California BOTANIC GARDEN

OCCASIONAL PUBLICATIONS No. 19

A CONSERVATION PLAN FOR *CALOCHORTUS EXCAVATUS* (INYO COUNTY STAR-TULIP, LILIACEAE)

SOPHIA E. WINITSKY

Published by California Botanic Garden, 1500 North College Avenue, Claremont, California 91711

2021

OCCASIONAL PUBLICATIONS

Number 19

A CONSERVATION PLAN FOR *CALOCHORTUS EXCAVATUS* (INYO COUNTY STAR-TULIP, LILIACEAE)

SOPHIA E. WINITSKY

California
BOTANIC GARDEN

OCCASIONAL PUBLICATIONS

CALIFORNIA BOTANIC GARDEN OCCASIONAL PUBLICATIONS (ISSN 1094-1398) are published at irregular intervals in volumes of various sizes. This series of publications is designed to feature results of original botanical research by members of the California Botanic Garden staff, or by botanists who have collaborated in a Garden program. Proceedings of symposia sponsored by the Garden may also be published in this series.

The CALIFORNIA BOTANIC GARDEN OCCASIONAL PUBLICATIONS series is published by California Botanic Garden, 1500 North College Avenue, Claremont, California 91711-3157.

For information about orders for CALIFORNIA BOTANIC GARDEN OCCASIONAL PUBLICATIONS, contact Irene Holiman at the address above or via e-mail: *iholiman@calbg.org* or fax at (909) 626-7670. For all other inquiries, contact Vanessa Ashworth at *aliso@calbg.org*. General information about the Garden and its programs can be obtained at *www.calbg.org*.

(Cover photograph by Sophia Winitsky)

PUBLICATION DATA

A Conservation Plan for *Calochortus excavatus* (Inyo County Star-Tulip, Liliaceae). January 2021. Sophia E. Winitsky. CALIFORNIA BOTANIC GARDEN OCCASIONAL PUBLICATIONS, Number 19, vi + 16 pages. ISSN 1094-1398. Series Editor Vanessa Ashworth; Managing Editor Lucinda McDade. First printing: 100 copies, January 2021.

This publication was printed with support from the California Native Plant Society (CNPS). Founded in 1965, CNPS is a science-based non-profit organization dedicated to increasing understanding and appreciation of California's native plants, and to conserving them and their natural habitats. Learn more at *https://www.CNPS.org*.

CALIFORNIA
NATIVE PLANT SOCIETY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

Occasional Publications 19, pp. 1–16
A Conservation Plan for *Calochortus excavatus* (Inyo County Star-Tulip, Liliaceae)

1.0 EXECUTIVE SUMMARY

Calochortus excavatus Greene, commonly known as the Inyo County star-tulip, is a perennial geophyte, endemic to eastern California. There are seventy known populations, which all occur within alkali meadows, a severely threatened community type. The majority of populations are located on land owned by the Los Angeles Department of Water and Power within the Owens Valley, in Inyo and Mono counties. *Calochortus excavatus* is ranked a 1B.1 species by the California Native Plant Society, which means it is endangered and seriously threatened throughout its range. Grazing, groundwater pumping, human disturbance, invasive species and habitat conversion currently threaten *C. excavatus* populations. This conservation plan aims to provide all stakeholders with comprehensive steps toward the conservation of this species.

2.0 SCOPE AND PURPOSE

A conservation assessment of *Calochortus excavatus* was deemed necessary due to the unknown demographics of the 70 element occurrences, all of which occur within alkali meadows, a severely threatened community type. This conservation plan compiles all data existing on the population status, biology and conservation concerns relevant to *C. excavatus* and provides steps for acquiring the data necessary to ensure the long-term conservation of the species.

3.0 METHODS

All existing data, including location, observed threats (Fig. 1–4) and population status, on the recorded element occurrences of *Calochortus excavatus* were accessed through the California Natural Diversity Database (CNDDB). A literature review on the biology, ecology and life history of the genus *Calochortus* as well as studies on alkali meadow communities, were compiled to inform conservation recommendations and implementation. Field surveys were conducted in the spring of 2018 and again in the summer of 2020 to census populations and assess habitat suitability. A total of 12 herbarium vouchers were collected from flowering populations and deposited at California Botanic Garden (RSA-POM).

4.0 BACKGROUND

4.1 *Species Description and Taxonomy*

The genus *Calochortus* (Liliaceae) was originally described by Frederick Pursh in 1814. The description was based on a *Calochortus elegans* Pursh specimen of the Lewis and Clark expedition, collected in present-day Idaho by Meriwether Lewis. There are approximately 73 species of *Calochortus* that are distributed throughout North and Central America (Gerritsen and Parsons 2007). The name *Calochortus* means beautiful grass, and the bulbs are edible. Species in the genus are distinguished from other members of Liliaceae by their short style, septicidal capsule and sepaloid outer perianth segment (Ownbey 1940; Munz and Keck 1959). They are monocots with generally umbel-like inflorescences, wide wedge-shaped petals, erect flowers and linear to lanceolate leaves. Their petals and sepals vary greatly in color and can have colorful markings. Flowers have six stamens and a gland at the base of each petal (Ownbey 1940).

A monograph of *Calochortus* was written in 1940 by Marion Ownbey, in which he categorized species in *Calochortus* into three morphologically distinct sections: *Calochortus*, *Cyclobothra* and *Mariposa*. *Calochortus excavatus* belongs to the *Mariposa* section, which has the distinguishing features of membranous bulb coats, three-angled capsules, and petals usually turning inward at night. Ownbey (1940) also created four subsections within section *Mariposa*: *Gunnisoniani*, *Macrocarpi*, *Nuttalliani* and *Venusti*. *Calochortus excavatus* is in subsection *Nuttalliani.* Some of the key traits of subsection *Nuttalliani* are circular and depressed glands, sepals that are shorter than the petals, and seeds that are strongly flattened or lenticular (Ness 1989). A phylogenetic study of *Calochortus* looked at variation throughout the genus (Patterson and Givnish 2004), in which seven distinct clades of *Calochortus* were described, named according to the geographic regions of occurrence. *Calochortus excavatus* was placed within the Great Basin-Rocky Mountains clade and it occurs within the Great Basin Floristic Province as described in the Jepson eFlora (Jepson Flora Project 2020).

Calochortus excavatus was first described by Edward L. Greene in 1890 from a collection made by W. H. Shockley (No. 427) at Bishop Creek, Inyo County. There are no known synonyms of *Calochortus excavatus* (Tropicos 2020); however, it was reduced to synonymy under *C. nuttallii* in Jepson's *A Flora of California* (1909–1939) and was then re-elevated to a species in Ownbey's monograph (1940). Plants of this species are 10–30 cm tall and grow from ovoid bulbs that send out a

Fig. 1–4. Threats facing *Calochortus excavatus*.—1. LA aqueduct transporting water from the Owens Valley to Los Angeles.—2. Development relating to aqueduct maintenance.—3. Human disturbance in habitat.—4. Drought and disturbance leading to vegetation type conversion.

slender stem with basal leaves that are linear, glaucous and 10–25 cm long. *Calochortus excavatus* has 1–4 flowers with paired bracts. The sepals, measuring 20–30 mm, are lanceolate and shorter than the petals that measure 30–40 mm (Fiedler 2012). The perianth is bell-shaped (Ownbey 1940). The petals are obovate, cuneate, usually obtuse, and white to faintly lavender-colored abaxially and dark purple to black adaxially (Fig. 5). The nectaries are round, depressed and covered in yellow, red or black hairs. The anthers are reddish-brown to purple and the same length as the filaments (Fig. 6). The fruit, measuring 5–8 cm, is linear to lanceolate and erect, and seeds are dropped from a capsule (Fig. 7). *Calochortus excavatus* blooms from April to June (Fiedler 2012). Nearby *Calochortus* species with similar floral forms include *C. leichtlinii* Hook. f. and *C. bruneaunis* A. Nelson and J.F. Macbr. (Fig. 8–10).

4.2 *Biology and Ecology*

The genus *Calochortus* is distributed across western North America and southward into Central America (Gerritsen and Parsons 2007). However, across this broad range, the habitat requirement for different species varies greatly; most species have very limited geographic distributions and are adapted to local conditions (Fiedler 1986). Forty species occur in California, half of which are rare or threatened (Fiedler 1985). Many species are edaphically restricted and one quarter of *Calochortus* species has adapted to survive with higher concentrations of trace minerals found in serpentine soils (Fiedler 1987; Patterson and Givnish 2004). Many California species have restricted ranges because of mountainous terrain. The genus' characteristic heavy seeds also limit dispersal (Patterson and Givnish 2004). *Calochortus excavatus* is halophytic and adapted to alkaline soils and fairly constant moisture. *Calochortus excavatus* is associated with restricted perennial alkaline meadows, found within the shadscale scrub plant community dominated by *Atriplex confertifolia* (Torr. & Frém.) S. Watson (Sawyer and Keeler-Wolf 2009). Shadscale scrub is widespread throughout the Owens Valley; however, the alkali meadows with perennial water found within the shadscale scrub are decreasing rapidly due to both drought and groundwater pumping. Alkali meadows were once common throughout the Owens Valley and are now considered "very threatened" as a community type (California Native Plant Society [CNPS] Bristlecone Chapter 2020).

Calochortus excavatus is a bulbiferous perennial herb with leaves emerging aboveground three to four months before flowering. Flowering occurs between early April and late July, depending on elevation, which ranges from 3000 to 7000 ft (900 to 2000 m) (CCH 2020). The Owens Valley increases in elevation from south to north. *Calochortus excavatus* grows along the valley floor and the toe slopes. It begins dormancy and is reduced to an underground bulb by the end of late summer through the very cold winter. Basal leaves emerge in February to March. There are no studies on long-term dormancy of *C. excavatus*, but a study on *C. lyallii* Baker and *C. macrocarpus* Douglas showed an average 18% and 26% dormancy in bulbs, respectively, per flowering season, with the ability to remain dormant for up to four years (Miller et al. 2004).

Members of *Calochortus* sect. *Mariposa* have a range of generalist pollinators including bees, butterflies, ants, and other insects (Dilley et al. 2000). Beetles are attracted to and feed on the nectar of the glands at the base of the petals. While liquid nectar is found in other sections of *Calochortus*, it is usually absent in section *Mariposa.* Instead, members of this section have a solid, sugar-like nectar found in small quantities between the dense hairs of the glands (Dilley et al. 2000). The main families of insects known to visit *Calochortus* include small-bodied bees (Anthrophoridae, Colletidae, Halictidae and Megachilidae) and beetles (Cerambycidae, Cleridae, Dasytidae, Melyridae and Mordellidae). The pollinators found on *Calochortus* are usually generalists or attracted to the community assemblage, rather than *Calochortus* specialists (Dilley et al. 2000).

Following flowering, a narrow, spear-shaped fruit develops. Dispersal of seed seems to be limited and there are no known animal or bird dispersers of *Calochortus* seeds. Generally, the heavy seeds drop near to the parent plant and they lie dormant until the following year's rains (Bullock 1976). Long-distance dispersal may also be limited by high elevation mountain ranges surrounding populations.

4.3 *Habitat*

Calochortus excavatus occurs in alkali meadows within shadscale scrub communities, ranging from 1300 to 2000 m elevation throughout the Owens Valley (Fiedler 2012). These are halophytic communities with a soil alkalinity ranging from pH 8 to 10. Dominant shrubs of shadscale scrub include: *Ambrosia dumosa* (A. Gray) W.W. Payne (white bursage), *Atriplex confertifolia* (Torr. & Frém.) S. Watson (shadscale), *Atriplex polycarpa* (Torr.) S. Watson (cattle saltbush), *Atriplex spinifera* J.F. Macbr. (Mojave saltbush), *Chrysothamnus viscidiflorus* (Hook.) Nutt. (green rabbitbrush) and *Larrea tridentata* (DC.) Coville (creosote bush) (Sawyer and Keeler-Wolf 2009). The shrub canopy is generally open with microphyllous

Fig. 5–7. *Calochortus excavatus* flowers and fruit.—5–6. Mariposa lily floral form.—7. Spear-shaped fruit.

Fig. 8–10. Similar-looking *Calochortus* species of the eastern Sierra Nevada.—8. *Calochortus leichtlinii* with sagittate yellow or white anthers and a red to black spotted mark above the nectary.—9. *Calochortus excavatus* with dark red anthers and a dark purple petal base.—10. *Calochortus bruneaunis* with a red or purple arch above the nectary and variable anther color.

shrubs and sparse to dense herbs underneath (Billings 1949).

Shadscale vegetation is a common plant community distributed throughout the Great Basin Desert (Hall 1991). Soil of the widespread scrub environments is sandy, while within the more localized meadow habitats, where *Calochortus excavatus* is found, the shallow, poorly drained soils hold perennial moisture. Little moisture is retained from rainfall, which is less than 10 inches (25.4 cm) per year on average (Hall 1991) so meadows are generally either fed by nearby springs or seeps, or they occur at the base of alluvial fans, collecting water from the Sierra Nevada, Inyo and White Mountain ranges. The water table in alkali meadows is relatively high and reaches 1–3 meters deep. This water level and the meadow habitat are ideal for both grazing pastures and groundwater pump placement (CNPS Bristlecone Chapter 2020). Alkali meadows are also usually near the base of the valley and therefore easily accessible via highways and adjacent to towns, as well as the natural place for water to accumulate, making them especially cost-effective and efficient locations for water development. Although still fairly common throughout Inyo and Mono counties, alkali meadows in general are considered a rare and threatened vegetation community type by the California Natural Diversity Database (CNDDB 2020).

The dominant species cover of alkali meadows are perennial grasses, which can account for 15–100% of canopy cover (Fig. 11–14; CNPS Bristlecone Chapter 2020). This habitat type is also known as an alkali-saline wetland, with species adapted to both saline and alkaline soils (Sawyer and Keeler-Wolf 2009). Some of the most common grasses are *Distichlis spicata* (L.) Greene (saltgrass), *Spartina gracilis* Trin. (alkali cordgrass), *Elymus cinereus* Scribn. & Merr. (Great Basin wild rye), *Sporobolus airoides* (Torr.) Torr. (alkali sacaton) and *Poa secunda* J. Presl (one-sided blue grass; Ellsworth 2016). Within California, alkali meadows are very rare outside of the Owens Valley. As a consequence of water tables being lowered by increased groundwater pumping, the extent of these habitats is declining, and the vegetation types are converting to scrub. Rabbitbrush and saltbush from the surrounding shadscale scrub are moving into drying alkali meadows, and eventually the dominant canopy will convert from grasses to shrubs (Fig. 14; Elmore et al. 2006). In addition to an overall drier habitat throughout the Owens Valley due to extraction (Fig. 1–2), there are decreasing numbers of smaller seeps and springs (Elmore et al. 2003). This may lead to grazers congregating in higher densities around the remaining springs, further disturbing sensitive species. Loss of suitable habitat due to similar habitat destruction threatens many other alkali meadow endemic plant species, such as *Crepis runcinata* (E. James) Torr. & A. Gray subsp. *hallii* Babc. & Stebbins (Hall's meadow hawksbeard) and *Spartina gracilis* Trin. (alkali cordgrass; CNPS Bristlecone Chapter 2020).

4.4 *Distribution and Abundance*

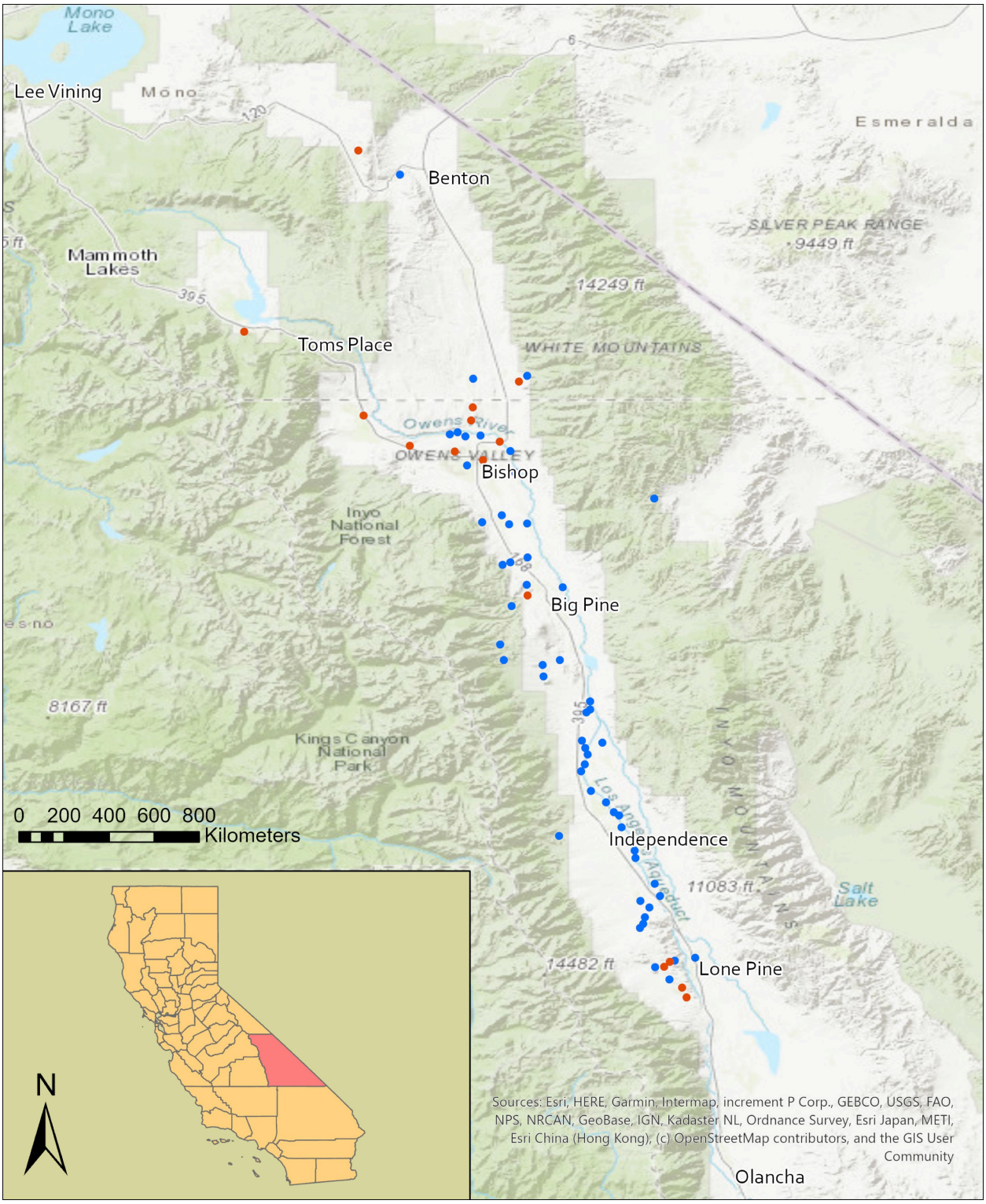
The distribution of *Calochortus excavatus* extends throughout lower elevations of the Owens Valley, which spans 100 miles north to south and is approximately ten miles wide in Inyo and Mono counties, California (Map 1). The Owens Valley is bounded to the west by the Sierra Nevada and to the east by the White and Inyo mountains. There are no known occurrences across the Nevada border, which lies directly east of the White and Inyo mountain ranges. The highest density of *C. excavatus* populations occurs in the 7.5-minute USGS quadrangles of Big Pine, Blackrock and Fish Slough. Most populations are close to the center of the Owens Valley, near U.S. Route 395 and the Owens River, and therefore, near human settlement. The most southern occurrence is between Owens Lake and Lone Pine, along Lubken Creek and near U.S. Route 395. The most northern occurrence is along U.S. Route 395 one mile southeast of Bridgeport, Mono County. Populations range widely in size, with some occurrences known from fewer than five plants, and five populations that have more than 1000 plants recorded.

The majority of land in the Owens Valley is managed and owned by the Bureau of Land Management (BLM), private landowners, and the Department of Water and Power for the City of Los Angeles (LADWP). The vast majority of *C. excavatus* habitat is owned by Los Angeles Department of Water and Power; this accounts for 59 out of 70 occurrences. However, four populations occur on private residential land, two on Inyo National Forest land and six on BLM land (Table 1; CNDDB 2020). None has been confirmed as extirpated, although vegetation type conversion has occurred throughout their range.

4.5 *Population Trends*

All recorded populations of *Calochortus excavatus* are either fluctuating or have unknown demographic trends. Many occurrences have been seen only once; for those more fieldwork is necessary. Some element occurrences (EOs 1, 5, and 13; see Table 1) are highly fluctuating in the number of reported individuals, with this variation usually being attributed to years of drought, but may also be related to survey timing (CNDDB 2020). Eight of the 70 documented occurrences have not been revisited since the 1980s, and

Fig. 11–14. *Calochortus excavatus* habitat seen at four CNDDB element occurrences in 2020.—11. Margins of alkali meadow seen at EO3.—12. *Sarcobatus vermiculatus* (Hook.) Torr. and other associated taxa in the Alabama Hills at EO32.—13. A meadow behind Baker Creek Campground supports *Calochortus excavatus* and *Sidalcea covillei* Greene, another endangered plant with the CNPS rank 1B.1, at EO13.—14. The marshes on the north shore of Black Lake face vegetation type conversion to *Ericameria nauseosa* shrubland at EO9.



Map 1. *Calochortus excavatus* element occurrences as of 2020 (CNDDB 2020). Red dots represent occurrences visited while compiling habitat information for this management plan and blue dots represent unvisited populations. The inset shows Inyo County, where 67 of the 70 occurrences of *C. excavatus* are located.

Table 1. Element occurrences (EOs) for *Calochortus excavatus* (CNDDB 2020). (Abbreviations: BLM = Bureau of Land Management, LADWP = Los Angeles Department of Water and Power, PVT = private residence, USFS Inyo NF = United States Forest Service: Inyo National Forest).

Total	EO #	USGS Quadrangle and County	Year last seen	Owner/Manager	Most recent population status and trend	Threats
1	1	Fish Slough (Inyo)	2006	LADWP	99 plants, fluctuating	Small dirt road through population, grazing, recreation
2	2	Fish Slough (Inyo)	2008	LADWP	878 plants, increasing	Grazing, recreation
3	3	Lone Pine (Inyo)	2004	LADWP	282 plants	Horses, grazing
4	4	Bishop (Inyo)	2012	BLM, LADWP	150 plants in 1993 (number not known for recent surveys)	Grazing, groundwater pumping, vandalism
5	5	Fish Slough, Rovana (Inyo)	2002	LADWP	28 plants, fluctuating	Unknown
6	6	Laws (Inyo)	2008	LADWP	6 plants in 1993, unknown numbers for most recent survey	Grazing, off road vehicles
7	7	Independence (Inyo)	2006	LADWP	13 plants	Grazing excluded, numbers still low
8	8	Independence (Inyo)	2002	LADWP	241 plants in 1995	Grazing
9	9	Benton Hot Springs (Mono)	2010	BLM, LADWP, PVT	<100 in 1997, decreasing	Invading species
10	10	Lone Pine (Inyo)	2011	LADWP	2111 plants, increasing	Road construction, grazing
11	11	Fish Springs (Inyo)	1993	LADWP	32 plants	Grazing
12	12	Big Pine (Inyo)	1993	LADWP	52 plants	Grazing
13	13	Big Pine (Inyo)	2008	LADWP	400 plants, fluctuating	Grazing, road construction
14	15	Fish Slough (Inyo)	2008	BLM, LADWP	Over 1000 plants	Grazing
15	17	Bishop (Inyo)	1995	LADWP	1000 plants (95)	Grazing
16	19	Laws (Inyo)	2008	LADWP	51 plants, increasing	Grazing, off road vehicles
17	20	Lone Pine (Inyo)	1980	BLM-PVT	15 plants in 1983, none found since	Unknown
18	21	Bishop (Inyo)	1985	PVT-Bishop Reservation	360 plants in 1985	Horses
19	22	Fish Slough (Inyo)	1993	LADWP	5 plants	Grazing
20	23	Independence (Inyo)	2008	LADWP	36 plants	Grazing, groundwater pumping
21	24	Blackrock (Inyo)	2006	LADWP	42 plants	Grazing
22	25	Independence (Inyo)	2006	LADWP	7997 plants	Grazing
23	27	Big Pine (Inyo)	1995	LADWP	7 in 1995	Grazing
24	28	Fish Springs (Inyo)	2004	LADWP	Unknown	Grazing
25	29	Fish Springs (Inyo)	1993	LADWP	117 plants	Grazing
26	32	Lone Pine (Inyo)	2006	LADWP	1250 plants, increasing	Grazing
27	33	Fish Slough (Inyo)	2006	LADWP	89 plants	Grazing
28	34	Poleta Canyon (Inyo)	2003	LADWP	634 plants	Grazing
29	35	Chalfant Valley (Mono)	1993	BLM-PVT	20 plants	Unknown
30	36	Laws (Inyo)	2008	LADWP	368 plants	Off road vehicles
31	37	Independence (Inyo)	1988	LADWP	48 plants, none seen since 1988	Ponding for irrigation
32	38	Manzanar (Inyo)	2003	LADWP	46,086 plants	Grazing cattle and elk
33	39	Manzanar (Inyo)	2004	LADWP	38 plants	Unknown
34	40	Manzanar (Inyo)	2004	LADWP	17 plants	Unknown
35	41	Blackrock (Inyo)	2006	LADWP	28 plants	Grazing

Table 1 Continued.

Total	EO #	USGS Quadrangle and County	Year last seen	Owner/Manager	Most recent population status and trend	Threats
36	42	Blackrock (Inyo)	1996	LADWP	11 plants	Groundwater pumping, vandalism, fire regime changes
37	43	Blackrock (Inyo)	2008	LADWP	100 plants	Grazing
38	44	Fish Slough (Inyo)	1989	LADWP	Unknown	Unknown
39	45	Lone Pine (Inyo)	2004	LADWP	278 plants	Unknown
40	46	Manzanar (Inyo)	1993	LADWP	35 plants	Grazing
41	47	Blackrock (Inyo)	2008	LADWP	100 plus plants	Grazing
42	48	Poleta Canyon (Inyo)	2003	LADWP	937 plants	Grazing
43	49	Poleta Canyon (Inyo)	1995	LADWP	118 plants	Grazing, rabbitbrush invasion
44	50	Fish Slough (Inyo)	1995	LADWP	190 plants	Grazing
45	51	Lone Pine (Inyo)	1998	LADWP	22, then none since 1998	Unknown
46	52	Manzanar (Inyo)	2004	LADWP	2 plants	Unknown
47	53	Blackrock (Inyo)	2008	LADWP	28 plants	Grazing
48	54	Blackrock (Inyo)	1997	LADWP	21 plants	Grazing
49	55	Blackrock (Inyo)	1997	LADWP	20 plants	Unknown
50	56	Big Pine (Inyo)	2003	LADWP	11,703 plants	Grazing
51	57	Big Pine (Inyo)	1996	LADWP	1 plant	Unknown
52	58	Fish Springs (Inyo)	2003	USFS-Inyo NF	5 plants	Unknown
53	59	Lone Pine (Inyo)	1897	Unknown	Unknown	Unknown
54	60	Lone Pine (Inyo)	2008	LADWP	30 plants	Grazing
55	61	Union Wash (Inyo)	2003	LADWP	1601 plants	Unknown
56	62	Independence (Inyo)	1999	LADWP	18 plants	Unknown
57	63	Independence (Inyo)	2002	LADWP	Possible extension of EO8 (together 3320 plants)	Unknown
58	64	Kearsarge (Inyo)	2000	LADWP	12 plants	Unknown
59	65	Blackrock (Inyo)	2003	LADWP	12 plants	Unknown
60	66	Fish Springs (Inyo)	2000	LADWP	100 plants	Unknown
61	67	Big Pine (Inyo)	2008	USFS-Inyo NF	5 plants	Non-native species (cheatgrass), recreation
62	68	Poleta Canyon (Inyo)	2000	LADWP	100 plants	Grazing
63	69	Fish Slough (Inyo)	2006	LADWP	4 plants	Grazing
64	70	Rovana (Inyo)	2002	LADWP	2 plants	Unknown
65	71	Big Alkali (Mono)	1949	BLM	Unknown	Unknown
66	72	Deep Springs Lake (Inyo)	1934	Unknown	Unknown	Unknown
67	73	Tom's Place, Convict Lake (Mono)	1958	Unknown	Unknown	Unknown
68	74	Benton Hot Springs (Mono)	2008	Private	Unknown	Unknown
69	75	Union Wash (Inyo)	2005	LADWP	165 plants	Grazing
70	76	Big Pine (Inyo)	2010	BLM	2 plants	Grazing

16 occurrences were last visited in the 1990s. Forty-five occurrences were last visited in the 2000s. There are four populations that have been visited multiple times and which continue to be monitored by the BLM's regional office in Bishop; however, their trending status is still unclear (CNDDB 2020). Sixteen occurrences were visited during the development of this conservation plan, primarily to assess habitat, and only two occurrences were flowering at the time of visitation and will be updated through the CNDDB.

4.6 *Threats*

Calochortus excavatus habitat is facing many threats (Fig. 1–4). Many ranches currently graze cattle throughout the Owens Valley and historically the region has been heavily grazed. Recreational activities, including off-road vehicle use, hiking and fishing are increasing in popularity in eastern California. Depending on the population's location, this could result in trampling or even the development of additional paths, roads or infrastructure. A principal threat is the lowering of the water table as a result of water withdrawal that will result in altered hydrology in *C. excavatus* habitat. Water diversion and development for the City of Los Angeles began in the early 1900s when the Los Angeles aqueduct was built.

Water Pumping: Although only four of the populations have recorded evidence of groundwater disturbance, 59 of the occurrences of *C. excavatus* are on land owned by the Los Angeles Department of Water and Power (CNDDB 2020). The Los Angeles Aqueduct was built in 1913 and diverted the majority of the flow of the Owens River to the ever-expanding City of Los Angeles (Wood 1973). Before water exportation began, there was stable surface water on Owens Lake, the terminus of the closed Owens Valley watershed. Today only a small portion of the Owens River is allowed to reach the lake, which has become a dry lakebed sometimes used for recreation, with trails, birdwatching, camping and mining activities. It still has some perennial seeps on its western edge, but the majority of the lake is dry.

Since Owens Lake dried in 1926, the first aqueduct was insufficient to meet Los Angeles' growing water needs and a second aqueduct was built in 1970. Harvesting of groundwater was needed to meet water export quotas, especially throughout the droughts of the late 1980s, where groundwater was a significant percentage of the water diverted from the Owens Valley (Elmore et al. 2003). In the Owens Valley, the alkali meadows are highly dependent on the influx of groundwater so they are able to sustain moisture through periodic droughts (Elmore et al. 2003). Even excluding drought years, groundwater is necessary for the continuation of alkali meadows because rates of evapotranspiration within alkali meadows are higher than precipitation even in years with average rainfall (Pritchett and Manning 2009). As alkali meadows dry, there is less available habitat for *C. excavatus.*

Grazing Allotments: Grazing has been documented as a threat for 31 of the populations in the CNDDB (2020). Grazing was more prominent throughout the Owens Valley before the LADWP purchase, however LADWP and BLM both lease land to ranchers, which puts *C. excavatus* in danger of both direct consumption by grazing animals and indirect harm by trampling by large animals. Cattle, mules and horses graze throughout the Owens Valley.

Recreational Vehicles: Another threat is off-road vehicle use, which is gaining popularity throughout eastern California. Vehicles can run over plants or cause further habitat destruction if roads need maintenance or construction, which may cause population fragmentation, change in drainage and waterways, bring in non-native species and cause soil compaction (Davidson and Fox 1974).

Invasive Species: *Chrysothamnus viscidiflorus* (green rabbitbrush), *Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & G.I. Baird (rubber rabbitbrush) and *Bromus tectorum* L. (cheatgrass) are invading *C. excavatus* habitat. Both rabbitbrush species are native, but can invade open spaces once the water table has changed significantly and the area is no longer dominated by native grasses. Cheatgrass is a non-native invasive species that is now widespread in the Owens Valley. Cheatgrass emerges before many native grasses in the early spring, and has also been known to change the fire regime of the area, as well as to outcompete native species (Young and Clements 2009).

4.7 *Conservation Status*

CNPS ranked *Calochortus excavatus* a 1B.1 on their state-wide plant inventory, the Inventory of Rare and Endangered Plants in California (CNPS 2020). This means it is rare, severely threatened and endemic to California. Globally, *C. excavatus* is ranked as G2 (imperiled) and has a state rank of S2 (imperiled) (NatureServe 2020). It is identified as a Species of Conservation Concern for both the Inyo National Forest and the Bureau of Land Management. There is only one population that is mapped as a polygon from 2006 and is one of only two populations occurring on Inyo National Forest land (CNDDB 2020). Grazing is currently excluded from this population. Some surveys have been required for Environmental Impact Statements. For

example, surveys were performed for the Owens Valley Radio Observatory near Big Pine (TEAM Engineering and Management, Inc. 2010). Other monitoring has been part of the LADWP's Habitat Conservation Plan under the USFWS management plan (LADWP 2010). INF and BLM also conduct rare plant monitoring. However, many populations have not been visited since the 1990s; also, many populations have only been documented once and need more fieldwork to verify the current status of the populations. One occurrence (EO7) has a grazing exclosure, installed as early as the 1970s (CNDDB 2020). There are insufficient data from monitoring this exclosure to remark on the effectiveness of this method. More fieldwork is needed before building more exclosures. Other than monitoring related to Habitat Conservation Plans and Environmental Impact Statements, which have not been continuous, there has been little systematic demographic data collection and no conservation plans have been implemented for *C. excavatus.*

5. CONSERVATION

5.1 *Conservation Objectives*

The following is an overview of the objectives for the conservation of the species *Calochortus excavatus*:

1. Ensure stable numbers of individuals within populations, as well as potentially increasing the number of individuals within populations.
2. Research and improve understanding of the ecology and biology of the species in order to tailor conservation objectives appropriately.
3. Document and then minimize the human threats in each population, specifically targeting grazing, water pumping and recreational development.
4. Research potential for *ex-situ* conservation: attempt to propagate *Calochortus excavatus* in addition to placing seeds in long-term seed storage.
5. Monitor habitat status; assess overall acreage of alkali meadow ecosystems throughout the Owens Valley, both with and without populations. Quantify canopy cover and extent of invasive plants in meadows with populations.
6. Incorporate as many conservation objectives as possible into the existing required rare plant monitoring done by LADWP, INF and BLM.

5.2 *Conservation Criteria and Recommendations*

More information on the biology and ecology of *Calochortus excavatus* should be gathered before implementing a conservation plan. Data should be collected in the following areas in order to prioritize populations and areas of conservation concern as well as to provide landowners with site-specific recommendations and objectives:

5.2.1 Census

All seventy populations should be visited with appropriate timing, and individuals should be counted, and phenology should be recorded. Numbers in the census should be compared to previous records to determine population trends. Polygons should be mapped with GPS coordinates so that in the future populations can be easily relocated and data can be efficiently expanded upon, facilitating assessment of range changes and metapopulation dynamics over time. This census should occur annually when possible in cooperation with the landowner. To begin, all individual plants within polygons should be counted. If populations exceed 1000 individuals, transects can be installed to observe population trends. All populations visited with this conservation plan's methodology will be recorded in a table that includes population numbers, measures taken for protection, date visited, GPS points of transects if created. This table will be available to stakeholders and will help prioritize future fieldwork.

5.2.2 *Fire History*

Many geophytes and other species of *Calochortus* emerge aboveground from the dormant bulb state in higher numbers after fires than in years without fire disturbance, but no research has been done specifically on *C. excavatus.* Geophytes within sage scrub tend to resprout heavily the first year after fire and numbers taper off in subsequent years (Keeley et al. 2006). Although it has been suggested that fire may be an effective management strategy for maintaining alkali meadow habitat (Pritchett and Manning 2009), this area is at risk of invasion from cheatgrass, which quickly spreads after fires.

5.2.3 *Water History*

Alkali meadows are highly dependent on groundwater; only after the water table has been severely lowered do these habitats become dependent on precipitation (Elmore et al. 2006). The nearest LADWP monitoring well for each population should be noted so that future partners know which well is closest to each population. There are 300 wells throughout the Owens Valley, and they record depth to groundwater twice a year. When collecting population data, the depth to

water measurement (DTW) last recorded at the nearest monitoring well should be included. Further water development and pumping or maintenance needed at a site should be noted and further investigated.

Grazing livestock may exacerbate this water shortage. As surface water and soil moisture dry up in other areas of the valley, grazing livestock will congregate where surface water is available, locally increasing trampling damage to the alkali meadow vegetation.

5.2.4 *Recreation*

Impacts of any recreational development or potential development on occupied *Calochortus excavatus* habitat should be assessed. If roads, trails or construction exist, the proximity to the population should be noted. The status of this infrastructure should also be assessed to determine when and how maintenance should occur to minimize impacts on *C. excavatus*. LADWP is expanding their trail system, recreational outreach, and wildlife and bird watching infrastructure (LADWP 2010). The plans for this recreational infrastructure should be reviewed and should incorporate the locations of known *C. excavatus* populations. Interpretation signage or exclosures should be built around populations in the vicinity of recreational activities to make people aware of the sensitivity of the area. Lists of roads, trails and structures adjacent to a population should be given to the landowners and stakeholders with suggestions of how to avoid populations when maintaining the existing infrastructure.

5.2.5 *Grazing Exclusion*

The extent of grazing disturbance should be noted at each population. Elk, horses, cattle and mules are known to trample as well as to eat *Calochortus* leaves and flowers (Gray and Bahm 2015). EO15 has part of its population fenced off and protected from grazing. Grazing has also been removed from EO67, which was previously grazed. The effects of these exclosures should be assessed, by comparing population trends and damage to vegetation of these occurrences to other populations on grazing allotments without exclosures. If more fieldwork proves this method effective, the merits of establishing exclosures at each site should be evaluated.

5.2.6 *Changes in Community Composition*

Data about canopy cover should be recorded at each population. This will include percent cover of grasses, forbs, shrubs and trees within and directly around the population as well as a list of invasive species, and their percent cover if it is significant—over 1%. This will help prioritize element occurrences if they are experiencing habitat conversion from alkali meadow, or if there has been a significant change in habitat between monitoring visits. *Calochortus excavatus* prefers open, sunny areas that are easily invaded by shrubs such as *Chrysothamnus* spp. and *Atriplex* spp. once soils become drier or fire intervals shorten.

Bromus tectorum is an invasive grass known to outcompete native plants, especially native forbs, in the Owens Valley (Young and Clements 2009). The percent cover of this non-native invasive grass should be recorded to determine whether its abundance has an impact on recruitment and persistence of *Calochortus excavatus.* Both an increase in shrub cover and an increase of invasive grasses can alter fire regimes. Invasive plants should be removed depending on the severity of invasion and proximity to the *Calochortus* populations.

5.2.7 *Propagation*

More research is needed to determine whether propagation of *Calochortus excavatus* and *ex-situ* conservation is feasible and effective. Seeds have been collected and will be held at Santa Barbara Botanic Garden. Seed experimentation documenting germination rates, germination requirements and plant survival rate is necessary to understand whether there is potential for *ex-situ* conservation.

5.2.8 *Potential Habitat*

It is important to conduct an inventory of alkali meadow environments without recorded populations, both in California and adjacent Nevada. These alkali meadows are located along the toe slopes and alluvial flats along the Owens Valley. They should be identified from existing aerial imagery and soil maps. If there are alkali flat areas near other populations of *Calochortus excavatus* those should be visited during the census of the nearby population. Since habitat degradation is the major threat to the viability of *C. excavatus*, protecting any suitable alkali meadow is vital for conserving potential habitat. This would require a team effort with local agencies and conservation groups that have already begun putting measures forward to protect alkali meadows, i.e., the Eastern Sierra Land Trust, the Adobe Ranch and CNPS.

5.2.9 *Pollination, Reproduction and Dormancy*

More research into reproductive biology, pollination, recruitment and seed dispersal needs to be done to explore the role that infertility, inbreeding or dispersal might play in limiting *Calochortus excavatus* population

trends, in addition to habitat degradation. Pollination studies should be performed to identify the main pollinators as well as the most effective pollinators. Three-year monitoring of individual plants is the minimum time frame to gain understanding of the dynamics of vegetative dormancy in this species (Miller et al. 2004). Further investigation into life history, including the age of individuals, time needed for germination, and mortality rates and factors, will inform more specific conservation actions. Reproduction studies should count flower, fruit and seed production, and track seed dispersal. This ecological and biological information will lead to more recommendations on how to best support *C. excavatus.*

5.3 *Site-Specific Actions*

5.3.1 *On-Going Fieldwork at Each Site*

Monitoring of populations should occur annually, at least until a population trend is determined. Depending on the site, permission can be granted for third-party monitoring, for example volunteers for the CNPS or the Eastern Sierra Land Trust, at populations that the land managers are not censusing themselves. The first annual sampling should be a training session for these partners in order to ensure consistency amongst monitoring teams. A CNDDB element occurrence data sheet should be completed along with a supplementary data sheet specifically addressing *Calochortus excavatus.* This data will include individual counts, phenology (percentages of fruit/flower/vegetative structures at time of visit), pollinator observations, water table level as shown by the nearest DWP monitoring well, location of well, depth of water within meadow, fire history, canopy cover, invasive presence, recreation disturbance, observations of grazing effects (trampling/herbivory), range extension or change of population.

5.3.2 *Private Landowners*

Ranchers and other private landowners should be informed individually about their populations. Maps with population data and information on the main threats should be given to the landowners. Training on monitoring protocol should be provided and they should be shown in the field the perimeter of their populations' polygons. If landowners are ranchers, grazing exclosures can be suggested where benefits are substantial and exclosures should be monitored for effectiveness.

5.3.3 *LADWP*

Los Angeles Department of Water and Power (LADWP) is the landowner for the majority of the element occurrences. Restoration of watersheds and riparian communities as well as environmental education and recreation are part of LADWP's mission to mitigate their relationship with the residents of the Eastern Sierras and Owens Valley, as well as concerned parties in the Los Angeles area (LADWP 2010). Plans for further recreational development should be reviewed in light of mapped *Calochortus excavatus* populations in order to minimize impacts of trails and other infrastructure development on populations. If populations occur close to recreational areas, including campgrounds, trails, or bird-watching areas, both protective barriers and interpretive signage will help to inform the public about the rare plant and sensitive habitat.

Grazing allotments on LADWP properties should be assessed for exclosure installments. To avoid cattle clustering around *C. excavatus* populations, watering troughs should not be placed on alkali meadows. Rather, alternative methods of providing water and placement of troughs are suggested to protect sensitive habitat so that cattle do not need to rely on meadow seepage; i.e., troughs should direct cattle away from sensitive habitat, especially during bloom months.

All of the populations of *C. excavatus* are on different sub-watersheds throughout the Owens Valley; however, all of these watersheds are connected by larger-scale water diversion activities managed by the LADWP. The main conservation objective for *C. excavatus* populations occurring on LADWP lands is planning water development with these populations in mind. The Ecological Society of America wrote a "Review of Methods for Vegetation Monitoring and Analysis in the Owens Valley" (2016) that provides a structure to monitor groundwater pumping effects through LIDAR and vegetation monitoring. These methods include remote sampling, transects, life history tables, threshold tracking and adaptive management practices. These methods should be referenced if habitat degradation is continuous and then applied to annual monitoring. This would include monitoring for the entire health of the alkali meadow and would involve a larger human effort, but may be necessary for the continuation of *C. excavatus.*

5.3.4 *BLM and USFS*

The Bishop Bureau of Land Management (BLM) and United States Forest Service (USFS) already have *Calochortus excavatus* on their sensitive species lists. Alkali meadows on their lands are monitored as at-risk habitat, but the species' population trends are not monitored. These populations need to be assessed, prioritized and integrated into their existing annual sensitive species monitoring with an updated approach consistent with data collected on other populations in the valley. Populations that are on land leased for grazing will be examined for potential exclosures for protection. Inyo National Forest and BLM crews that monitor post-

fire regeneration could be educated on recognizing *C. excavatus*.

6.0 IMPLEMENTATION

6.1 *Implementation Schedule*

Before implementation begins, all landowners and stakeholders should be contacted and met with regarding their knowledge of *Calochortus excavatus* on their property as well as the status and threats to the alkali meadows on their land. Implementation of the suggested conservation actions mentioned below will begin the spring of 2021 (Table 2) with the initial survey, including the mapping of each population. Other information recorded in the initial site visits includes data on distribution, abundance, localized threats, ecology, habitat and associated species. As funding is received, action items will be implemented with the schedule outlined in Table 2.

6.2 *Potential Difficulties in Implementation*

There are 70 EOs that need initial surveys, which will require participation from many parties for multiple years. Continuous monitoring may only be possible at a subset of these occurrences due to funding and participation. If LADWP does not participate in

Table 2. Suggested implementation schedule for conservation action items for *Calochortus excavatus*. (Abbreviations: EO = element occurrence).

Action item	Specifics	Timeline	Priority
Initial site visits and survey of potential habitat with no recorded EOs.	Conduct population censuses at each EO and more specifically document site-specific threats. Map populations.	2021–2022	High
	Collect information on the habitat, canopy cover (i.e., graminoid, herb, shrub, tree), associated species and water source.		
	Look for *Calochortus excavatus* in similar habitats outside sites of current EOs.		
Monitoring	Set up transects in larger populations and count individuals within mapped polygons at the smaller-sized EOs. Parties identified after the initial consultations (CNPS, landowners, Eastern Sierra Land Trust) will claim responsibility for different populations or regions.	2021–2028	High
	Element occurrences that will not be visited annually should be visited after any significant precipitation events, fire disturbance or plans to build or change land use. Monitoring results will be reviewed after the first five years and a longer-term monitoring plan will be decided upon based on the recent censuses and updated population trends.		
Genetic conservation	Collect seeds for long-term storage and germination experiments.	2020–2021	Medium
Further ecological and biological research	Observational studies at EOs with differing elevation, water sources and species composition. Record pollinator diversity and distribution. Set up dormancy observational studies with individuals at selected populations. Visit these individuals every spring for 3–5 consecutive years. Compare dormancy proportions throughout three populations each year to see if dormancy rates are localized or related to larger climatic trends.	2021–2028	Medium
	Compare population trends between populations that have documented groundwater changes and populations that have not experienced recent declines in groundwater. Prioritize monitoring trips based on these results.		
Infrastructure	Install cattle exclosures and educational signage at high-risk sites and monitor for effectiveness.	2021–2023	Medium high

monitoring or does not provide funding, substantial outside funding from various conservation partners may be needed. In this case, certain EOs will need to receive prioritization. If LADWP does not provide access for monitoring their populations, this plan will only be applied to the accessible populations. The number of exclosures and signage applied to EOs will also be dependent on funding. For this reason, analyzing the utility, feasibility and effectiveness of these monitoring methods will be critical for the budget of this conservation plan. Once more information is gathered in the first few years about the current status and biology of *Calochortus excavatus*, conservation actions will be adapted to reflect recent observations. Other implementation difficulties may arise due to the species' sensitivity to groundwater levels. Many populations occur on land that is owned by LADWP and managed particularly for its water resources, so these EOs may need different recommendations related to water development, and closer monitoring.

ACKNOWLEDGEMENTS

This plan was developed in a class led by Naomi Fraga and Loraine Washburn and I would like to thank them for providing us with this opportunity, continuously editing and sharing feedback for this document and introducing us to other members of the plant conservation community. Thanks to Gary Wallace and Jennifer Rodriguez for providing additional feedback to this plan and to Carrie Kiel and Melissa Johnson for sharing about their process creating conservation plans. I would like to thank Nora Bales for her mapping expertise and Amy Patten, Rachel Slaughter and Anabel Winitsky for help in the field, as well as, Vanessa Ashworth, Fred Roberts and an anonymous reviewer for their feedback. This project was made possible with the financial support of CNPS Bristlecone Chapter and California Botanic Garden.

LITERATURE CITED

BILLINGS, W. D. 1949. The shadscale vegetation zone of Nevada and eastern California in relation to climate and soils. *Amer. Midl. Naturalist* **42**: 87–103.

BULLOCK, S. H. 1976. Comparison of the distribution of seed and parent-plant populations. *S. W. Naturalist* **21**: 383–389.

CALIFORNIA NATURAL DIVERSITY DATABASE [CNDDB]. 2020. California Department of Fish and Wildlife. *https://www.wildlife.ca.gov/Data/CNDDB* (15 Aug 2020).

CALIFORNIA NATIVE PLANT SOCIETY [CNPS] BRISTLECONE CHAPTER. 2020. Alkali meadow. *http://bristleconecnps.org/conservation/issues/water_agreement/ecological/vegetation/alkali_meadow.php* (15 Aug 2020).

CALIFORNIA NATIVE PLANT SOCIETY [CNPS]. 2020. CNPS inventory of rare plants. *https://www.cnps.org/rare-plants/cnps-inventory-of-rare-plants* (14 Aug 2020).

CONSORTIUM OF CALIFORNIA HERBARIA [CCH]. 2020. *http://ucjeps.berkeley.edu/consortium* (18 Oct 2016).

DAVIDSON, E. AND M. FOX. 1974. Effects of off-road motorcycle activity on Mojave Desert vegetation and soil. *Madroño* **22**: 381–390.

DILLEY, J. D., P. WILSON AND M. R. MESLER. 2000. The radiation of *Calochortus*: generalist flowers moving through a mosaic of potential pollinators. *Oikos* **89**: 209–222.

ECOLOGICAL SOCIETY OF AMERICA. 2016. Review of methods for vegetation monitoring and analysis in the Owens Valley, California. *http://www.inyowater.org/wp-content/uploads/2016/03/ESA-Owens-Valley-Report-February-22-2016.pdf* (11 Nov 2016).

ELLSWORTH, A. 2016. Final land management plan for River Spring Lakes Ecological Reserve, Mono County, California. California Natural Resources Agency, State of California. *https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=123490&inline.*

ELMORE, A. J., J. F. MUSTARD AND S. J. MANNING. 2003. Regional patterns of plant community response to changes in water: Owens Valley, California. *Ecol. Applic.* **13**: 443–460.

———, S. J. MANNING, J. F. MUSTARD AND J. M. CRAINE. 2006. Decline in alkali meadow vegetation cover in California: the effects of groundwater extraction and drought. *J. Appl. Ecol.* **43**: 770–779.

FIEDLER, P. L. 1985. Heavy metal accumulation and the nature of edaphic endemism in the genus *Calochortus* (Liliaceae). *Amer. J. Bot.* **72**: 1712–1718.

———. 1986. Concepts of rarity in vascular plant species, with special reference to the genus *Calochortus* Pursh (Liliaceae). *Taxon* **35**: 502–518.

———. 1987. Life history and population dynamics of rare and common mariposa lilies (*Calochortus* Pursh: Liliaceae). *J. Ecol.* **75**: 977–995.

———. 2012. *Calochortus excavatus*. *In* Jepson Flora Project [editors], Jepson eFlora. *https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=16727* (14 Aug 2020).

GERRITSEN, M. E. AND R. PARSONS. 2007. *Calochortus*: mariposa lilies & their relatives. Timber Press, Inc., Portland, OR.

GRAY, E. C. AND M. A. BAHM 2015. Evaluation of population trends and potential threats to a rare serpentine endemic, *Calochortus coxii* (crinite mariposa lily). 2015 Progress Report. Institute for Applied Ecology, Bureau of Land Management, Roseburg District. Corvallis, OR.

HALL, C. 1991. A natural history of the White-Inyo Range, eastern California. University of California Press, Berkeley.

JEPSON, W. L. 1909–1939. A flora of California. University of California, Berkeley.

JEPSON FLORA PROJECT (editors). 2020. Jepson eFlora. *https://ucjeps.berkeley.edu/eflora/* (14 Aug 2020).

KEELEY, J. E., C. J. FOTHERINGHAM, AND M. BAER KEELEY. 2006. Demographic patterns of postfire regeneration in Mediterranean-climate shrublands of California. *Ecol. Monogr.* **76**: 235–255.

LOS ANGELES DEPARTMENT OF WATER AND POWER (LADWP). 2010. Owens Valley Watershed Management Program. *https://www.ladwp.com/.*

MILLER, M. T., G. A. ALLEN AND J. A. ANTOS. 2004. Dormancy and flowering in two mariposa lilies (*Calochortus*) with contrasting distribution patterns. *Canad. J. Bot.* **82**: 1790–1799.

MUNZ, P. A. AND D. D. KECK. 1959. A California flora. University of California Press, Berkeley.

NATURESERVE. 2020. A network connecting science with conservation. *http://www.natureserve.org/* (15 Aug 2020).

NESS, B. D. 1989. Seed morphology and taxonomic relationships in *Calochortus* (Liliaceae). *Syst. Bot.* **14**: 495–505.

OWNBEY, M. 1940. A monograph of the genus *Calochortus*. *Ann. Missouri Bot. Gard.* **27**: 371–560.

PATTERSON, T. B. AND T. J. GIVNISH. 2004. Geographic cohesion, chromosomal evolution, parallel adaptive radiations, and consequent floral adaptations in *Calochortus* (Calochortaceae): evidence from a cpDNA phylogeny. *New Phytol.* **161**: 253–264.

PRITCHETT, D. W. AND S. J. MANNING. 2009. Effects of fire and groundwater extraction on alkali meadow habitat in Owens Valley, California. *Madroño* **56**: 89–98.

PURSH, F. 1814. *Calochortus*, p. 240. *In* Flora Americae Septentrionalis, or a systematic arrangement and description of the plants of North America, vol. I. Taylor, London, UK.

SAWYER, J. O. AND T. KEELER-WOLF. 2009. A manual of California vegetation online. *http://vegetation.cnps.org/* (6 Aug 2020).

TEAM ENGINEERING AND MANAGEMENT, INC. 2010. Owens Valley solar array expansion project draft assessment Inyo County, California. Prepared on the behalf of National Science Foundation. *https://www.nsf.gov/od/oia/programs/mri/OVSA_finalDRAFT_EA.pdf* (5 Aug 2020).

TROPICOS. 2020. Tropicos.org, Missouri Botanical Garden. *http://www.tropicos.org* (5 Aug 2020).

WOOD, R. C. 1973. The Owens Valley and the Los Angeles Water controversy; Owens valley as I knew it. University of the Pacific, Stockton, CA.

YOUNG, J. A. AND C. D. CLEMENTS. 2009. Cheatgrass: fire and forage on the range. University of Nevada Press, Reno.