicate known occurrences that were not surveyed for this study. Inset map shows the state of California, with San Luis Obispo County highlighted in pink and a star marking the area depicted in the larger map. Satellite image © Google Earth 2015.

EO14 is not mapped due to its questionable location). The CNDDB lists 31 extant elemental occurrences (EOs), with populations ranging in size from five to over 1000 individuals (Table 1). However, only six of 31 occurrences have been surveyed in the past 10 years, 16 occurrences have not been surveyed in the past 15 years, and 13 occurrences were last surveyed more than 20 years ago (CNDDB 2015). In addition, development in SLO County has continued at a rapid pace as a result of a growing human population (an increase of 17% in SLO County over the last 20 years; U.S. Census Bureau 2016), further warranting updated documentation of population abundance and health.

4.6 *Population Trends*

Population trends are not well characterized for *C. obispoensis*. The CNDDB list of occurrences (Table 1) provides census dates and estimated population numbers, but these are outdated and incomplete for many localities. Population trends are thus largely unknown, and field surveys are urgently needed to assess current population status. Although I conducted surveys in June 2015 at six known occurrences (see shaded cells in Table 1), it is possible the number of individuals was underestimated as the flowering season begins in early May, and individuals without flowering stalks can be difficult to locate visually. Additionally, my surveys were conducted following four years of extreme drought in California, such that surveys during wetter years will be necessary before population trends can be assessed. Lastly, extant populations may consist of individuals that are in flower, non-flowering mature plants, immature leafing seedlings, and a seed bank. Surveys are unlikely to capture all of these states and therefore may provide incomplete data. Perhaps the most useful and reliable information from surveys of geophytes is data related to the extent of occupied suitable habitat. Single negative presence/absence surveys cannot reliably attest to the absence of this species. To fully characterize population trends over the long-term, censuses must be conducted over consecutive years at each site to account for normal fluctuations in apparent population size. This is especially important for species where individual plants may remain dormant in some years, which appears to be the case in *C. obispoensis*.

4.7 *Limiting Factors*

Rarity is often defined using the framework of Rabinowitz et al. (1986), which considers the three axes of range size, habitat specificity, and local abundance. In the British flora, Rabinowitz et al. (1986) found these three axes to be independent, habitat specificity to be the most frequent form of rarity, and relatively few species to be rare on all three axes. However, a recent study by Harrison et al. (2008) found *C. obispoensis* to be triply rare, due to its small range size, high degree of habitat specificity, and low local abundance.

In Fiedler's (1987) study of life history characteristics and population dynamics of rare and common species of *Calochortus*, several alarming trends were found that may be limiting factors to the survival and reproduction of *C. obispoensis*. Although no significant difference was found between common and rare species in terms of mean seed weight or mean number of seeds per capsule, the rare *C. obispoensis* had significantly lower seedling survival and seedling establishment relative to the common species *C. albus*. Additionally, only the largest individuals of *C. obispoensis* produced flowers and fruit, perhaps reflective of the slow growth rate of this species and the longer time required for this species to reach sexual maturity. Between 1981 and 1983 the percentage of flowering individuals ranged from 0 to 23%, while only 0–6% reproduced successfully (n = 300; Fiedler 1987). In contrast, surveys conducted in June 2015 at Laguna Lake Park (EO22) revealed that 100% of the individuals observed (n = 105) had reproductive structures (buds and/or flowers); 69% of these individuals were observed with immature fruits. Additional surveys are needed later in the season to determine the frequency with which immature fruits successfully ripen into mature capsules. Six mature capsules resulting from open-pollination were collected in July 2015 at Laguna Lake Park to determine the number of seeds per capsule. The numbers of fully formed (presumably viable) seeds per capsule ranged from 25 to 104, while the number of shriveled (presumably non-viable) seeds per capsule ranged from 11 to 41. Reproduction may vary among populations depending on the age/size of individuals and overall health of the population, as well as available resources and weather.

Fiedler (1987) also reported that individuals of *C. obispoensis* experienced severe herbivory of the basal leaf in each of three size classes and in all three years of study. Herbivores most damaging to the basal leaves and reproductive structures of *Calochortus* include the valley pocket gopher (*Thomomys bottae*), black-tailed jackrabbit (*Lepus californicus*), Audubon's cottontail (*Sylvilagus audubonii*), brush rabbit (*Sylvilagus bachmani*), and mule deer (*Odocoileus hemionus*). Shortening of the basal leaf can reduce the life span of individuals by decreasing the amount of photosynthate produced by the major photosynthetic organ, while herbivory of flowers, fruits, and seeds negatively impacts reproductive potential and regeneration of this rare species. Damage to individual plants due to

Table 1. Summary of known elemental occurrences (EOs) of *Calochortus obispoensis*, taken from the CNDDB website with updates resulting from this study. Shaded EOs were surveyed by the author in June of 2015. Threats are categorized as habitat destruction or modification (A), overutilization (B), disease or predation (C), inadequacy of existing regulations (D), and other factors affecting continued existence (E).

Location of Occurrence	EO Number	Owner/Manager	Population Status	Threats (A–E)
Cuesta Ridge	EO1	State—Camp San Luis Obispo	100 (2003)	(A) Military activities, trampling, recreation, traffic
Cuesta Ridge	EO2	Private	ca. 240 (1983); ca. 60 (2015)	(A) Shooting, trampling
Hill N of Highway 101, opposite Reservoir Canyon	EO3	Private	0 (1988)	Unknown
Cuesta Ridge, 1 mi N of Cal Poly SLO	EO4	CSU—Cal Poly, San Luis Obispo	200–300 (1988)	(C) Grazing on lower slopes
Irish Hills along Perfumo Canyon Road	EO5	Private	ca. 2500 (1991); ca. 100 (2015)	(A) Home development, recreation, trampling
Camp San Luis Obispo	EO6	DOD—Army National Guard	Unknown number (2003)	(A) Non-native plants, trampling, fire, military activities; (C) Cattle grazing
Summit of Carpenter Canyon, N of Arroyo Grande	EO8	Private	Unknown number (1988)	Unknown
Mouth of Canyon No. 1 near Grover City, N of Arroyo Grande	EO9	Unknown	5 (1995)	(A) Development
Pennington Creek	EO10	CSU—Cal Poly, San Luis Obispo	>100 (1988)	(C) Grazing
Mouth of Reservoir Canyon, E of SLO	EO11 (incl. EO7)	City of San Luis Obispo	35 (1988); ca. 200 (2015)	(A) Broom invasion; (C) Grazing
Upper Poly Canyon along Brizziolari Creek	EO12	CSU—Cal Poly, San Luis Obispo	3 colonies ranging from 10–50 plants (1984); ca. 120 (2015)	(A) Recreation, erosion, road work
Behind San Luis Obispo High School	EO13	Unknown	Unknown (1984, 1988)	Unknown
Serrano Creek (location uncertain)	EO14	Unknown	Unknown	Unknown
Hill E of South Higuera Road	EO15	Private	1200 (1988); ca. 65 (2015)	(A) Potential development, recreation; (C) Grazing
Serpentine ridge W of Broad Street	EO16	Private	>50 (1985); >70 (1988)	(A) Development; (C) Grazing
Western ridge of Indian Knob, N of Pismo Beach	EO17	TNC, Private—PGE	Unknown (1980)	(A) Surface mining and potentially oil development
Froom Ranch	EO18	Private	200–400 (1988)	(A) Development; (C) Grazing
Ridge between East Corral de Piedra Creek and S branch of West Corral de Piedra Creek	EO19	Private	50 (1987)	(C) Grazing
Ridge W of West Corral de Piedra Creek	EO20	Private	>10,000 (1992)	(A) Road development (C) Grazing
Serpentine ridge E of Highway 101 and SW of Mt. Lowe	EO21	Private	16 (1987)	(C) Grazing
Laguna Lake Park	EO22	City of San Luis Obispo	300 (1988); 500 (2015)	(A) Recreation (C) Grazing
Camp San Luis Obispo, Training Areas U & X	EO24	State—Camp San Luis Obispo	<25 (2002)	(A) Military activity, erosion, non-native plants, fire, mining (C) Grazing

Table 1 Continued

Location of Occurrence	EO Number	Owner/Manager	Population Status	Threats (A–E)
Upper Stenner Creek	EO25	Private—SPRR, DOD	>100 (1992)	(A) Road widening and powerline construction
Upper Stenner Creek	EO26	Private—SPRR	3 (1998)	(A) Eucalyptus invasion
Spring S of Cambria Mine	EO27	Private	<25 (1989)	(A) Proposed home development
Stenner Creek Road	EO28	Unknown	Unknown (1999)	(A) Adjacent to road
See Canyon	EO29	Private	50 (2003)	Unknown
Camp San Luis Obispo, Training Area X	EO30	State—Camp San Luis Obispo	<20 in several colonies (2002)	(A) Non-native plants, military activities, fire, trampling (C) Grazing
Camp San Luis Obispo, Training Area A	EO32, EO34	State—Camp San Luis Obispo	<20 (2002); Unknown (2003)	(A) Non-native plants, military activities, fire, trampling (C) Grazing
Camp San Luis Obispo, Training Area W	EO33	State—Camp San Luis Obispo	<20 in four colonies (2000)	(A) Non-native plants, military activities, fire, trampling (C) Grazing

Abbreviations: CSU: California State University; DOD: Department of Defense; PGE: Pacific Gas & Electric Company; SPRR: Southern Pacific Railroad; TNC: The Nature Conservancy.

herbivory was observed at two of the six occurrences surveyed in June 2015 (EO15, EO22; Fig. 1, 7).

4.8 *Threats*

Numerous threats have been documented for almost every extant occurrence of *C. obispoensis*, with the exceptions being those occurrences that have not been properly surveyed so that threats remain unknown (see Fig. 7 for threats documented at sites visited in June 2015). Potential threats to populations are listed below according to the Federal ESA section 4(a)(1), which describes five threat factors (A–E).

A. The present or threatened destruction, modification, or curtailment of its habitat or range. Habitat destruction and modification are likely the most important threats to address for the continued survival of this species. Twenty-two of the 31 extant occurrences have some form of habitat destruction documented. Development (including commercial, residential, roads, mineral and oil extraction) is a documented threat to EOs 5, 9, 15, 16, 17, 18, 20, 25, and 27 (Fig. 6). *Calochortus obispoensis* occurs on military-owned lands in several localities, with destructive military activities including target practice being documented at EOs 1, 2, 6, 24, 30, 32, 33, and 34. Changes in fire frequency and timing may also affect population well-being and survival, especially given the species' prevalence in dry habitats. Fire has been documented on military lands at the following occurrences: EOs 6, 24, 30, 32, 33, and 34. Non-native plant invasion, including *Eucalyptus globulus* (blue gum) and *Spartium junceum* (Spanish broom), has been documented at EOs 6, 11 (EO 7 is a former occurrence that was amalgamated with EO 11), 24, 26, 30, 32, 33, and 34. Invasive plants such as *Eucalyptus* spp. pose a threat to native species because understory establishment is inhibited by the production of allelopathic chemicals and by the physical barrier formed by high volumes of bark strips, limbs, and branch debris. Invasive *Spartium* spp. form dense thickets that crowd out native species. Lastly, erosion of habitat due to ungulates and human recreational activities is a threat to EO 12, and erosion possibly due to military activities is documented at EO 24.

In addition to the documented threats to habitat, climate change is likely to impact habitat quality in areas currently occupied by *C. obispoensis*. Climatic stability is thought to be associated with high diversity and the persistence of specialized species, whereas climatic instability is associated with overall lower species diversity and presence of species that are not habitat specialists (Jansson and Dynesius 2002). In a study by Harrison et al. (2008), the distributions of triply rare species, including *C. obispoensis*, were characterized by higher total and summer rainfall, higher winter temperatures, and lower summer temperatures compared to the distributions of more common congeners. Several studies propose that high levels of rarity, endemism, and overall species richness may be expected to occur in regions that provide conditions that allow rare habitat specialists to resist climatically driven extinctions (Harrison et al. 2008; Jetz et al. 2004; Jansson and Dynesius 2002). Edaphically restricted plants are representative of species that may be unable to deal with rapid climate change because of their often sparse and patchy distribution on the soils to which they are adapted (Harrison et al. 2008).

Serpentine soils are found predominantly in three ecological regions of California: the northwest,

including the northern coastal range from Humboldt County to San Francisco Bay and the Klamath Mountains; the southern coastal range, from San Francisco Bay to Santa Barbara; and the foothills of the Sierra Nevada Mountains to the east. The northwestern regions are expected to continue to support serpentine endemics in the face of climate change due to their cool temperatures, high precipitation, and topographically heterogeneous and extensive serpentine outcrops (Harrison et al. 2008). This is in contrast to the southern coastal range (including SLO County) and Sierran foothills, where serpentine areas are smaller and relatively uniform topographically, and the climate is warmer and drier (Harrison et al. 2008). The southern coastal range is also under heavier development pressure, such that *ex situ* conservation or assisted migration may be critical for the preservation of rare serpentine plants (Harrison et al. 2008).

B. Overutilization for commercial, scientific, or educational purposes. Although commercial overutilization has not been specifically documented for *C. obispoensis*, species of *Calochortus* have long been collected from the wild for cultivation and commercial sale due to their often showy and charismatic flowers. The ease with which many species are cultivated makes them popular choices for gardens, and many species have suffered from over-collection. Given the large human population in SLO County and the accessibility of many populations of *C. obispoensis*, it is quite possible that this species is collected for cultivation, warranting further exploration of this possible threat.

Fig. 7. Documented threats to *Calochortus obispoensis* include development, grazing, and trampling. (A) Housing developments near a population of *C. obispoensis*; (B) arrows point to evidence of herbivory to the tips of flowering stems of *C. obispoensis*; (C) a plant at risk of trampling in the middle of a recreational trail; (D) a seasonally grazed cattle pasture that supports hundreds of individuals of *C. obispoensis*.

C. Disease or predation. Because species of *Calochortus* stay green late into spring when the surrounding vegetation becomes dry and unpalatable, there is a heavy impact from herbivory, with all size-classes being affected (Fiedler 1987). Generalist herbivores including cattle (*Bos taurus*), valley pocket gopher, black-tailed jackrabbit, Audubon's cottontail, brush rabbit, and mule deer have been documented at EOs 4, 6, 10, 11, 15, 16, 18, 19, 20, 21, 22, 24, 30, 32, 33, and 34. As previously stated, herbivory likely affects survival and reproductive success of individuals.

D. Inadequacy of existing regulatory mechanisms. This species is not afforded any protections under the Federal or State ESAs. There are no known protections under the SLO County statutes. The Camp SLO Integrated Natural Resources Management Program (INRMP) lists *C. obispoensis* as a "sensitive" species, but management practices are limited to conducting preactivity or opportunistic surveys, and avoiding plants to the greatest extent possible (Camp SLO Training Site INRMP [California Army National Guard 2011]).

E. Other natural or man-made factors affecting its continued existence. Trampling of individuals due to recreational activities is a documented threat at EOs 1, 2, 5, 12, 15, and 22 (Fig. 7). Detailed population genetic studies are needed to determine if there are other natural or human-made factors that may affect this species' continued existence. *Calochortus obispoensis* may be vulnerable owing to the fact that populations (many of which are small in size) are restricted to serpentine substrates, such that gene flow between populations may be infrequent or even non-existent. The dispersal distance of seeds is thought to be less than 10 m, but little is known about pollen movement between populations. Studies tracking pollinator movements and paternal identity of seeds would greatly contribute to our understanding of gene flow within and among populations. Studies examining genetic diversity within and among populations are also needed to assess potential threats associated with small population size and low rates of migration (e.g., inbreeding depression).

4.9 *Conservation Status*

Calochortus obispoensis is currently listed as a 1B.2 taxon and is therefore considered "fairly endangered" in California (CNPS 2015). At the state level, the species is listed as "very imperiled" (S2.1), while at the global level the species is considered "imperiled" (G2). Despite these classifications indicating a high level of concern for survival of this species, *C. obispoensis* has not been listed under the California or Federal ESAs. Although *C. obispoensis* was proposed as a candidate for protection under the Federal ESA in 1985, further information on wild populations was needed before it could be officially listed. In 1990, *C. obispoensis* was no longer considered a candidate species under the Federal ESA because it was determined to be more abundant and widespread than previously believed and not subject to the degree of threats that would warrant listing (U.S. Fish and Wildlife Service 1990). Subsequently, no protection for this species has been implemented at the local, state, or federal level.

5.0 CONSERVATION

5.1 *Conservation Objectives*

The primary objectives for conserving *C. obispoensis* in SLO County are as follows:

1. To verify and maintain all known existing occurrences, and identify specific conservation needs at each occurrence. Currently all 31 known occurrences are threatened by some combination of development, grazing, trampling, fire, erosion, and invasive species.
2. To preserve existing habitat of *C. obispoensis*.
3. To limit impacts from disturbances that destroy or degrade habitat and/or populations (e.g., residential development, cattle grazing, and trampling in recreation areas).
4. To conduct molecular studies to assess the genetic diversity within and among populations. This will provide a sound basis for further conservation actions, such as identification of critically important occurrences, and the need for seed banking and out-planting.

5.2 *General Conservation Actions*

Visit specific sites

All known occurrences of *C. obispoensis* should be surveyed in years of adequate rainfall to verify persistence of suitable habitat and assess population extent and health. Information collected should include area and location of the suitable habitat that is occupied, total number of individuals per population, number of reproductive individuals, pollinators and floral visitors observed, associated plant species, GPS coordinates, digital images of individuals and their habitat, qualitative description of population health, and observed threats. Following detailed assessments of each population, CNDDB records of *C. obispoensis* should be updated with current data on each occurrence. In addition, surveys of potential habitat should be conducted in the surrounding areas. Rock outcrops and open grasslands on serpentine soils should be targeted

for these surveys, which might reveal additional occurrences as well as suitable habitat for establishing new populations.

Document response to climatic variation

The extent of area occupied and the abundance of the species at each occurrence are not well characterized and should be documented in years of both plentiful and sparse rainfall. It seems likely that the number of individuals at each occurrence fluctuates from year to year based on varying climatic factors such as temperature and rainfall. This species may also be indirectly impacted by climatic variation in that if it is better able to withstand high temperatures and low rainfall than other co-occurring plant species, it may be more susceptible to predation. Preliminary surveys have indicated that this may be the case, as in a given area during a dry year *C. obispoensis* is often the only green plant present, making it attractive to herbivores (M. Johnson, pers. obs.).

Document and maintain genetic variation

The genetic diversity within and among populations of *C. obispoensis* should be assessed from known occurrences. Data on gene flow within and among populations will provide information on potential threats such as inbreeding depression, which is associated with small population size and low rates of migration. From each population, a small amount of fresh leaf material should be collected from several individuals and preserved in silica gel for molecular analysis. It is vital to understand and conserve genetic diversity of this species given its narrow distribution. Information on population genetics will serve to inform potential conservation strategies, particularly if *ex situ* management is deemed appropriate. To successfully preserve populations, seeds should be collected from each occurrence during the months of July–August and maintained in a conservation seed bank.

5.3 *Conservation Tasks*

Conservation tasks for *C. obispoensis* are as follows:

1. Survey all known occurrences. Individuals should be mapped and monitored over consecutive years to determine if population sizes fluctuate on an annual basis. Efforts should also be made to record baseline demographic data, such as time to reproductive maturity, how often individuals flower over consecutive years, the percentage of flowers that successfully produce seed, etc. In addition, abiotic factors such as annual temperature and precipitation should be documented to determine whether population trends are associated with these climatic factors.

2. Survey areas that may host potential habitat. This species is restricted to serpentine substrates including open grasslands. As such, areas that support this substrate and preferred habitat types within and around SLO County should be surveyed for additional populations.

3. Determine the level of genetic diversity within and among populations. This information will be vital in determining if *ex situ* conservation of the species should be pursued. If *ex situ* conservation is deemed necessary, population genetic data will inform appropriate strategies for establishing and supplementing populations (i.e., preventing inbreeding and outbreeding depression).

5.4 *Out-of-State Considerations*

Calochortus obispoensis and its closest relatives are endemic to California. There are no out-of-state considerations for this species.

5.5 *List of Likely Participants*

- California Native Plant Society
- California Department of Fish and Wildlife
- California State Polytechnic University, San Luis Obispo
- Camp San Luis Obispo (California National Guard)
- City of San Luis Obispo
- Rancho Santa Ana Botanic Garden
- Santa Barbara Botanic Garden
- State of California
- Private Land Owners

6.0 IMPLEMENTATION

6.1 *Action Assessment*

Calochortus obispoensis is a species with a small range size, high degree of habitat specificity, and low local abundance. Habitat destruction due to development, recreation, changes in fire frequency and timing, erosion, invasive species, and climate change, as well as damage to and destruction of individual plants by grazing/herbivory and trampling, all pose threats to the existence of this species. Preservation of known occurrences and suitable habitat is vital to the conservation of *C. obispoensis*.

Table 2. Recommended conservation tasks and implementation schedule for *Calochortus obispoensis*. Tasks should be implemented by those listed as likely participants in the conservation of this species (section 5.5).

Task	Description	Time frame	Priority
Survey known occurrences	Monitor and map populations over consecutive years	2016–2026	High
Survey potential habitat	Locate sites that may host additional populations by targeting serpentine rock outcrops	2016–2018	High
Assess genetic diversity	Determine levels of genetic variation within and among populations	2018–2020	Medium

6.2 *Federal Listing*

This species may warrant state or federal listing, and petitioning of *C. obispoensis* for listing should be considered after further investigation.

6.3 *Other Actions*

Rancho Santa Ana Botanic Garden was granted funds from the California Native Plant Society to conduct field surveys of this species in SLO County. The allocated funding permitted surveys at six out of 31 known occurrences, yielding the plan that is presented here.

6.4 *Implementation Schedule*

To ensure the conservation of *C. obispoensis*, the implementation of conservation tasks should be conducted based on priority and should take place within the timeframe listed in Table 2.

6.5 *Potential Difficulties in Implementation*

Availability of adequate funding necessary for the study of *C. obispoensis* may serve as an impediment. RSABG was awarded funding from the California Native Plant Society to survey known occurrences, but it was not possible to conduct an exhaustive survey nor to make the detailed assessments called for above. Longer-term, more intensive monitoring will be costly. Difficulties may be encountered with access to populations that occur on private land and on US Department of Defense properties if access permissions are not granted. Severe drought may have negative impacts on survival and reproduction, thus prohibiting seed collection and out-planting if *ex situ* conservation is deemed appropriate.

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