Calochortus flexuosus S. Watson (winding mariposa lily): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Calochortus flexuosus (winding mariposa lily). Photograph by Peggy Lyon, used with permission.

Summary of Key Components for Conservation of *Calochortus flexuosus*

Calochortus flexuosus S. Watson (winding mariposa lily), an attractive member of the Lily family, has unique contorted stems and a yellow band at the base of its white to pink petals. It grows in dry habitats in the southwestern United States and apparently reaches its eastern limit in southwestern Colorado. Within the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS), it is found only in Colorado, where it has been documented from 15 locations. The total population is estimated to be between 6,000 and 9,000 plants. More populations are likely to be found with additional inventory effort, and botanists agree that inventory is warranted before conservation actions are proposed. *Calochortus flexuosus* is ranked globally secure (G4) by NatureServe and imperiled in Colorado (S2) by the Colorado Natural Heritage Program. This species has not been ranked by the State Heritage Programs in California, Nevada, Utah, Arizona, or New Mexico. In Colorado, this species has been documented on Bureau of Land Management (BLM), Ute Mountain Ute Indian Reservation, state, and private lands. Although *C. flexuosus* is not known from National Forest System lands within Region 2, it is on the USFS Region 2 Sensitive Species List. It is not included on the Colorado BLM Sensitive Species List, nor is it listed or a candidate for listing under the Federal Endangered Species Act.

There are several tangible threats to the persistence of *Calochortus flexuosus* in Colorado. In order of decreasing priority, these include exotic species invasion, oil and gas development, motorized recreation, effects of small population size, collection for horticultural trade, grazing, global climate change, and pollution. A large portion of the range of *C. flexuosus* in Colorado is vulnerable to oil and gas development; however, the scale and timeframe of extraction activities that might affect occurrences of *C. flexuosus* are unknown. Motorized recreation is increasing in areas where this species grows, and it is extremely difficult to enforce regulations or close areas to protect populations. There are currently five occurrences that are protected to some degree in the Canyons of the Ancients National Monument (BLM), the McKenna Peak Wilderness Study Area (BLM), and the Dry Creek Basin State Wildlife Area (State of Colorado).

TABLE OF CONTENTS

ACKNOWLEDGMENTS 2
AUTHORS' BIOGRAPHIES 2
COVER PHOTO CREDIT 2
SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *CALOCHORTUS FLEXUOSUS* 3
LIST OF TABLES AND FIGURES 6
INTRODUCTION 7
- Goal of Assessment 7
- Scope of Assessment 7
- Treatment of Uncertainty in Assessment 7
- Treatment of This Document as a Web Publication 8
- Peer Review of This Document 8

MANAGEMENT STATUS AND NATURAL HISTORY 8
- Management Status 8
- Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies 8
- Biology and Ecology 9
  - Classification and description 9
    - History of knowledge 9
    - Non-technical description 10
    - Published descriptions and other sources 10
  - Distribution and abundance 10
  - Population trend 17
  - Habitat 17
  - Reproductive biology and autecology 21
    - Reproduction 22
    - Pollinators and pollination ecology 22
    - Phenology 22
    - Fertility and propagule viability 23
    - Dispersal mechanisms 23
    - Phenotypic plasticity 23
    - Mycorrhizal relationships 23
    - Hybridization 23
  - Demography 23
  - Community ecology 25
    - Herbivores 25
    - Competitors and symbioses 25

CONSERVATION 25
- Threats 25
  - Exotic species invasions 27
  - Oil and gas development 27
  - Motorized recreation 28
  - Small population size 29
  - Collection for horticultural trade and other uses 29
  - Grazing 30
  - Global climate change 30
  - Pollution 30
- Conservation Status of *Calochortus flexuosus* in Region 2 31
  - Is distribution or abundance declining in all or part of its range in Region 2? 31
  - Do habitats vary in their capacity to support this species? 31
  - Vulnerability due to life history and ecology 31
  - Evidence of populations in Region 2 at risk 31
- Management of *Calochortus flexuosus* in Region 2 31
  - Implications and potential conservation elements 31

Tools and practices 32
Species inventory 32
Habitat inventory 32
Population monitoring 33
Habitat monitoring 34
Beneficial management actions 34
Seed banking 34
Information Needs 35
Distribution 35
Life cycle, habitat, and population trend 35
Response to change 35
Metapopulation dynamics 35
Demography 36
Population trend monitoring methods 36
Restoration methods 36
Research priorities for Region 2 36
DEFINITIONS 38
REFERENCES 40

EDITORS: Janet Coles, Beth Burkhart, and Kathy Roche, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Table 1. Summary data for the 15 known occurrences of *Calochortus flexuosus* in Colorado. 14

Table 2. List of species that have been documented one or more times occurring with *Calochortus flexuosus* in Colorado. 18

Figures:

Figure 1. Close up of *Calochortus flexuosus*. 11

Figure 2. Habitat of *Calochortus flexuosus*..... 11

Figure 3. Distribution of *Calochortus flexuosus* within USDA Forest Service Region 2..... 12

Figure 4. Distribution of *Calochortus flexuosus* in southwestern Colorado. 13

Figure 5. Hypothetical life cycle diagram for *Calochortus flexuosus*, including the known life history stages gleaned from limited observations and from information on other members of *Calochortus*..... 24

Figure 6. Envirogram outlining the malentities of *Calochortus flexuosus*. 26

Figure 7. Envirogram outlining the resources of *Calochortus flexuosus*. 26

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Calochortus flexuosus* is the focus of an assessment because it is a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce a species distribution (FSM 2670.5(19)). A sensitive species requires special management, so understanding of its biology and ecology is critical.

This assessment addresses the biology of *Calochortus flexuosus* throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, it provides the ecological backgrounds upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, the assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Calochortus flexuosus* with specific reference to the geographic and ecological characteristics of the lands encompassed by Region 2. Although some of the literature on the species originates from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *C. flexuosus* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. All known publications, reports, and element occurrence records on *Calochortus flexuosus* are referenced in this assessment, and all of the experts on this species were consulted during its synthesis. All known specimens of *C. flexuosus* that were collected within Region 2 were reviewed to verify populations and to incorporate specimen label data. Specimens were searched for at COLO (University of Colorado Herbarium), CS (CSU Herbarium), RM (Rocky Mountain Herbarium), SJMC (San Juan College Herbarium), and GREE (University of Northern Colorado Herbarium). The assessment emphasizes refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment, however, when information was unavailable elsewhere; non-refereed publications or reports were regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species. These data required special attention, however, because of the diversity of persons and methods used in their collection. Because basic research has not been conducted on many facets of the biology of *C. flexuosus*, literature on its congeners was used to make inferences.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed

in physics. The geologist, T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding.

Treatment of This Document as a Web Publication

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication will facilitate their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project have been peer reviewed before their release on the Web. Peer review is intended to improve the quality of writing and to increase the rigor of the assessment. Review for this species assessment was administered by the Center for Plant Conservation. Two anonymous peer reviewers provided comments that were synthesized by USFS project partners.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Calochortus flexuosus was added to the Region 2 list of sensitive species (November 2003) based on erroneous location information. This species is currently not known to occur on National Forest System lands in Region 2. It does occur on lands managed by the BLM's San Juan Field Office, but it is not included on the BLM Colorado State Sensitive Species List. It is also found on the Ute Mountain Indian Reservation, State of Colorado lands (Dry Creek Basin State Wildlife Area and state school trust sections), and private lands. It is not listed under the federal Endangered Species Act, nor do any Colorado state laws recognize it. NatureServe (2004) considers *C. flexuosus* to be "globally secure" (G4). The Colorado Natural Heritage Program (2004) considers the species to be "imperiled in the state" (S2) because it is known from only 15 occurrences in Colorado, and only two of these are large (1,000 or more individuals estimated). For explanations of NatureServe's heritage ranking system, see the **Definitions** section of this document.

Calochortus flexuosus occurs in three areas that offer it some protection: Canyons of the Ancients National Monument (BLM), McKenna Peak Wilderness Study Area (BLM), and Dry Creek Basin State Wildlife Area. Canyons of the Ancients National Monument prohibits off-road vehicle use but allows oil and gas development and grazing (Clinton 2000). The McKenna Peak Wilderness Study Area (WSA) is managed to preserve wilderness values, but Congress has not yet designated it as wilderness (Bureau of Land Management 2003). As in designated wilderness, there are no roads or motorized vehicles allowed in the McKenna Peak WSA (San Juan Mountains Association 2004); however, there is grazing as well as wild horse herd management. The Dry Creek Basin State Wildlife Area is managed for big game hunting and winter range for deer and elk; off-road vehicle use is prohibited in this area (Colorado Division of Wildlife 2004a).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There have been no known cases in which an occurrence of *Calochortus flexuosus* was extirpated due the failure to enforce any existing regulations. However, this does not mean that existing regulations are adequate to ensure the species' survival. No management plans have been prepared that specifically address the conservation needs of *C. flexuosus*. The Colorado Natural Heritage Program (CNHP) has identified several Potential Conservation Areas (PCAs) containing *C. flexuosus*: Navajo Wash, Mesa Verde, Sand Canyon, Cannonball Mesa, Four Corners, Egnar, and Big Gypsum Valley (Colorado Natural Heritage Program 2004). A PCA is an estimate of the primary area supporting the long-term survival of targeted species and plant communities, based on an assessment

of the biotic and abiotic factors affecting the persistence and viability of targets within the area. None of these PCAs includes National Forest System lands. The CNHP has supplied information regarding these PCAs to the BLM (Lyon and Sovell 2000, Anderson et al. 2001) and San Miguel County (Lyon and Sovell 2000) to increase awareness of this species and its habitat during planning and management.

Calochortus flexuosus has no legal protection that would prevent the destruction of habitat or individuals. At this time, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency. There are no laws in place that protect this species on private lands. While there are no clearly documented occurrences on private land in Region 2, it is likely that the species does occur on private lands within its known range. Current laws and regulations protecting this species are clearly inadequate to conserve the species within its native habitat in Region 2. Given current trends and land use within the range of this species, extirpation is a possibility, but not likely given the remote nature of some of the occurrences and potential habitat. Changes in land use planning are needed to ensure the long-term viability of populations, especially on BLM and Ute Mountain Indian Reservation lands. Establishing management plans that account for this species' needs and monitoring population trends and habitat destruction might also confer protection needed to ensure the long-term persistence of *C. flexuosus* in Region 2.

Biology and Ecology

Classification and description

Calochortus flexuosus S. Watson (winding mariposa lily) is a member of the Liliaceae (Lily family), a relatively small family with approximately 485 species in 22 genera worldwide (Zomlefer 1994). The Liliaceae is in class Liliopsida (monocotyledons), subclass Lilidae, and order Lilales (USDA Natural Resources Conservation Service 2004). The Liliaceae is found primarily in temperate regions of the northern hemisphere, and it is most diverse in Asia (Heywood 1993, Zomlefer 1994). *Calochortus* is among the largest genera in this family. The genus was described by Pursh in 1814 (Ownbey 1940).

Dahlgren et al. (1985) and Weber and Wittmann (2001) place *Calochortus* in the Calochortaceae (Mariposa family), a monotypic family that includes only one genus, *Calochortus*. More research on the Liliaceae is needed to determine the most appropriate classification (Zomlefer 1994).

History of knowledge

S. Watson first described *Calochortus flexuosus* in 1873 using material collected by Mrs. E.P. Thompson in 1872 near Kanab, Kane County, Utah. The species was discovered in Arizona in the San Francisco Mountains in 1884, in Nevada in the Grapevine Mountains in 1891, in Colorado at McElmo Creek in 1892, in California in Death Valley in 1907 (Ownbey 1940), and in New Mexico sometime after 1940. In 1940, Ownbey included *C. flexuosus* in his monograph of *Calochortus* (Ownbey 1940). The species is also described by Harrington (1954) in the *Manual of the Plants of Colorado*, by Munz and Keck (1963) in *A California Flora*, by Cronquist and others (1977) in *Volume Six of the Intermountain Flora, the Monocotyledons*, by Welsh and others (1987 and 1993) in *A Utah Flora*, and by Fiedler and Zebell (2002) in the *Flora of North America*. Although there is some question as to the family placement of this genus, there does not appear to be any question regarding the validity of this taxon.

The first discovery of *Calochortus flexuosus* in Colorado was in 1892 by Alice Eastwood who collected this species at McElmo Creek in Montezuma County. It was then documented in 1914 by Edwin Payson in the vicinity of Naturita in Montrose County. At the time of Ownbey's 1940 monograph of *Calochortus*, it was only known from these two imprecisely described locations in Colorado. In 1952, Dr. William Weber collected *C. flexuosus* at another location in Montezuma County near the Four Corners. In 1970, Bertha Anderson collected this species at another imprecisely described locale between Cortez and the Four Corners. In 1980, Harmon and Schleuter collected *C. flexuosus* for the first time in San Miguel County, in the vicinity of Egnar, Colorado.

In the late 1980s, Colorado Natural Areas/ Natural Heritage Program researchers reviewing element occurrence records for *Calochortus flexuosus* misinterpreted a location reported by Bill Jennings in a personal communication to Susan M. Galatowitsch. The notes for the personal communication do not provide the year, but the information was entered into the Colorado Natural Heritage data system in 1989. The location was described as "on highway right of way on Highway 160 down hill to San Juan River – North side of River, So. facing slope," and it was mapped in a location that met this description in Archuleta County. However, Mr. Jennings was in another location that

also met this description, in the Four Corners area of Montezuma County (Jennings personal communication 2004). Unfortunately, because of this misunderstanding, the USFS was lead to believe that *C. flexuosus* was on National Forest System lands since the erroneous location was on the Pagosa Ranger District of the San Juan National Forest.

During the 1980s, 1990s, and early 2000s, botanists who were aware of the significance of *Calochortus flexuosus* conducted surveys in southwestern Colorado (Moore 1998, Lyon and Sovell 2000, Anderson et al. 2001, Colyer personal communication 2004, Jennings personal communication 2004, Stewart personal communication 2004). During this time, 10 new locations were documented in Colorado, including a new county record for Dolores County, bringing the total of known occurrences to 15. To date, *C. flexuosus* has been documented only in Montezuma, Dolores, San Miguel, and Montrose counties in Colorado. It has not been seen in Montrose County since 1914, despite efforts to find the species in this area (Lyon and Sovell 2000).

Non-technical description

Calochortus flexuosus is a perennial plant that is reported to be "rarely bulbose" (Ownbey 1940, Fiedler and Zebell 2002). However, bulbs appear to be present on several specimens at the University of Colorado Herbarium. When present, the bulbs are ovoid with membranaceous coats. The stems are most often decumbent and twining, the leaves are linear, the inflorescence is one to four-flowered white to pink, and each petal has a transverse yellow band at the gland and usually a purple spot on the claw. Sepals are similarly marked but shorter than the petals. Sepals are glabrous while petals have sparse, short, thick hairs around the gland. Glands are not depressed and are densely covered with short processes. The fruit is lanceolate, acute, 3-angled, and erect (Ownbey 1940).

Calochortus flexuosus could be confused with *C. nuttallii* in Colorado. However, *C. flexuosus* can be distinguished by its twining habit and its characteristic lanceolate acute capsules (Ownbey 1940) as well as the petal gland being not or only slightly depressed and not surrounded by a membrane (Weber and Wittmann 2001). Also, while both species are in the section *Mariposa* of the genus *Calochortus*, *C. nuttallii* is in subsection *Nuttallliani* and *C. flexuosus* is in subsection *Venusti* (Beal and Ownbey 1943). The two species are not very closely related. The closest relative to *C. flexuosus* is probably *C. catalinae* (Ownbey 1940, Beal and Ownbey 1943), which does not occur in Colorado.

Published descriptions and other sources

A photograph of *Calochortus flexuosus* appears in *The Bulbs of North America* (Callahan 2001) and in a brochure called "What you should know about the rare plants of San Miguel County" (Colorado Natural Heritage Program 2000). Photographs are also available on the World Wide Web (International Bulb Society 2003, Schweich 2004) and in **Figure 1** and **Figure 2** of this assessment.

Illustrations of *Calochortus flexuosus* are available in the *Intermountain Flora, Volume 6* (Cronquist et al. 1977) as well as the *Flora of North America, Volume 26* (Fiedler and Zebell 2002). The original description appears in the American Naturalist Journal (Watson 1873), and additional descriptions are available in floras (Harrington 1954, Cronquist et al. 1977, Fiedler and Zebell 2002). Weber and Wittmann (2001) is the most readily available and up-to-date source with keys for field identification within Colorado, but it does not include a full description.

Distribution and abundance

The genus *Calochortus* contains a relatively large number of rare, localized, and endemic taxa (Fiedler et al. 1998). However, compared to other species of *Calochortus*, *C. flexuosus* is relatively common (Fiedler and Zebell 2002). *Calochortus flexuosus* is known from the southwestern United States in California, Nevada, Utah, New Mexico, and Arizona. It is a peripheral species within Region 2, known only from an approximately 30 by 85 mile (48 by 137 km) range in Montezuma, Dolores, San Miguel, and Montrose counties, Colorado (**Figure 3**). Its distribution within the boundary of Region 2 is limited to BLM, Ute Mountain Indian Reservation, state, and private lands in southwestern Colorado (**Figure 4**). All the known occurrences of *C. flexuosus* in Colorado are within 75 miles (120 km) of each other and collectively occupy less than 35,000 acres (14,175 hectares) (Colorado Natural Heritage Program 2004). A considerable amount of apparently suitable habitat appears to be unoccupied; additional occurrences are likely to be discovered. The area that has the greatest likelihood of supporting *C. flexuosus* on National Forest System lands in Region 2 is the lowest elevations of the Ryman Creek drainage in Dolores County (**Figure 4**). This area is near known occurrences, and habitat for *C. flexuosus* appeared to be present (Stewart personal

Figure 1. Close up of *Calochortus flexuosus*. Gary A. Monroe@USDA-NRCS PLANTS Database.

Figure 2. Habitat of *Calochortus flexuosus*. Peggy Lyon, Colorado Natural Heritage Program.

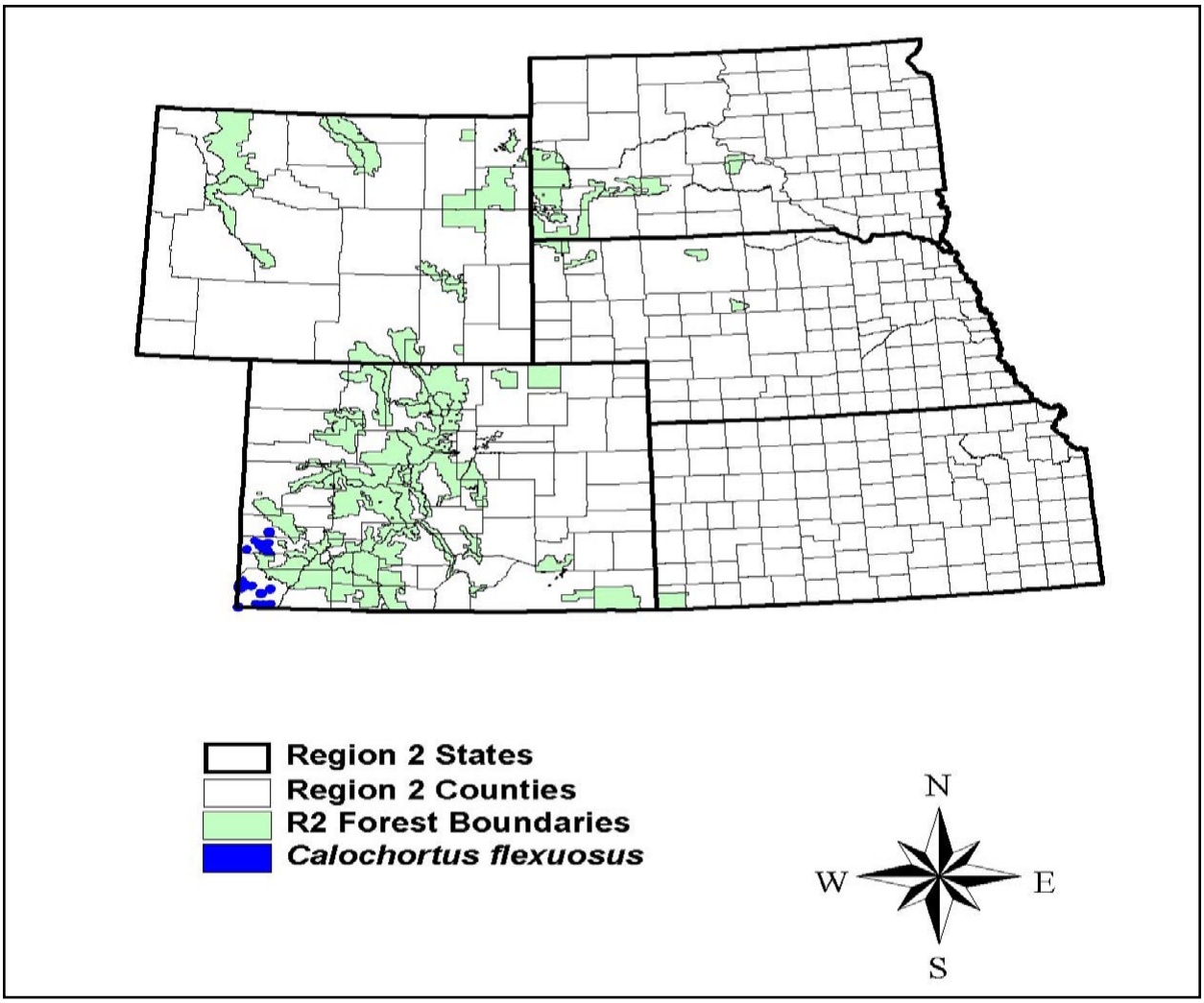

Figure 3. Distribution of *Calochortus flexuosus* within USDA Forest Service Region 2. *Calochortus flexuosus* has not been documented on National Forest System lands in Region 2. **Figure 4** shows the distribution of *C. flexuosus* in southwestern Colorado in greater detail.

communication 2004). However, USFS botanist Leslie Stewart checked the Ryman Creek area in 2005, found only *C. gunnisonii*, and determined that the habitat was probably not suitable for *C. flexuosus* (Kratz personal communication 2005).

Calochortus flexuosus is more common in the rest of its range in the southwestern United States in California, Nevada, Utah, New Mexico, and Arizona. It is reportedly easy to find on the Colorado Plateau outside of Colorado in Arizona, Utah, and New Mexico (Jennings personal communication 2004). Callahan (2001) reports *C. flexuosus* as occurring in a disjunct population in Colorado. However, this reference does not note that the species is found in southeastern Utah, northeastern Arizona, or New Mexico, areas in which the species has now been documented. Cronquist and others (1977) report that it is fairly common from the Mojave Desert of southeast California across Nevada and Utah to southwestern Colorado and Arizona between about 1,600 to 6,600 ft. (500 to 2,000 m) elevation. The *Flora of North America* presents a rangewide distribution map (Fiedler and Zebell 2002).

Table 1 displays summary data on the 15 known occurrences of *Calochortus flexuosus* in Colorado. Peggy Lyon and Leslie Stewart (personal communication 2004) observed large differences in total number of individuals during different years. *Calochortus flexuosus* exhibits the behavior of a typical desert geophyte; most years it is rare or not evident, but in a few years conditions are favorable and plants emerge and flower, sometimes abundantly.

Several recent botanical surveys located *Calochortus flexuosus* occurrences in Colorado (e.g.,

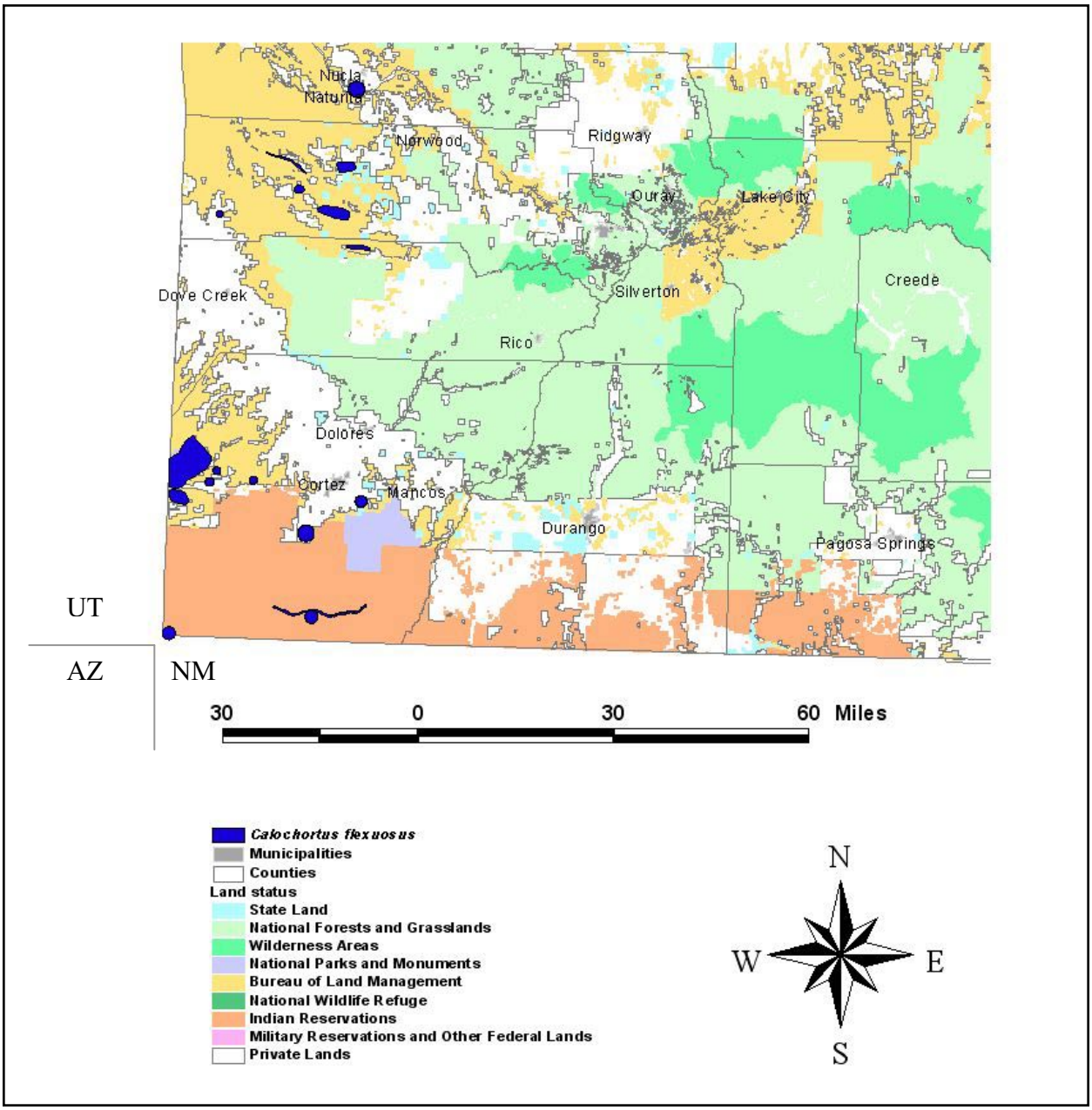

Figure 4. Distribution of *Calochortus flexuosus* in southwestern Colorado. In Region 2, this species is found only in Montezuma County (in the far southwestern corner of the state) and north through Dolores, San Miguel, and Montrose counties, Colorado. A range-wide distribution map, showing the distribution of this species in California, Nevada, Arizona, Utah, New Mexico, and Colorado appears in *Volume 26 of the Flora of North America* (Fiedler and Zebell 2002).

Moore 1998, Lyon and Sovell 2000, Anderson et al. 2001, Stewart personal communication 2004, Coles personal communication 2006), and there are large areas of potential habitat that remain to be searched. Prolonged plant dormancy, the fact that much of this potential habitat is in remote areas and limited access to private land have made it difficult to search areas within the known distribution of *C. flexuosus*, or to be certain that the plant is truly absent if it isn't found. While it is possible that it is limited to the range as we know it, inventories are necessary to verify this.

There has been no rigorous quantification of the total *Calochortus flexuosus* population in Colorado. It is known from 15 occurrences, but most plants were recorded in just two occurrences:

Table 1. Summary data for the 15 known occurrences of *Calochortus flexuosus* in Colorado. Location names are provided as a reference rather than to identify a specific place on the ground. Site description and habitat information are taken directly from herbarium labels, field notes, and personal communications.

Location name	County	Date first observed	Date last observed	Observers	Occurrence extent and abundance	Current land ownership/ management	Site description, habitat information
McElmo Creek	Montezuma	Jun-1892	Jun-1892	Alice Eastwood	None reported	Private	[Eastwood 1892]: No information provided
Naturita	Montrose	26-May-1914	26-May-1914	E. Payson	None reported	Bureau of Land Management (BLM) and/or private	[Payson 1914]: Soil: red clay
Northwest of Mesa Verde	Montezuma	May-1992	Jun-1992	Marilyn Colyer	Estimated 500 individuals; area covered by population = 600 acres; scattered colonies.	BLM	[Colyer et al. 1992]: Associated plant community: mat *Atriplex* grassland. Habitat type: desert saltbrush and grassland/plains under mesa escarpment. Parent material: Mancos shale colluvium and Point Lookout influence. Associated with *Oryzopsis hymenoides*, *Atriplex corrugata*, *Chenopodium rosea*, *Phacelia splendens*, *Sphaeralcea coccinea*, and *Sporobolus airoides*.
Mancos Canyon	Montezuma	02-May-1987	17-May-1991	Betsy Neely; William Weber; Marilyn Colyer	[Colyer et al. 1991]: 3000 individuals estimated, after very wet May. Scattered populations. Size of area covered by population = 1500 acres. [Weber 1991]: abundant.	Ute Mountain Indian Reservation	[Neely 1987]: On sandy soils of Point Lookout Sandstone; with *Pinus Juniperus*, *Chrysothamnus*, *Petradoria*, *Ephedra*, and *Astragalus*. [Colyer et al. 1991]: Associated plant community: mat *Atriplex* grassland. Habitat type: desert saltbrush and grassland/plains under mesa escarpment. Parent material: Mancos shale colluvium and Point Lookout influence. Associated species: *Oryzopsis hymenoides*, *Atriplex corrugata*, *Chenopodium rosea*, *Phacelia spendens*, *Sphaeralcea coccinea*, and *Sporobolus airoides*. [Weber 1991]: In Mancos Shale.
Four Corners	Montezuma	07-Jun-1952	25-Apr-1987	J. Erdman and J. Watson; William Weber; Bill Jennings	None reported	Ute Mountain Indian Reservation, highway right of way	[Weber 1952]: Low hills, desert. [Erdman and Watson 1964]: Dry ridge top. [Jennings 1987]: South facing slope.
Four Corners to Cortez	Montezuma	22-May-1970	22-May-1970	Bertha Anderson	None reported	Ute Mountain Indian Reservation or private	[Anderson 1970]: Sandy bank.
Egnar	San Miguel	19-Jun-1980	19-Jun-1980	W.E. Harmon and L. Schleuter	None reported	Private	[Harmon and Schleuter 1980]: *Pinyon/juniper*, scrub oak, mountain mahogany, bitterbrush and lupines growing on clayey soil.

Table 1 (cont.).

Location name	County	Date first observed	Date last observed	Observers	Occurrence extent and abundance	Current land ownership/ management	Site description, habitat information
Big Gypsum Valley	San Miguel	26-May-1999	May-2003	Peggy Lyon; Leslie Stewart	[Lyon 1999]: Abundant. More than 500 plants counted. [Stewart 2003, regarding a subpopulation]: 100-200 plants.	BLM	[Lyon 1999]: Grassy hillside with *Sphaeralcea coccinea*, *Delphinium scaposum*, *Hilaria jamesii*, *Oryzopsis hymenoides*, and *Krascheninnikovia lanata* on gentle west facing hillside.
Sand Canyon	Montezuma	29-Apr-2000	29-Apr-2000	David Anderson and Susan Spackman	Number of individuals: 4.	BLM; Canyons of the Ancients National Monument	[Spackman et al. 2000]: Open *pinyon/juniper* woodland with sandstone outcrops. Soils are sandy with high cover of cryptobiotic crusts. Associated with *Penstemon breviculus*, *Juniperus osteosperma*, and *Yucca harrimaniae*. Soil: sandy.
Hovenweep Canyon	Montezuma	26-Apr-1994	09-Jun-2004	David Anderson and Susan Spackman; Lynn Moore; Ron Hartman; Leslie Stewart; Peggy Lyon	[Anderson and Spackman 2000]: Estimate hundreds (200-400). [Anderson and Spackman 2000 regarding a separate subpopulation]: estimate 600. [Stewart 2001 regarding another subpopulation]: estimate 1,000-2,000. [Lyon 2004]: Plants appear to be common, but are past flowering so difficult to count.	BLM; Canyons of the Ancients National Monument; private	[Moore 1994 regarding a subpopulation]: desert shrubland with scattered shrubs, sagebrush, greasewood, *Amelanchier*, *Ribes*, and rabbitbrush with occasional juniper on rocky slopes above and around creek. [Hartman 1995]: Pinyon-juniper and grassland, sandstone caprock with shale below. [Moore 1995 regarding a subpopulation]: *Pinyon-juniper*, *Purshia*, rabbitbrush, and *Atriplex*. Strong selenium odor. [Spackman et al. 2000]: Grassland dominated by *Hilaria jamesii* and *Sporobolus airoides* on south facing slope of mesa. Grassland is adjacent to open *Juniperus osteosperma* woodland. Associated with *Gutierrezia sarothrae*, *Yucca harrimaniae*, *Phlox longifolia*, *Oenothera*, *Allium*, and *Eriogonum ovalifolium*. [Spackman et al. 2000 regarding a subpopulation]: Reddish sandstone outcrops. Some rocks appear to be conglomerate. *Hilaria jamesii* grassland with scattered *Juniperus osteosperma*, *Gutierrezia sarothrae* and *Atriplex canescens*. Associated with *Sporobolus cryptandrus*, *Hilaria jamesii*, and *Phlox*. [Stewart 2001]: Associated with *Atriplex* and *Hilaria jamesii*. [Lyon 2004]: Roadside in desert shrub community with *Atriplex confertifolia*, *Sarcobatus vermiculatus*, and *Gutierrezia sarothrae*. Very heavily grazed and trampled.
Flodine Park	Montezuma	May-2001	May-2001	Leslie Stewart	Estimate 100-500	BLM; Canyons of the Ancients National Monument	[Stewart 2001]: Vegetation is dominantly shadscale and galleta with some Indian ricegrass, alkali sacaton, six weeks fescue, sand dropseed, bottlebrush squirreltail, fourwing saltbush, scarlet globemallow. Cheatgrass and filaree dominate.

Table 1 (concluded).

Location name	County	Date first observed	Date last observed	Observers	Occurrence extent and abundance	Current land ownership/ management	Site description, habitat information
Disappointment Valley	Dolores	May-2002	May-2002	Leslie Stewart	Estimate 10-100	BLM; McKenna Peak Wilderness Study Area	[Stewart 2002]: Vegetation is dominantly shadscale and galleta with some Indian ricegrass, alkali sacaton, six weeks fescue, sand dropseed, bottlebrush squirreltail, fourwing saltbush, scarlet globemallow. Cheatgrass and filaree are common.
Spring Creek	San Miguel	May-2003	May-2003	Leslie Stewart	Estimate 100-200	BLM; state; private	[Stewart 2003]: Vegetation is dominantly shadscale and galleta with some Indian ricegrass, alkali sacaton, six weeks fescue, sand dropseed, bottlebrush squirreltail, fourwing saltbush, scarlet globemallow. Cheatgrass and filaree are common.
Dry Creek	San Miguel	May-2002	May-2002	Leslie Stewart	Estimate 10-50	BLM; state: Dry Creek Basin State Wildlife Area	[Stewart 2002]: Wyoming big sagebrush, basin big sagebrush and four wing saltbush community with little understory but includes galleta, Indian ricegrass, alkali sacaton, six weeks fescue, sand dropseed, bottlebrush squirreltail, scarlet globemallow.
Gypsum Gap	San Miguel	May-2002	May-2002	Leslie Stewart	Estimate 10-50	BLM	[Stewart 2002]: Vegetation is dominantly shadscale and galleta with some Indian ricegrass, alkali sacaton, six weeks fescue, sand dropseed, bottlebrush squirreltail, fourwing saltbush, scarlet globemallow. Cheatgrass and filaree are common.
Total:					**6,134-8,104; estimate 6,000-9,000 plants**		

Mancos Canyon and Hovenweep Canyon (**Table 1**). However, these occurrences were never rigorously counted. Four of the 15 occurrences have not been visited in more than 15 years, and their reports do not contain abundance estimates.

Similarly, there has been no rigorous quantification of the total area occupied by *Calochortus flexuosus* in Colorado. While some botanists have reported visual estimates of the total acreage of certain occurrences, others have drawn large polygons on maps that represent much larger areas, certainly including some areas of unoccupied habitat (Colorado Natural Heritage Program 2004). For the purposes of this research, we conclude that the known occupied habitat in Colorado is certainly less than 35,000 acres (14,175 ha). A further complication is that *C. flexuosus*' tendency to prolonged dormancy makes it difficult to be certain that apparently unoccupied habitat is truly unsuitable.

Population trend

There are no quantitative data that could be used to infer the population trend of *Calochortus flexuosus* in Colorado. Occurrence size estimates in **Table 1** are rough, and there has been no population monitoring that could provide insight into population trend. The fact that in most years *C. flexuosus* is in a dormant form complicates estimates of abundance and occurrence extent. Impacts to *C. flexuosus* individuals and habitat resulting from recreational use, grazing, oil and gas development, and associated roads strongly suggest a downward trend. Loss of habitat, anthropogenic disturbance of habitat, and plant harvesting have probably caused at least a slight downward trend since the area was settled.

Populations fluctuate naturally due to annual climatic variation. As *Calochortus flexuosus* is probably a stress-tolerant species, it is likely that while drought probably reduces or eliminates recruitment of seedlings, juvenile plants may be capable of surviving one or more bad years. In favorable years, large numbers of plants have been observed to flower (Lyon personal communication 2004). This makes it difficult to assess the population size accurately in any given year.

Habitat

Rangewide, *Calochortus flexuosus* is found on dry stony slopes and desert hills between 3,000 and 8,330 ft. (500 to 2500 m) elevation (Callahan 2001, Fiedler and Zebell 2002). Callahan (2001) reports that this species may have an affinity for alkaline soils. The habitat is described by Cronquist and others (1977) as "dry stony slopes, rocky mesas and flats." Tidestrom and Kittell (1941) report that the species is known from "slopes and canyons of the grass and pinyon belts." Shreve and Wiggins (1964) report the habitat as "desert mesas and hillsides."

As in other portions of its range, *Calochortus flexuosus* tends to grow in dry, rocky, desert areas in Colorado. Weber and Wittmann (2001) describe its habitat in Colorado as "desert flats." Further details regarding the habitat of this species in Colorado has been documented largely through the work of Lyon (personal communication 2004), Stewart (personal communication 2004), Anderson and others (2001), Moore (1998), Colyer (personal communication 2004), and others. Populations found along roads were thought to be moving into the habitat created by the roads (Lyon personal communication 2004). Colyer (personal communication 2004) notes that *C. flexuosus* is found along the base of escarpments and at the base of slopes in alluvium. Habitat information for each occurrence is presented in **Table 1**. A complete list of associated species is presented in **Table 2**.

In Colorado, *Calochortus flexuosus* is found on fine-textured soils (clay to sand) derived most commonly from the Mancos (Cretaceous) and Morrison (Jurassic) formations (Tweto 1979, Colyer personal communication 2004). *Calochortus flexuosus* was also noted to occur on Point Lookout Sandstone (Cretaceous) in Mancos Canyon (Colorado Natural Heritage Program 2004). These substrates are exposed in many locations in Colorado where *C. flexuosus* has not been documented (Tweto 1979, Chronic 1980, Foutz 1994). The species appears to prefer clay loam soils but is also found on silty and sandy clay loams (Stewart personal communication 2004). *Calochortus flexuosus* is often found on the Claysprings Uzacol Zwicker complex of soils that are common in the lowlands of southwest Colorado and are derived from shale (Stewart personal communication 2004). Colyer (personal communication 2004) notes that the best populations are found growing in pure clay. Moore noted (personal communication 2004) that the soils have a strong selenium odor. Our understanding of the distribution of *C. flexuosus* in Region 2 would probably benefit from research investigating distribution patterns of this species in relation to edaphic characteristics.

Plant communities associated with *Calochortus flexuosus* in Colorado have been described as grasslands, desert shrublands, and open pinyon juniper woodlands. More specifically, *C. flexuosus* has been

Table 2. List of species that have been documented one or more times occurring with *Calochortus flexuosus* in Colorado. Most taxa were documented by Lynn Moore (Moore 1998) with voucher specimens at the Rocky Mountain Herbarium at the University of Wyoming in Laramie. Taxa documented by other researchers that were not collected by Moore are noted with an asterisk. Non-native species are listed in bold, rare natives are underlined.

Family	Genus	Species	Variety
Agavaceae	*Yucca*	*harrimaniae*	
Anacardiaceae	*Rhus*	*trilobata*	var. *trilobata*
Apiaceae	*Cymopterus*	*bulbosus*	
Apiaceae	*Cymopterus*	*fendleri*	
Asteraceae	*Artemisia*	*spinescens*	
Asteraceae	*Brickellia*	*oblongifolia*	var. *linifolia*
Asteraceae	*Chaenactis*	*stevioides*	var. *stevioides*
Asteraceae	*Chaetopappa*	*ericoides*	
Asteraceae	*Chrysothamnus**	sp.	
Asteraceae	*Cirsium*	*neomexicanum*	
Asteraceae	*Erigeron*	*pumilus*	var. *concinnus*
Asteraceae	*Gutierrezia*	*sarothrae**	
Asteraceae	*Haplopappus*	*armerioides*	
Asteraceae	*Haplopappus*	*spinulosus*	var. *paradoxus*
Asteraceae	*Haplopappus*	*spinulosus*	var. *spinulosus*
Asteraceae	*Hymenopappus*	*filifolius*	var. *cinereus*
Asteraceae	*Hymenoxys*	*ivesiana*	
Asteraceae	*Malacothrix*	*sonchoides*	
Asteraceae	*Petradoria*	*pumila**	
Asteraceae	*Platyschkuhria*	*integrifolia*	var. *oblongifolia*
Asteraceae	*Senecio*	*flaccidus*	var. *flaccidus*
Asteraceae	*Senecio*	*multilobatus*	
Asteraceae	*Tetradymia*	*spinosa*	
Asteraceae	*Thelesperma*	*marginatum*	
Asteraceae	*Townsendia*	*incana*	
<u>Asteraceae</u>	<u>*Townsendia*</u>	<u>*strigosa*</u>*	
Boraginaceae	*Cryptantha*	*crassisepala*	var. *elachantha*
Boraginaceae	*Cryptantha*	*flava*	
Boraginaceae	*Cryptantha*	*fulvocanescens*	
Boraginaceae	*Cryptantha*	*gracilis*	
Boraginaceae	*Cryptantha*	*pterocarya*	var. *pterocarya*
Boraginaceae	*Cryptantha*	*recurvata*	
Boraginaceae	*Lappula*	*marginata**	
Boraginaceae	*Lappula*	*redowskii*	
Boraginaceae	*Lappula*	*texana*	
Boraginaceae	***Alyssum***	***parviflorum***	**var. *micranthum***
Boraginaceae	*Arabis*	*pulchra*	var. *pallens*
Boraginaceae	*Arabis*	*selbyi*	
Boraginaceae	***Conringia***	***orientalis***	
Boraginaceae	*Descurainia*	*pinnata*	var. *osmiarum*

Table 2 (cont.).

Family	Genus	Species	Variety
Boraginaceae	*Draba*	*cuneifolia*	var. *cuneifolia*
Boraginaceae	*Draba*	*reptans*	
Boraginaceae	*Lepidium*	*densiflorum*	var. *densiflorum*
Boraginaceae	*Lepidium*	*densiflorum*	var. *pubecarpum*
Boraginaceae	*Lepidium*	*montanum*	var. *montanum*
Boraginaceae	*Lesquerella*	*rectipes*	
Boraginaceae	*Physaria*	*acutifolia*	var. *acutifolia*
Boraginaceae	***Sisymbrium***	***altissimum***	
Boraginaceae	*Streptanthella*	*longirostris*	var. *longirostris*
Boraginaceae	*Streptanthus*	*cordatus*	
Cactaceae	*Opuntia*	*polyacantha*	var. *rufispina*
Cactaceae	*Sclerocactus*	*whipplei*	var. *roseus*
Caryophyllaceae	*Arenaria*	*eastwoodiae*	var. *eastwoodiae*
Caryophyllaceae	*Silene*	*antirrhina*	
Caryophyllaceae	*Atriplex*	*canescens*	var. *canescens*
Caryophyllaceae	*Atriplex*	*confertifolia*	
Caryophyllaceae	*Atriplex*	*corrugata**	
Caryophyllaceae	*Atriplex*	*saccaria*	
Caryophyllaceae	*Chenopodium*	*rosea**	
Caryophyllaceae	*Grayia*	*spinosa*	
Caryophyllaceae	***Halogeton****	***glomerata****	
Caryophyllaceae	*Krascheninnikovia*	*lanata**	
Caryophyllaceae	*Monolepis*	*nuttalliana*	
Caryophyllaceae	*Sarcobatus*	*vermiculatus**	
Cupressaceae	*Juniperus*	*osteosperma*	
Ephedraceae	*Ephedra*	*viridis*	var. *viridis*
Euphorbiaceae	*Euphorbia*	*fendleri*	
Fabaceae	*Astragalus*	*calycosus*	var. *scaposus*
Fabaceae	*Astragalus*	*flavus*	
Fabaceae	*Astragalus*	*lentiginosus*	var. *diphysus*
Fabaceae	*Astragalus*	*missouriensis*	var. *missouriensis*
Fabaceae	*Astragalus*	*mollissimus*	var. *thompsoniae*
Fabaceae	*Astragalus*	*nuttallianus*	var. *micranthiformis*
Fabaceae	*Lupinus**	sp.	
Fabaceae	***Melilotus***	***officinalis***	
Fabaceae	*Quercus*	*gambelii**	
Geraniaceae	***Erodium***	***cicutarium***	
Grossulariaceae	*Ribes**	sp.	
Hydrangeaceae	*Fendlera*	*rupicola*	
Hydrangeaceae	*Phacelia*	*crenulata*	
Hydrangeaceae	*Phacelia*	*ivesiana*	
Hydrangeaceae	*Phacelia*	*splendens**	
Liliaceae	*Allium*	*geyeri*	var. *geyeri*

Table 2 (concluded).

Family	Genus	Species	Variety
Liliaceae	*Allium*	*macropetalum*	
Liliaceae	*Calochortus*	*nuttallii*	
Malvaceae	*Sphaeralcea*	*coccinea*	
Nyctaginaceae	*Mirabilis*	*linearis*	
Oleaceae	*Fraxinus*	*anomala*	
Onagraceae	*Oenothera*	*cespitosa*	var. *navajoensis*
Pinaceae	*Pinus*	*edulis*	
Plantaginaceae	*Plantago*	*patagonica*	var. *patagonica*
Poaceae	*Aristida*	*purpurea*	var. *fendleriana*
Poaceae	*Aristida*	*purpurea*	var. *longiseta*
Poaceae	***Bromus***	***tectorum***	
Poaceae	*Elymus*	*elymoides*	var. *brevifolius*
Poaceae	*Elymus*	*salinus*	
Poaceae	*Hilaria*	*jamesii*	
Poaceae	*Hordeum*	*pusillum*	
Poaceae	*Oryzopsis*	*hymenoides*	
Poaceae	*Poa*	*fendleriana*	
Poaceae	*Poa*	*secunda*	var. *incurva*
Poaceae	*Poa*	*secunda*	var. *secunda*
Poaceae	*Sporobolus*	*airoides*	var. *airoides*
Poaceae	*Sporobolus*	*cryptandrus**	
Poaceae	*Stipa*	*neomexicana*	
Poaceae	*Vulpia*	*octoflora*	
Polemoniaceae	*Gilia*	*ophthalmoides*	
Polemoniaceae	*Ipomopsis*	*gunnisonii*	
Polemoniaceae	*Ipomopsis*	*polycladon*	
Polemoniaceae	*Ipomopsis*	*pumila*	
Polemoniaceae	*Leptodactylon*	*pungens*	var. *pungens*
Polemoniaceae	*Phlox*	*longifolia*	var. *longifolia*
Polygonaceae	*Eriogonum*	*inflatum*	
Polygonaceae	*Eriogonum*	*ovalifolium*	var. *ochroleucum*
Polygonaceae	*Eriogonum*	*ovalifolium*	var. *purpureum*
Polygonaceae	*Stenogonum*	*salsuginosum*	
Ranunculaceae	*Delphinium*	*scaposum*	
Rosaceae	*Amelanchier*	*utahensis*	
Rosaceae	*Cercocarpus**	sp.	
Rosaceae	*Purshia*	*mexicana*	var. *stansburiana*
Salicaceae	*Populus*	*deltoides*	var. *wislizeni*
Scrophulariaceae	*Castilleja*	*angustifolia*	var. *dubia*
Scrophulariaceae	*Cordylanthus**	*wrightii**	
Scrophulariaceae	*Penstemon*	*breviculus**	
Scrophulariaceae	*Penstemon*	*utahensis*	
Solanaceae		*pallidum*	

documented in Colorado within plant communities dominated by *Achnatherum hymenoides* (Indian ricegrass), *Sporobolus* spp. (dropseed), *Pleuraphis jamesii* (James' galleta), *Atriplex* spp. (saltbush), *Juniperus osteosperma* (Utah juniper), *Pinus edulis* (twoneedle pinyon), *Quercus gambelii* (Gambel oak), and *Cercocarpus* sp. (mountain mahogany; Colorado Natural Heritage Program 2004). *Calochortus flexuosus* also grows in open sites accompanied by few other species of vascular plants.

Calochortus flexuosus is found across an approximately 2,500 ft. (762 m) elevation range in Colorado. The range of elevation documented in CNHP records (2004) is 4,700 ft. (1,400 m), in the Four Corners area, to 7,300 ft. (2,225 m), at the Egnar location. *Calochortus flexuosus* is found on flat to sloping terrain, and it has been documented frequently on west-facing slopes, with some occurrences on north and south aspects (Colorado Natural Heritage Program 2004). However, orientation is not reported at all locations (Colorado Natural Heritage Program 2004).

Within Region 2, *Calochortus flexuosus* occurs entirely within the Colorado Plateau Ecoregion (Bailey 1995). In 1914, Payson made a collection of *C. flexuosus* labeled "Naturita," which is in the Southern Rocky Mountain Ecoregion, about 3 miles from the border of the Colorado Plateau Ecoregion. Presumably, he may have been in the Colorado Plateau Ecoregion.

The Western Regional Climate Center (2004) has collected information on the local climate at *Calochortus flexuosus* sites between 1929 and 2003. The closest weather station to most occurrences of *C. flexuosus* in Colorado is in Cortez, Colorado, in Montezuma County. At this weather station, the maximum temperatures occur in July (average = 89 °F [32 °C]). *Calochortus flexuosus* flowers before the hottest time of year, from April through June, when the average maximum temperatures are between 63° and 83 °F (17° to 28 °C). Cortez receives 13 inches (33 cm) annual precipitation on average per year. Precipitation is distributed roughly evenly throughout the year, with peaks during the monsoon season of August (1.55 inches [3.94 cm]) and March (1.2 inches [3.05 cm]). June is the driest month (0.46 inches [1.17 cm]), when most *C. flexuosus* plants have already set seed and gone dormant.

Although fires do occur within the habitat of *Calochortus flexuosus*, we do not know how the species responds to fire. Many *Calochortus* species are gap specialists and depend on disturbances such as fire to open the habitat, to provide nutrients, and to allow for a boom year in reproduction (Fiedler personal communication 2004). Although the specific response of *C. flexuosus* to fire has not been investigated, it is probably not negatively impacted because its underground bulbs, when present, increase its probability of survival during fire events (Lyon personal communication 2004). Colyer (personal communication 2004) recalls that after fires in Mesa Verde, *C. nuttallii* was found in greater numbers than ever before. However, the presence of cheatgrass (*Bromus tectorum*) at several occurrences (Colorado Natural Heritage Program 2004) may alter the fire regime to one less favorable for *C. flexuosus*.

The characteristics of high quality and marginal habitat for *Calochortus flexuosus* are not known. Areas with natural vegetation with few human activities are probably the best examples of high quality habitat. The best sites within Region 2 are likely found in Hovenweep Canyon, northwest of Mesa Verde, in Mancos Canyon, and in Big Gypsum Valley (Colorado Natural Heritage Program 2004).

Southwestern Colorado has a long history of cattle grazing. This has influenced the ecology of the area and may be partially responsible for the distribution of *Calochortus flexuosus*.

Reproductive biology and autecology

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), characteristics of *Calochortus flexuosus* most closely approximate those of a stress-tolerant ruderal species. As with many species of *Calochortus*, *C. flexuosus* is a slow-growing perennial that flowers intermittently over a relatively long life. The bulbs are also characteristic of stress-tolerant species. *Calochortus flexuosus* may persist for several years as a bulb or corm awaiting favorable conditions for flowering. The soils that support *C. flexuosus* are typically unstable since they are often fine textured, poorly aggregated, and sparsely vegetated. This and the high temperatures and aridity of its desert habitat are probably the main sources of stress for *C. flexuosus*. Most *Calochortus* species are gap or fire specialists and depend on disturbance (fire in California) to open the habitat, provide nutrients, and allow for reproduction (Fiedler personal communication 2004). While the role of fire in the habitats that support *C. flexuosus* is not known, there are other observations suggesting that disturbance plays a role in the autecology of this species. *Calochortus flexuosus* has been found along roads, on a sandy bank, and in areas that are grazed by cattle (Colorado Natural Heritage Program 2004). It is commonly found in areas with a high percentage

of bare ground and sparse vegetation (Colorado Natural Heritage Program 2004). In a discussion of stress-tolerant ruderals, Grime (2001) notes that areas with a combination of severe stress and disturbance in terrestrial habitats tend to be devoid of vegetation since there are no plant strategies that can cope with both simultaneously. While *C. flexuosus* has some affinity for disturbed areas, it also persists in grassy meadows with little bare ground and other areas with well-developed vegetation (Colorado Natural Heritage Program 2004). More information is needed to determine how the species responds to different types and intensities of disturbance.

While its life history, tolerance of disturbance, and ability to colonize disturbed sites tag *Calochortus flexuosus* as a ruderal species, it also has attributes of a stress-tolerator as defined by Grime (2001). It thrives in soils that are heavy, droughty, and deficient in nutrients and are too stressful for most species of vascular plants.

As a perennial with a relatively large proportion of biomass allocated to the production of propagules, the life history pattern of *Calochortus flexuosus* is best classified as *r*-selected (using the classification scheme of MacArthur and Wilson 1967). The role of disturbance in the autecology of *C. flexuosus* also typifies it as an *r*-selected species as does its lack of strong competitive interactions (Pianka 1970).

Reproduction

Like all members of the genus *Calochortus*, *C. flexuosus* has perfect, actinomorphic flowers. Based on the biology of many of its congeners, *C. flexuosus* may reproduce sexually and vegetatively (Fiedler 1986, Fiedler 1987). Vegetative reproduction, which occurs through the production of bulblets, is rare (Fiedler personal communication 2004). It is not known if this species is self-incompatible and an obligate outcrosser, or if it is capable of self-pollination. Most likely, the species primarily outcrosses and occasionally self-pollinates (Fiedler personal communication 2004). At least one species of *Calochortus*, *C. leichtlinii*, is known to be capable of self-fertilization (Holtsford 1985). Although *C. flexuosus* may or may not be self-compatible, reproductive output is probably greater when plants are outcrossed. *Calochortus flexuosus* appears to have adaptations that promote outcrossing. The relatively large flowers, scent patches (Skinner personal communication 2004), and nectar glands (Fiedler personal communication 2004) may play a role in attracting pollinators.

Most *Calochortus* are reported to be easy to grow from seed, with flowers produced by the third year of growth (Chapman 2000). Although species-specific research has not been done, it is likely that *C. flexuosus* reproduces readily from seed.

Calochortus flexuosus is a diploid species with 14 chromosomes (2n = 14). This is based on cytological studies conducted by Beal and Ownbey (1943), using material from a specimen collected by Ira W. Clokey (no. 5872) on gravelly slopes and hillsides at Glendale Junction, about 50 miles (80 km) northeast of Las Vegas, Nevada. Beal and Ownbey (1943) also conclude that *C. catalinae* (Santa Catalina mariposa lily), a species that is known from southern California, is a close relative of *C. flexuosus*, both cytologically and morphologically.

Pollinators and pollination ecology

The pollination ecology of *Calochortus flexuosus* has not been investigated, and insect visitors to *C. flexuosus* have not been documented. Other species of *Calochortus* are visited by beetles and bees (Fiedler personal communication 2004, Rozen personal communication 2004, Skinner personal communication 2004). Specialist bee pollinators of *Calochortus* include species of *Macrotera* (Andrenidae: formerly included in *Perdita*) and *Dufourea* (Halictidae; Ascher personal communication 2004).

A study of 25 different species of *Calochortus* at 40 sites in California concluded that *Calochortus* flowers appear to be generalists in terms of their pollinators (Dilley et al. 2000). The study found that *Calochortus* flowers attracted insects in several orders, especially beetles that fed at glands on the petals and bees that collected pollen. Several Colorado researchers observed beetles visiting common *Calochortus* species, but they do not know if they are pollinators. Cariveau (personal communication 2004) noted beetles feeding on the nectar glands of a common *Calochortus*, and Kevan (personal communication 2004) found soldier beetles in *Calochortus* flowers in the Mosquito Range of Colorado.

Phenology

Calochortus flexuosus bears one to four flowers on a 10 to 30 cm (4 to 12 inch) stem that is usually sprawling and twining in habit (Callahan 2001), but that may also be erect or decumbent (Ownbey 1940). As a desert plant species found in habitats with short growing seasons, *C. flexuosus* has a relatively short flowering period (Lyon personal communication 2004).

It typically flowers in April through June (Cronquist et al. 1977, Colorado Natural Heritage Program 2004), but it is not likely to be in flower for that full length of time (Lyon personal communication 2004). By late June most flowers have dried and given way to fruits. Because *C. flexuosus* occurs in xeric sites, the periodicity of successful recruitment may coincide with wet or otherwise favorable years during which seedlings can become established.

Fertility and propagule viability

Seed germination requirements for *Calochortus flexuosus* have not been investigated, and the seed coat of *C. flexuosus* has not been observed. Seed biology studies and germination trials of another species of *Calochortus*, *C. umpquaensis*, indicate that germination is stimulated by a long (12 to 14 week) period of cold, moist, dark stratification. This ensures that seeds only germinate in the spring (Center for Plant Conservation 2004a). Germination trials on *C. coxii* at The Berry Botanic Garden obtained 100 percent germination after 8 weeks of cold stratification followed by a constant 68 °F (20 °C) or alternating 50 °F /68 °F (10 °C /20 °C) environment (Center for Plant Conservation 2004b). It is not known if *C. flexuosus* would respond to similar treatments.

In studies of *Calochortus umpquaensis*, microhabitat was found to strongly influence seedling establishment (Center for Plant Conservation 2004a). Plants rarely established in close proximity to other vegetation. Microhabitat conditions favored by *C. flexuosus* have yet to be determined, but most plants are found in relatively open sites.

Dispersal mechanisms

The seeds of *Calochortus flexuosus* are dispersed by gravity (Fiedler personal communication 2004) and to a lesser extent by precipitation running across the soil surface. This suggests that *C. flexuosus* has a limited ability to colonize new sites. It is possible that movement of soil by humans may have led to its introduction to some sites. Grazing and road building activities may also have distributed seeds.

Phenotypic plasticity

Calochortus flexuosus does not exhibit a great degree of phenotypic plasticity. Plants vary in size, stature, and reproductive effort, probably due to year-to-year variations in climate. There is some variation in the pink to white coloring of the corolla (Colorado Natural Heritage Program 2004). Enormous phenotypic plasticity exists for some species of *Calochortus* (Fiedler personal communication 2004).

Mycorrhizal relationships

Roots of *Calochortus flexuosus* have not been assayed for the presence of mycorrhizal symbionts. Fiedler (personal communication 2004) found some evidence of mycorrhizae associated with *Calochortus* species in California, but she has not conducted further research regarding this relationship.

Hybridization

Hybridization is unlikely in *Calochortus flexuosus* (Fiedler personal communication 2004) since there are no closely related congeners in the immediate vicinity with which it could exchange pollen. *Calochortus nuttallii*, a species of *Calochortus* that does co-occur with *C. flexuosus*, is in a different subsection of the genus and has a different chromosome count (*C. flexuosus* has 14 chromosomes [2n = 14; Beal and Ownbey 1943] and *C. nuttallii* has 16 [2n = 16; Ownbey 1940]). The closest relative to *C. flexuosus*, *C. catalinae*, is found in California.

Demography

The demographics of populations of *Calochortus flexuosus* have not been investigated. A demographic study of eight other species of *Calochortus* in California used matrix models to define population stage distribution (proportion of seedlings, juveniles, and reproductive adults; Fiedler et al. 1998). The study found a great deal of variability between populations, habitats, and years. Reproduction was predicted to be most limiting to population growth, more variable, and less predictable than mortality. Reproductive output varied considerably across habitats (Fiedler et al. 1998). *Calochortus flexuosus* recruitment may be episodic with seeds persisting in the seed bank, and mature plants persisting underground. Demographic studies would be complicated by the uncertainty as to whether emerging plants were seedlings or adults that had spent the previous year as a dormant bulb.

In demographic studies of *Calochortus umpquaensis*, a positive correlation was found between February through May precipitation and flower production. The study also found that microhabitats strongly influence seedling establishment. Plants rarely established in close proximity to other vascular plants. In forested habitats, the distribution of plants closely

corresponded to the availability of leaf litter microsites. In meadow habitats, plants occupied mossy microsites (Center for Plant Conservation 2004a).

Maintaining genetic integrity and eliminating inbreeding and outbreeding depression are important management considerations for *Calochortus flexuosus*. Since it is likely a primarily outcrossing species, *C. flexuosus* is vulnerable to inbreeding depression in small populations or in populations with limited pollinator activity. Given the moderate degree of disturbance and fragmentation of the habitat for *C. flexuosus*, it is possible that occurrences are becoming isolated and that genetic diversity is being lost. Maintaining distinct genetic populations and natural levels of gene flow are also important for the conservation of this species.

The lifespan of *Calochortus flexuosus* has not been determined. Plants may spend one or more years underground as dormant bulbs, waiting to emerge and bloom until the environmental conditions are favorable. There are no data regarding the proportion of individuals within a population that are reproducing in a given year. In favorable years, many or most of the plants probably set seed. The longevity and dormancy of the seeds of *C. flexuosus* have not been studied. **Figure 5** is a hypothetical life cycle diagram for *C. flexuosus*.

No Population Viability Analysis (PVA) has been performed for *Calochortus flexuosus*. Apparently there has never been a PVA of any member of the genus *Calochortus* or other members of the Calochortaceae or Liliaceae from which inferences could be drawn for

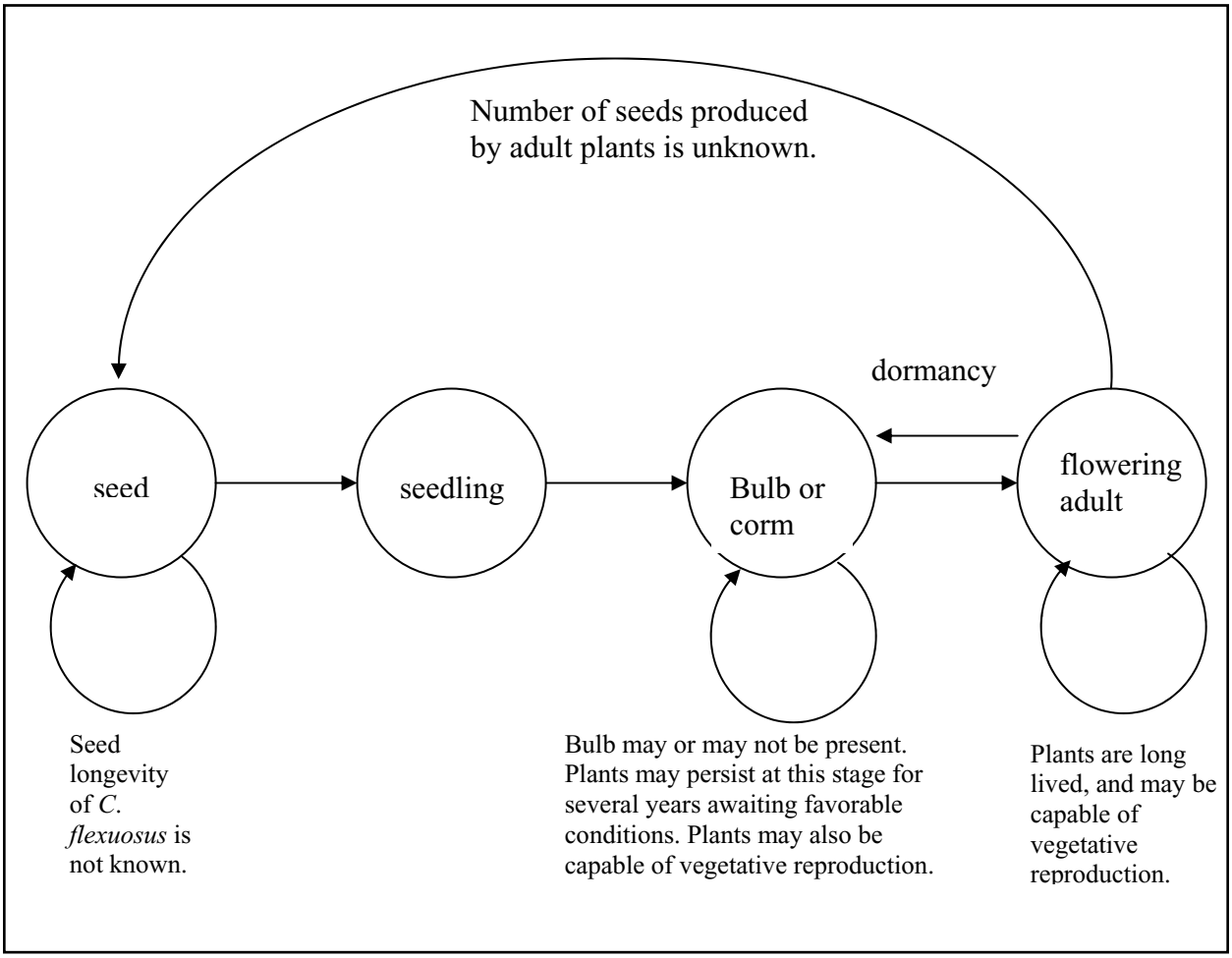

Figure 5. Hypothetical life cycle diagram for *Calochortus flexuosus*, including the known life history stages gleaned from limited observations and from information on other members of *Calochortus*. No transition probabilities are known for *C. flexuosus*. Demographic modeling of other species of *Calochortus* indicates that there is a great deal of variability between species, so it is difficult to make inferences regarding *C. flexuosus*. The time frame from seed to flowering adult is likely about three years, based on the biology of its cogeners (Callahan 2001). The life span of flowering adults has not been determined.

this report. One species of *Calochortus*, *C. tiburonensis*, is currently listed as threatened (U.S. Fish and Wildlife Service 1999), but there has been no PVA of this species to date.

Community ecology

The habitat of *Calochortus flexuosus* has been subjected to some modification and land use practices for at least 100 years. Thus, some of the natural vegetation and associated species for *C. flexuosus* may have been disrupted or removed. Please see the Habitat section of this document for details on the vegetation types associated with *C. flexuosus*. A list of all associated species that have been documented with *C. flexuosus* is included in **Table 2**.

Herbivores

The specific response of *Calochortus flexuosus* to browsing by herbivores has not been studied. It is likely that the plants are browsed to some extent since all parts of *Calochortus* plants are edible, and there are no known toxins in the genus (Callahan 2001). *Calochortus* species are palatable to deer, rabbits, and mice (Callahan 2001). When populations of these herbivores increase in response to the destruction of predators such as bobcat, and coyote, impacts to other species and ecological systems can be severe (Callahan 2001). In research involving four species of *Calochortus* in California (Fiedler 1986), two of the four species suffered significant damage from herbivore grazing. An overview of plant tolerance to consumer damage is presented in Stowe et al. (2000).

Competitors and symbioses

There has been no formal study of the community ecology and interspecific relationships of *Calochortus flexuosus*. As a habitat specialist, *C. flexuosus* may be a poor competitor, which may indicate that it is vulnerable to negative impacts from introduced species. Although *C. flexuosus* does not always occur in disturbed sites, it appears to do well with some disturbance since it has been found along roads and jeep trails, and on eroding slopes (Colorado Natural Heritage Program 2004).

For a discussion of the interactions of *Calochortus flexuosus* with exotic species, please see the Threats section of this document. Herbarium specimens and populations observed showed no signs of parasites or disease. There have been no substantiated reports of symbiotic and mutualistic interactions between *C. flexuosus* and other species. Envirograms that portray generalized interactions between *C. flexuosus* and its environment are presented in **Figure 6** and **Figure 7**.

CONSERVATION

Threats

In the chapter detailing the genus *Calochortus* in the *Bulbs of North America*, Callahan (2001) reports that all *Calochortus* species have been severely affected by human activities, the primary impacts being grazing and urbanization. Observations of *C. flexuosus* in Colorado have shown that although there are several threats to the persistence of this species in Region 2, the severity and extent of the threats are moderately low. In order of decreasing severity, the potential threats to *C. flexuosus* are exotic species invasion, oil and gas development, motorized recreation, effect of small population size, collection for horticultural and other uses, grazing, global climate change, and pollution. These threats and the hierarchy ascribed to them are speculative, and more complete information on the biology and ecology of this species may reveal other threats. The scale and time frame within which these activities affect populations of *C. flexuosus* is unknown. Assessment of threats to this species will be an important component of future inventory and monitoring work. Please see the sections below for specific treatments of these threats to habitat and individuals of *C. flexuosus*.

There is a strong public sentiment toward multiple use of the areas that support *Calochortus flexuosus* in Colorado. For example, a subcommittee of the Southwest Resource Advisory Council, formed to identify community concerns and issues to be considered in determining the management of the Canyons of the Ancients National Monument (formerly the Anasazi Area of Critical Environmental Concern [ACEC]) found that

> "Participants expressed overwhelming support for the continuation of multiple use management. They felt that the mineral, agricultural and recreational uses in the ACEC are all essential to the local tax base and a diversified local economy. Maintaining this diversity of economic benefits will insure a broad base of community support and responsibility for achieving cultural resource protection goals." (Anasazi ACEC working group 1999).

Grazing and oil and gas development are two uses that persist in the Canyons of the Ancients National Monument (Clinton 2000) and have the

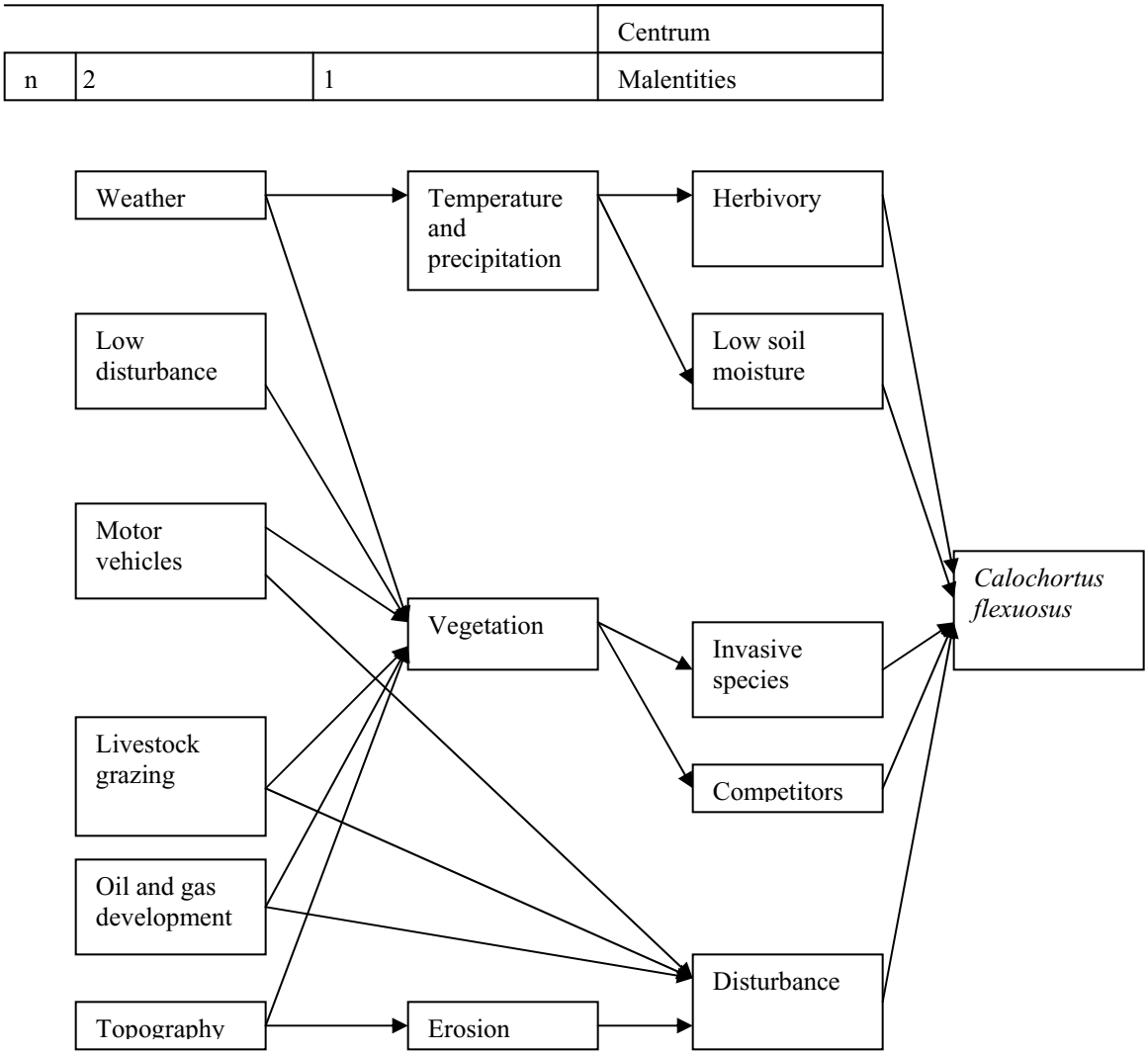

Figure 6. Envirogram outlining the malentities of *Calochortus flexuosus*.

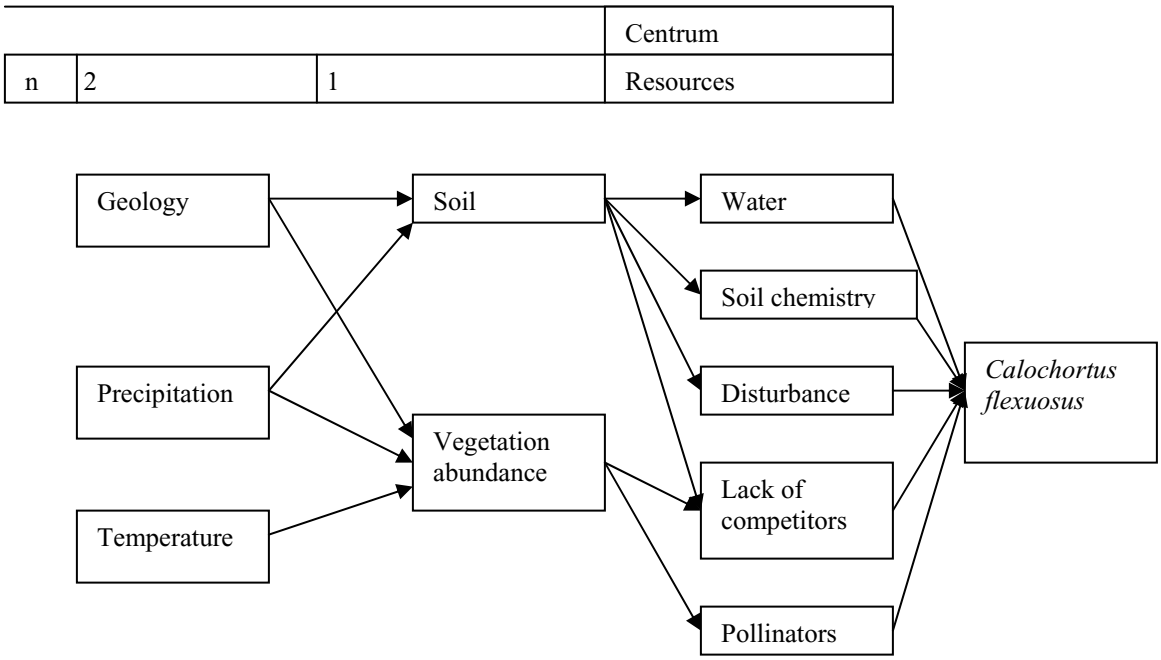

Figure 7. Envirogram outlining the resources of *Calochortus flexuosus*.

potential to affect individuals and occurrences of *Calochortus flexuosus*. The tendency toward multiple use throughout the range of this species in Region 2 is particularly alarming since the plants do not always express themselves above ground. Areas that support *C. flexuosus* could be developed unknowingly while the plants are dormant, and thereby cause significant regional declines.

Exotic species invasions

Eight exotic species have been documented with *Calochortus flexuosus* in Colorado (Colorado Natural Heritage Program 2004, Stewart personal communication 2004); several aggressive weeds have invaded its habitat and pose a serious potential threat to this species. Cheatgrass (*Bromus tectorum*) has been observed at six of the 15 occurrences (Sand Canyon, Hovenweep Canyon, Flodine Park, Disappointment Valley, Spring Creek, and Gypsum Gap), and it was reported as a dominant plant species in Flodine Park (Colorado Natural Heritage Program 2004, Stewart personal communication 2004). Redstem filaree (*Erodium cicutarium*) has also been observed at six of the 15 occurrences (Sand Canyon, Flodine Park, Disappointment Valley, Spring Creek, Hovenweep Canyon, and Gypsum Gap), and again, it is reported as a dominant plant species in Flodine Park (Colorado Natural Heritage Program 2004, Stewart personal communication 2004). Saltlover (*Halogeton glomerata*) was observed at the Hovenweep Canyon location (Colorado Natural Heritage Program 2005). Bur buttercup (*Ceratocephala orthoceras*) was observed in the Sand Canyon area, and Russian knapweed (*Acroptilon repens*), hoary cress (*Cardaria draba*), and tamarisk (*Tamarix ramossisima*) were observed in the Hovenweep Canyon area (Anderson et al. 2001 regarding Cannonball Mesa). African mustard (*Malcolmia africana*) is another exotic species that in some years can cover much of bare ground in Mancos shale barrens where *C. flexuosus* grows near Chimney Rock (Coles personal communication 2006). Most likely, these noxious weeds come into areas following disturbance. Disturbance created by the abundance of roads and unsanctioned off-road activity makes many areas more vulnerable to the spread of noxious weeds. *Calochortus flexuosus* is found along one of the main roads into Canyon of the Ancients National Monument in the Hovenweep Canyon area, and the road is acting as a major corridor for weed invasion (Anderson et al. 2001).

Other noxious weeds that have not been reported with *Calochortus flexuosus*, but have been reported in southwest Colorado, include leafy spurge (*Euphorbia esula*), yellow toadflax (*Linaria vulgaris*), dalmatian toadflax (*L. dalmatica*), field bindweed (*Convolvulus arvensis*), whitetop (*Cardaria draba*), perennial pepperweed (*Lepidium latifolium*), houndstongue (*Cynoglossum officinale*), diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*C. bibersteinii*), jointed goatgrass (*Aegilops cylindrica*), musk thistle (*Carduus nutans*), scotch thistle (*Onopordum acanthium*), and Canada thistle (*Breea arvense*) (Binkly 2000). The best strategy for protecting *C. flexuosus* from noxious weeds is to prevent the introduction of exotic plants by restricting road developments, carefully monitoring populations for changes in species composition, and implementing weed management plans without delay if noxious weeds are detected.

Colorado Natural Heritage Program botanists, in cooperation with the BLM, mapped occurrences of weeds in relation to occurrences of *Calochortus flexuosus* at Cannonball Mesa (part of the Hovenweep Canyon occurrence) and Sand Canyon (Anderson et al. 2001). Botanists with this project recommend that managing for the preservation of the cryptobiotic crusts will give the area a natural defense against weeds by maintaining the integrity of the soil (Anderson et al. 2001).

Oil and gas development

Southwestern Colorado is experiencing extensive oil and gas development (Colorado Oil and Gas Conservation Commission 2004), and it is likely that occurrences of *Calochortus flexuosus* have already been impacted by this use. The impacts from any oil and gas development could be severe, depending on the proximity of occurrences and/or potential habitat for *C. flexuosus*. Extraction, as well as associated roads and pipelines, could cause occurrence fragmentation and habitat destruction.

At least five of the 15 occurrences of *Calochortus flexuosus* appear to be in close proximity to oil and gas development activities. An oil and gas well location map for Colorado (Colorado Oil and Gas Conservation Commission 2004) shows that occurrences of *C. flexuosus* in the Hovenweep Canyon area, Flodine Park, Four Corners, and Mancos Canyon are particularly threatened, as there are wells in the vicinity of these occurrences. Several gas pads are also located in the Sand Canyon area (Anderson et al. 2001).

Public opinion regarding oil and gas development in the Canyons of the Ancients National Monument

is strongly in favor of development. The Anasazi ACEC working group (1999) report implies that oil and gas leasing has been positive because it has helped to identify the cultural resource sites (Anasazi ruins) and has limited access to the general public. The report states that the current BLM regulations provide adequate protection for the cultural resource sites (natural resources are not mentioned here), and recommends that no further restrictions be placed on leasing or development including road building, drilling, and pipeline rights-of-way (Anasazi ACEC working group 1999).

The only occurrences of *Calochortus flexuosus* in Colorado that may be protected from oil and gas development at this time are those in the BLM McKenna Peak Wilderness Study Area and the Dry Creek Basin State Wildlife Area. The Wilderness Study Area is managed to preserve wilderness values, but it has not been designated wilderness by Congress (Bureau of Land Management 2003). As in designated wilderness, however, there are no roads and motorized vehicles are not allowed access (San Juan Mountains Association 2004). Restrictions regarding oil and gas development are not specified. The Dry Creek Basin State Wildlife Area is managed for big game hunting and winter range for deer and elk, and off-road vehicle use is prohibited (Colorado Division of Wildlife 2004a). Restrictions specific to oil and gas development are not mentioned.

There are several uranium mines in the Big Gypsum Valley (Lyon and Sovell 2000), but the mines are currently not impacting known occurrences of *Calochortus flexuosus* (Lyon personal communication 2004).

Motorized recreation

Motorized recreation (including all-terrain vehicles, four-wheel-drive vehicles, and motorcycles) poses a threat to the quality and availability of habitat for *Calochortus flexuosus*. Use of these vehicles throughout the range of *C. flexuosus* in Colorado fragments areas of natural habitat. The proliferation of roads and disturbance from off-road vehicles is likely to encourage the spread of weeds into *C. flexuosus* habitat.

While its primary impact on *Calochortus flexuosus* is reduction of habitat, motorized recreation also impacts individuals and populations directly and indirectly. Disturbed sites may offer fewer species of pollinators for *C. flexuosus* than natural sites. Roads threaten occurrences of *C. flexuosus* directly by altering habitat and killing individuals and indirectly by increasing erosion and serving as dispersal corridors for exotic plant species. *Calochortus flexuosus* is likely an outcrossing species, and roads could act as barriers to pollinators and prevent effective gene flow by disrupting the trap lines of pollinators.

Motorized recreation has been observed at three of 15 *Calochortus flexuosus* occurrences in Region 2: Northwest of Mesa Verde, Mancos Canyon, and Hovenweep Canyon (Colorado Natural Heritage Program 2004). It is possible that motorized recreation is affecting other occurrences as well. Although recreationists are required to stay on existing roads within the Canyons of the Ancients National Monument (Clinton 2000), enforcement of this restriction is difficult (Stewart personal communication 2004). Evidence of illegal off-road activity was observed in the National Monument in 2000 (Anderson et al. 2001). The activity was seen to pose a direct threat and act as a vector for weed dispersal into uninfested areas (Anderson et al. 2001).

The only areas in Colorado that appear to be secure in this regard are the occurrences at Dry Creek and Disappointment Valley. A large portion of the occurrence at Disappointment Valley is found in the BLM McKenna Peak Wilderness Study Area, which is managed to preserve wilderness values (Bureau of Land Management 2003). As in designated wilderness, there are no roads or motorized vehicles allowed (San Juan Mountains Association 2004). The Dry Creek Basin State Wildlife Area also prohibits off-road vehicle use (Colorado Division of Wildlife 2004a), but the effectiveness of this restriction is unknown.

Motorized recreation has increased in southwestern Colorado in the last 10 years. This is due in part to an increase in the local population. Montezuma County grew by 27.6 percent between the 1990 and 2000 censuses (Colorado Division of Wildlife 2004b). Most of this growth was in rural areas, which increased by 38.9 percent during this time. The population in urban areas of the county (the towns of Cortez, Dolores, and Mancos) increased by 10 percent (Colorado Division of Wildlife 2004b). In San Miguel County, growth during the 1990 to 2000 period was even more dramatic, with an increase of 80.5 percent (Colorado Division of Wildlife 2004b).

Despite the increase in motorized recreation and the threats that this activity poses to *Calochortus flexuosus* and other native species, it is difficult for the BLM to close roads because of strong public interest in

access to these areas. For example, the Anasazi ACEC working group (1999) found that

> "The community wants to maintain the diversity of recreational uses (including biking, horseback, ATV, hiking, hunting, etc.), the freedom to explore, opportunities for solitude. . .Except in specific instances where resource degradation can be shown, non-motorized recreation should be dispersed over the widest possible range of roads and trails, while motorized uses should continue to be allowed on the existing network of roads, suitable for motorized travel. "

The specificity of the information regarding impacts to *Calochortus flexuosus* is probably not adequate to justify closing any roads leading to occurrences.

Small population size

With current population estimates between 6,000 and 9,000 individuals in five occurrences, *Calochortus flexuosus* may also be vulnerable in Colorado because of its small population size (Colorado Natural Heritage Program 2004). Four of the 15 known occurrences report fewer than 100 individuals, and five do not have population information (**Table 1**) Although rigorous population estimates are wanting, the prospect of natural catastrophes, such as severe drought, disease or pest outbreaks, appears to make this species vulnerable to local extirpations. The degree to which *C. flexuosus* can survive bad years will depend largely on how long individual plants can persist underground, or remain dormant as seeds. The minimum viable population size is not known for *C. flexuosus*, but even small populations may still be viable and of conservation importance. For conservation planning purposes, the Colorado Natural Heritage Program considers populations of *C. flexuosus* containing 20 or more plants as viable; this threshold will be revised when a minimum viable population size is determined (Colorado Natural Heritage Program 2004). It should also be noted that the number of plants observed in any one year does not reflect the full population size since some plants may be dormant for one or more years.

Collection for horticultural trade and other uses

Calochortus flexuosus is potentially threatened by collection for the horticultural trade because there is demand for attractive species that do well in rock gardens. *Calochortus flexuosus* is not currently listed as being available through the numerous on-line nursery catalogs (Internet search 2004). However, there is considerable demand for other species of *Calochortus*. Eleven of the 12 species of *Calochortus* available through California Native Bulbs were either sold out or not available (California Native Bulbs 2004), suggesting that new species of *Calochortus* might be desired.

Although *Calochortus flexuosus* is not known to be over-utilized by collectors for horticultural uses, *Calochortus* is a much-collected genus, with a history of being collected in huge numbers (Fiedler 1986). For example, in California in the early to mid-1900s, one collector of *Calochortus* bulbs employed men who collected 400 to 800 bulbs per hour to supply to nurseries (Fiedler 1986). This collecting may have contributed to the rarity or extinction of *Calochortus* species (Fiedler 1986). A collecting permit is not required for collecting *C. flexuosus* on BLM-managed lands (Stewart personal communication 2004).

The demand for cut flowers of *Calochortus* is on the rise in Mexico and Europe. Several species are grown commercially by Dutch bulb nurseries, and they are appearing in bulb catalogs (Callahan 2001). *Calochortus coxii*, a rare species known only from Oregon, is threatened by bulb collection and flower picking (Center for Plant Conservation 2004b). *Calochortus dunnii*, a California endemic, has such a showy flower that the main threat to its persistence in the wild is flower picking and collectors who dig the bulbs to grow in their own gardens (Center for Plant Conservation 2004b).

In general, bulbous plants should not be harvested from the wild (McGary 2001). When bulbous plants are moved while they are growing above ground (the only stage at which they will be noticed in the wild), the plants are not likely to survive (McGary 2001). While the plants are in the growth stage, the bulbs are tender and fragile, and the plant's reserves are depleted (McGary 2001). Fortunately, many *Calochortus* species are known to reproduce from seed, so if demands were to increase for *C. flexuosus*, it is likely that the plants could be grown for harvest.

The bulbs of *Calochortus flexuosus* are also edible and were used as food by the American Indians (Ownbey 1940, Watson 1873). They are crisp and starchy, and taste like a potato (Ownbey 1940). It is not known how much *C. flexuosus* is utilized as a food source today.

Calochortus flexuosus is not known to have any medicinal uses. However, there are several species

of *Calochortus* that are advertised on the Internet as having healing properties. For example, *C. leichtlinii* flower essence is used to "embrace the inner child and heal wounds of the past" (Holistic Healing 2004). *Calochortus albus* is reported to assist with "healthy maturation; and acceptance of adult responsibilities." *Calochortus tolmiei* is taken to improve "listening to others and to higher worlds, especially in dreams and meditation". *Calochortus monophyllus* "assists with empathy, and receptivity to the feelings and experiences of others" (Healing Waters Flower Essence 2004).

Grazing

Callahan (2001) considers grazing to be a significant threat to *Calochortus* species in general. He reports that *Calochortus* are very palatable and are therefore threatened by grazing by cattle, sheep, and goats. Plants that are not grazed are vulnerable to trampling and soil compaction associated with grazing activity (Callahan 2001).

Cattle grazing has been shown to significantly impact several species of *Calochortus* (Fiedler 1986), but at least three of the species studied, *C. excavatus*, *C. longebarbatus*, and *C. monanthus*, grow in wet mountain meadows, very different habitats than the desert habitat that supports *C. flexuosus*.

At least six locations for *Calochortus flexuosus* in Colorado are used for grazing cattle: Northwest of Mesa Verde, Mancos Canyon, Hovenweep Canyon, Flodine Park, Big Gypsum Valley, and Disappointment Valley (Colorado Natural Heritage Program 2004). It is likely that the other nine occurrences are experiencing some grazing as well. Impacts of grazing activity on *C. flexuosus* have not been investigated. Local botanical researchers in Colorado estimate that the impacts of cattle grazing to *C. flexuosus* are probably negligible (Lyon personal communication 2004, Stewart personal communication 2004). Livestock grazing has been historically heavy on the lands within the Canyons of the Ancient National Monument, Disappointment Valley, and Gypsum Valley, and there does not appear to be a negative effect on *C. flexuosus* (Stewart personal communication 2004). Further research is warranted to determine the effects of the current levels of cattle grazing to populations of *C. flexuosus*.

There is strong public support to continue cattle grazing in southwestern Colorado. The Anasazi ACEC Working Group (1999) determined that

> "The presence of farmers and ranchers on the ACEC landscape [refers to Canyons of the Ancients National Monument] is a source of protection, particularly in remote areas that they are most likely to frequent. In addition to direct economic benefits, agriculture provides indirect benefits such as open space, wildlife habitat, development and maintenance of ponds and reduced risk of wildfire damage to cultural resources. The future of the ACEC should not have a detrimental effect on the current agricultural base. Maintenance of livestock and wildlife distribution ponds should be allowed and new ponds should be constructed as needed. Grazing permits on the ACEC are a critical part of 30 ranching operations. Further restrictions on grazing or the transferability of grazing permits, could put these operations in jeopardy resulting in the fragmentation of dependent private ranch lands. Remote parts of the ACEC can remain so due to their inaccessibility. Further restrictions or designations which spotlight these areas may jeopardize both the viability of the livestock permittee and the cultural resources." (Anasazi ACEC working group 1999).

Global climate change

Global climate change is likely to have wide-ranging effects. Projections based on current atmospheric carbon dioxide trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). This will significantly affect soil moisture, nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. A temperature increase could cause vegetation zones to climb 350 ft. (107 m) in elevation for every ºF of warming (U.S. Environmental Protection Agency 1997). Because the habitat for *Calochortus flexuosus* is already xeric, lower soil moisture in the growing season induced by decreased precipitation could introduce undue drought stress to this species.

Pollution

Atmospheric nitrogen deposition (both organic and inorganic forms) is increasing worldwide. Relatively low levels of nitrogen enrichment are advantageous to some species but deleterious to others, making it difficult to predict species- and community-level responses. It is not known how *Calochortus flexuosus* would respond to increased soil nitrogen, or how well it would compete with species that benefit.

Conservation Status of Calochortus flexuosus in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

Given the changes that have taken place within the occupied habitat of *Calochortus flexuosus* over the last 100 years, it can be assumed that in some places the distribution of this species has been diminished. Because the total pre-settlement population of *C. flexuosus* is not known, it is difficult to assess the effects of historic land use, infrastructure development, and management regimes on abundance. While prolonged or constant disturbance, such as oil and gas development, over-grazing, and off-road vehicle use, is likely to extirpate populations, periodic light to moderate disturbance may be beneficial.

Given the many different landowners and land managers within the distribution of *Calochortus flexuosus*, it is likely that management of some properties is not compatible with the persistence of *C. flexuosus*, but that a few properties are managed appropriately for the conservation of *C. flexuosus*. While the net human impact on the distribution and abundance of *C. flexuosus* is difficult and complicated to assess, the cumulative impact of oil and gas development, grazing, motorized recreation, and habitat fragmentation is almost certainly causing *C. flexuosus* to decline. Species-specific inventories and monitoring will help to determine the current population trend of this species.

Do habitats vary in their capacity to support this species?

Habitats where *Calochortus flexuosus* is found appear to vary in their capacity to support it. The species tends to favor Mancos shale (Colyer personal communication 2004) and is also found on the Point Lookout and Morrison Formations. However, many apparently suitable sites do not support *C. flexuosus*, although it is difficult to be certain that the species is truly absent unless a site is visited in consecutive years. These sites may be highly suitable but simply unoccupied, or the species may be dormant at the time of the survey. The nature of the disturbance regime of a given site may factor into its capacity to support *C. flexuosus*. However, much remains unknown about the nature of the disturbance regime to which *C. flexuosus* is adapted. Refinements of our understanding of the relationships between *C. flexuosus* and its habitat will be possible with more research.

Vulnerability due to life history and ecology

Assessing the vulnerability of *Calochortus flexuosus* due to its life history and ecology is complicated by the paucity of information available in these regards. As a long-lived, stress-tolerant perennial, it is buffered somewhat from the effects of environmental stochasticity such as drought. Because it may have effective mechanisms for selfing, it may also be buffered from impacts that affect its pollinators. The degree to which it can survive bad years will depend largely on how long individual plants can persist or how long seeds can remain dormant. The fact that in most years the plant is not visible in occupied habitat renders these sites vulnerable to disturbance or destruction because of the mistaken impression that the habitat is unoccupied.

Evidence of populations in Region 2 at risk

Although there is some evidence that occurrences of *Calochortus flexuosus* in Region 2 are at risk, further inventory and research on *C. flexuosus* is warranted before conservation actions are taken.

Oil and gas development, population growth, and an anticipated increase in motorized recreation have the potential to put populations of *Calochortus flexuosus* at risk in Region 2. However, this is a species that is rare in Region 2 because it is on the edge of its natural range. Research regarding the species' range-wide distribution is needed to shed light on conservation priorities in Colorado. There are at least three areas that offer a degree of protection to *C. flexuosus* in Region 2: Canyons of the Ancients National Monument, McKenna Peak Wilderness Study Area, and Dry Creek Basin State Wildlife Area.

While the total population of *Calochortus flexuosus* in Region 2 is estimated to be between 6,000 and 9,000 plants, the actual number is likely to be much higher, but only in the rare years when the species comes out of dormancy and blooms. It is likely that additional plants will be found with further inventories undertaken in years when the species is evident.

Management of Calochortus flexuosus in Region 2

Implications and potential conservation elements

Current data suggest that *Calochortus flexuosus* is a peripheral species in Region 2 that is imperiled

in this part of its range due to a small number of occurrences and potential threats to its habitat. Management policies will need to address motorized recreation, human and natural disturbance regimes, pollinator resources, and restoration of native plant communities. Given (1994) offers practical advice regarding restoration that will assist with the development of effective management and restoration policies. The Tools and practices and Threats sections contain additional information on mitigating threats stemming from management activities.

Desired environmental conditions for *Calochortus flexuosus* include sufficiently large areas where the natural ecosystem processes on which *C. flexuosus* depends can occur, permitting it to persist unimpeded by human activities and their secondary effects, such as competing exotic species. This includes a satisfactory degree of ecological connectivity between populations to provide corridors and other nectar resources for pollinators. From a functional standpoint, ecosystem processes on which *C. flexuosus* depends appear to remain intact to some extent. Whether this will remain true as the human population densities increase is uncertain. Although *C. flexuosus* populations are apparently viable, the natural ecosystems and ecosystem processes have been altered, and much of the habitat is disturbed and fragmented. Research on the ecology and distribution of *C. flexuosus* will help managers to develop effective approaches to management and conservation.

It is likely that a thoughtful assessment of current management practices on lands occupied by *Calochortus flexuosus* would identify opportunities for change that would be inexpensive and have minimal impacts on the livelihood and routines of local residents, managers, permittees, stewards, and recreationists, while conferring substantial benefits to *C. flexuosus*. The next section (Tools and practices) describes potential beneficial management actions that can be taken on behalf of *C. flexuosus*.

Tools and practices

Species inventory

Inventory is among the highest priorities for *Calochortus flexuosus*. Developing a detailed map of the species' distribution and abundance will provide a starting point from which population trends can be assessed, and it will help managers to determine appropriate sites for conservation. Species inventories are simple, inexpensive, and effective, and they are necessary for developing the understanding of the target species required to design a rigorous monitoring program. Encouraging researchers familiar with this species to search for new occurrences and to update historic records would contribute greatly to our knowledge of *C. flexuosus*.

Calochortus flexuosus is a relatively conspicuous species in the years in which it expresses itself above ground, and it is not difficult to distinguish from other members of *Calochortus*. It tends to grow in open habitats, which makes it easy to find, but it is inconspicuous in the vegetative stage. Field crews could quickly be taught to recognize it in the field. Searching for *C. flexuosus* is complicated by the need to obtain permission to enter private land throughout its known range, and by the fact that in most years few plants emerge or produce flowers. Inventories should be flexible; known occurrences should be visited first, and if plants are not evident, then it is likely to be a poor year for inventory and searches should be delayed until the next year.

Areas with the highest likelihood of new occurrences are those with the appropriate geologic substrate within the range of the known occurrences. Many areas within the known range of *Calochortus flexuosus* remain to be searched because of the difficulties in accessing remote areas. There are likely to be other occurrences on outcrops of Point Lookout Sandstone, Mancos Shale, and Morrison Formation substrates many miles away from known locations.

Habitat inventory

The Colorado Natural Heritage Program routinely uses aerial photography, topographic maps, soil maps, and geology maps to refine search areas when conducting inventories of large regions. This approach has worked well in Colorado and elsewhere. It is most effective for species about which we have basic knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. Searches for *Calochortus flexuosus* could be aided by modeling habitat based on the physiognomy of known occurrences. The intersection of topography, geologic substrate, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *C. flexuosus* in given locations. Techniques for predicting species occurrences are reviewed extensively by Scott and others (2002). Habitat modeling has been done for other

sensitive plant species in Wyoming (Fertig and Thurston 2003) and Colorado (Decker et al. 2005); these methods would apply to *C. flexuosus*.

Population monitoring

The best time for inventory and monitoring of *Calochortus flexuosus* in Colorado is from late April through early June, when the plants are flowering most actively. A monitoring program for *C. flexuosus* would begin by targeting a subset of known occurrences and could add other occurrences as they are discovered. Sampling sites with different levels of anthropogenic disturbance could be selected within the large occurrences in the Hovenweep Canyon area. Monitoring sites under a variety of land management scenarios will help to identify appropriate management practices for the conservation of *C. flexuosus* and to understand what drives its population dynamics and structure.

A monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and the scientific community. The most sensitive measure of population change will be gleaned from recruitment success. Monitoring interactions with pollinators could be effectively done by expanding on the methods employed by Dilley and others (Dilley et al. 2000). Suitable methods for monitoring pollinators are also discussed in Kearns and Inouye (1993). Measuring seed production will require a visit later in the summer after fruitset. It will be important to define *a priori* the changes that the sampling regime intends to detect, and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998). Years in which *Calochortus flexuosus* is abundant are relatively rare (Coles personal communication 2006) and are likely to be correlated with climate variables. It would be interesting and potentially useful to install small weather stations with the capability of recording daily temperature and precipitation at a handful of occurrences scattered throughout the species' range in Region 2.

Because of a high annual variability in reproductive effort, annual sampling of monitoring plots will be necessary for at least a decade to gain insight into the population dynamics of *Calochortus flexuosus*. A sampling design will ideally be effective in the few years when the species is abundant as well as in the many years when it is not. Elzinga et al. (1998) offers many suggestions regarding sampling design considerations.

The most rigorous population monitoring design is one that stratifies and selects sampling sites randomly throughout the range. Permanent plots could be selected within a habitat unit by randomly choosing X and Y Universal Transverse Mercator (UTM) coordinates within a sampling site. These plots could then be located using a highly accurate Global Positioning System (GPS) unit. Once they are established and marked, a recreation grade GPS could be used to relocate the plots. If subsequent power analysis indicates that the sample size is inadequate, it is easy to add more quadrats in this sample design. Elzinga et al. (1998) recommend several methods of monumentation, depending on site physiography and frequency of human visitation. This is an important consideration that will reap long-term benefits if done properly at the outset of the monitoring program.

Estimating the cover and/or abundance of associated species within the monitoring plots above could permit the investigation of interspecific relationships through ordination or other statistical techniques. In very sparsely vegetated plots, this can be difficult, but it can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding environmental constraints on *Calochortus flexuosus* would facilitate the management of this species. Gathering data on edaphic characteristics (e.g., moisture, texture, chemistry) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species. Comparing lysimetry data between occupied and unoccupied habitat could help to refine the definition of potential habitat if soil chemistry controls the distribution of *C. flexuosus*.

Adding a photo point component to this work following recommendations in Elzinga et al. (1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available that provides detailed instructions on establishing photo point monitoring plots. Photo monitoring sites should be selected carefully, and a sufficient number of sites need to be selected if the data are intended to detect population trends.

At present, research priorities lie in determining the distribution and abundance of *Calochortus flexuosus*. This goal may be difficult to achieve, given that in most years it can be very difficult to find,

whereas in a few years it may be so abundant that plants are hard to count or even estimate accurately. Thus, presence/absence monitoring may be the most effective technique for determining the range, if not abundance, for *C. flexuosus*.

Habitat monitoring

Habitat monitoring would be particularly beneficial to *Calochortus flexuosus*. Habitat monitoring should be conducted concurrently with population monitoring and within the same plots. Documenting habitat attributes (including climate factors such as precipitation), disturbance regime, and associated species during population monitoring will greatly augment our present understanding of the species' habitat requirements and management needs. Data fields for this information could be incorporated into monitoring forms. If environmental variables are quantified during monitoring activities, they could help to explain observations of population change. Habitat monitoring of known populations will alert managers to new threats such as weed infestations and human-caused disturbance. Noting damage from recreational uses may help managers to prevent serious degradation by providing support for changes in the management prescription.

Observer bias is a significant problem with habitat monitoring (Elzinga et al. 1998), unless field crews are trained carefully in how to estimate plant cover accurately and consistently. Habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. For example, using broad abundance classes to estimate weed infestations helps to reduce the effects of observer bias. To assess trampling impacts, using photographs of impacts to train field crews will help them to consistently rate the severity of the impact.

Beneficial management actions

Management practices that reduce the impacts of recreational uses on populations of *Calochortus flexuosus* are likely to contribute to the long-term survival of this species in Region 2. Research is needed to identify disturbance regimes that are compatible with *C. flexuosus*. Given the current limited knowledge based solely on observations, exclusion of motorized recreation (and enforcement) within all known occurrences, at least from April through June when the plant is growing and reproducing, is most likely to be compatible with the persistence of *C. flexuosus*. Another approach that might be considered on a site-by-site basis is the use of exclosures. Maschinski et al. (1997) found the use of exclosures to be effective in protecting the endangered sentry milkvetch (*Astragalus cremnophylax* var. *cremnophylax*) from trampling.

Six exotic plant species have been documented within *Calochortus flexuosus* occurrences, and management strategies that prevent further infestations are likely to confer great benefits to the species. However, weed control efforts have the potential to negatively impact *C. flexuosus*. Using plant-specific hand application for weed control and avoiding the use of broad-spectrum herbicides within populations of *C. flexuosus* is likely to be beneficial.

Roadside activities can be modified to benefit *Calochortus flexuosus* at the Four Corners and any other roadside locations that are identified. Installation and maintenance of utilities in right-of-ways could impact portions of these populations, but careful attention to avoiding *C. flexuosus* can greatly reduce impacts. Awareness of the species during future projects will help to ensure its viability. The Colorado Natural Heritage Program can provide accurate data on the distribution of this species to assist with avoiding impacts to populations. Inventory of areas in question by someone who is familiar with *C. flexuosus* will also be necessary in certain situations.

Inventory and monitoring would benefit *Calochortus flexuosus*. Much suitable habitat within the range of *C. flexuosus* remains to be searched. Identifying high quality occurrences (i.e., large numbers of plants in sites in excellent ecological condition within an intact landscape) will help managers to prioritize conservation efforts. Appropriate management of natural vegetation in the vicinity of *C. flexuosus* occurrences is likely to benefit pollinators and may improve the likelihood of persistence for undiscovered occurrences. Wilderness designation of the BLM McKenna Peak Wilderness Study Area would provide additional protection for the occurrence in Disappointment Valley.

Seed banking

No seeds or genetic material of *Calochortus flexuosus* are currently in storage at the National Center for Genetic Resource Preservation (Miller personal communication 2004). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002) although four other species

of *Calochortus* are represented in the collection. Collection of seeds for long-term storage will be useful if future restoration work is necessary.

Information Needs

Distribution

Inventories specifically targeting *Calochortus flexuosus* are a high priority for this species in Region 2. Until there is a complete picture of its distribution and abundance, it will not be possible to assess conservation needs and priorities for this species. Often when a species thought to be rare is actively sought and inventoried, it is found that the species is not as rare as previously believed. Although *C. flexuosus* has been sought in several studies, habitat throughout its range in Region 2 has not been thoroughly inventoried. Recent floristic inventories by Leslie Stewart (personal communication 2004) resulted in the discovery of new *C. flexuosus* occurrences, suggesting that other populations await discovery. Places to focus future search efforts include the areas around Naturita, Nucla, and the Paradox Basin in Montrose County (Jennings personal communication 2004), areas around Egnar in San Miguel County, low elevation areas in Dolores County (Lyon personal communication 2004), and the McElmo Creek Basin and areas between Cortez and the Four Corners in Montezuma County.

If occurrences contain more than 20 to 50 plants, voucher specimens should be collected to document each new occurrence and deposited at a regional herbarium. When specimens are collected, the flowers should be pressed so that the inside of at least one petal is visible, so that accurate identifications can be made. Also, the flower color and gland characteristics should be noted before the fresh flowers are pressed. Several occurrences lack specimens to document them. As population size allows, collections should be made to document locations at Flodine Park, Spring Creek, Dry Creek, Sand Canyon, Big Gypsum Valley, Northwest of Mesa Verde, Gypsum Gap, and Disappointment Valley.

Life cycle, habitat, and population trend

Research on the autecology and lifespan of *Calochortus flexuosus* is needed to refine the definition of appropriate habitat and to facilitate effective habitat monitoring and conservation stewardship of this species. The habitat for *C. flexuosus* has been roughly described, but the distinguishing characteristics of its natural habitat and disturbance regime are poorly understood. The particular environmental variables to which *C. flexuosus* responds are unknown. Being able to identify suitable habitat is particularly important for the conservation and management of this species since it does not always appear above ground.

The population trend of *Calochortus flexuosus* is not known and may be difficult to quantify. However, understanding the population biology of *C. flexuosus* is important for appropriate stewardship and management of this species. Since seeing fewer plants above ground may not necessarily signify a downward trend, and vice versa, it would be helpful for land managers to have estimates of true population trends.

Response to change

Rates of reproduction and establishment and the effects of environmental variation on these parameters have not been investigated for *Calochortus flexuosus*. Because of this knowledge gap, the potential effects of management cannot be assessed during project planning.

A better understanding of the specific responses of *Calochortus flexuosus* to disturbance is important for determining appropriate management practices. At present, how *C. flexuosus* responds to different types and intensities of disturbance is unknown. The Reproductive biology and ecology section of this assessment contains a discussion of the relationship of *C. flexuosus* to disturbance.

Increases in the rates of oil and gas development, grazing, and recreational use in the habitat of *Calochortus flexuosus* could decrease the availability and diversity of pollinators. In her studies of *Ipomopsis polyantha*, Collins (1995) noted that large-bodied insect species have greater nutrient reserves, which enable them to travel further to pollinator resources. Thus we might expect a shift towards larger pollinators if the area becomes more fragmented and populations of *C. flexuosus* become more insular. Pollinators capable of residing in disturbed habitats are also likely to be favored.

Metapopulation dynamics

Research has not been done to determine the importance of metapopulation structure and dynamics to the long-term persistence of *Calochortus flexuosus* at local or regional scales. Migration, extinction, and colonization rates are unknown for *C. flexuosus*. Baseline population dynamics and viability must first be assessed. The episodic nature of *C. flexuosus*, where

it resides underground in an area in most years but is common in a few years, may lend the appearance of a species that relies on metapopulation dynamics.

Demography

Only the broadest generalizations can be made at present regarding the demography of *Calochortus flexuosus*. Abundance has not been assessed for many occurrences, growth and survival rates are unknown, and the rate of reproduction is poorly understood. In most years, individual plants persist underground, either as corms or seed. Much work is needed before the potential for the species' long-term persistence can be assessed with demographic modeling techniques. Meyer et al (2006) describe a method for determining the population viability for an ephemeral desert mustard by including a controlled seed bank longevity study within the larger demographic study. Short-term demographic studies can provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002).

Population trend monitoring methods

There has been no monitoring of populations of *Calochortus flexuosus*. Monitoring a species that remains below ground in most years, is rare in some years and abundant in a few years presents special challenges for monitoring design. Menke and Kaye (2003) described a technique for monitoring populations of *C. greenei* that could apply to *C. flexuosus*. A mark-recapture approach as described by Alexander et al. 1997 may also be applicable. Selection of monitoring sites from a variety of land use scenarios will be necessary to monitor trends at the population level.

Restoration methods

There have been no known attempts to restore habitat or populations of *Calochortus flexuosus*. Therefore, there is no practical experience from which to draw in developing a restoration program. It is likely that *C. flexuosus* could be readily propagated in a greenhouse environment, but it might be difficult to transfer plants successfully into a natural or restored setting.

Species in the genus *Calochortus* are best cultivated in well-aerated, fast-draining soils with a pH of 5 to 6.5 (Chapman 2000). Seeds should be sown in the fall, around October; germination takes place within one to two months (Chapman 2000). Studies are needed to determine the effectiveness of these techniques in the applied restoration of *C. flexuosus*. In general, bulbous plants are vulnerable and should not be moved when aboveground parts are actively growing. During this phase, the bulbs are tender and fragile, and the plants' reserves are depleted (McGary 2001).

Research priorities for Region 2

Species inventories are needed to determine the distribution of *Calochortus flexuosus* in Region 2. Delineating the boundaries of known occurrences, locating new occurrences, and searching areas in the vicinity of historic occurrences are the best first steps toward developing a complete understanding of the distribution of *C. flexuosus*. Targeted searches at phenologically appropriate times (late April to early June) in suitable habitat in years when the plant is likely to flower will help to confirm the distribution and abundance of *C. flexuosus* and may identify opportunities for its conservation. Identifying robust occurrences in natural settings is important for setting conservation targets and priorities. Collecting detailed notes on associated species, habitat, geology, soil, and other natural history observations at all locations will be useful information. Documenting any threats and visible impacts to *C. flexuosus* will help managers to develop conservation strategies and to mitigate these threats.

Demographic studies are needed for *Calochortus flexuosus* in Region 2. Demographic data are more useful for assessing status and developing recovery efforts than is genetic information (Schemske et al. 1994). Determining the critical life history stages of *C. flexuosus* will allow managers to focus efforts on implementing management protocols that benefit those stages. A monitoring program that determines effective population sizes and investigates the growth, survival, and reproduction of individuals within populations will have considerable practical value and will help managers to determine the conservation status of *C. flexuosus* in Region 2.

Reaching a better understanding of the influence of human activities on individuals and habitat of *Calochortus flexuosus* in Colorado will assist land managers and planners. Identifying life history and phenological stages when *C. flexuosus* is less sensitive to recreational impacts would help greatly to mitigate threats by developing management practices that are compatible with *C. flexuosus*.

The role of disturbance in the autecology of *Calochortus flexuosus* remains poorly understood. An understanding of the specific tolerances of *C. flexuosus* to different human and natural disturbance regimes will assist with developing conservation strategies and management plans by determining the types of disturbance most likely to negatively impact it.

Information gleaned from studies of the physiological and community ecology of *Calochortus flexuosus* will be valuable in the event that a population needs to be restored, and it will help managers to determine biotic and abiotic factors that contribute to its survival. Understanding the plant-environment relationships of *C. flexuosus* will clarify the coping strategies employed by this species and will help to model its potential distribution.

Definitions

Actinomorphic – Flowers that are radially symmetrical (Harris and Harris 1999).

Autecology – the study of a single species and its relationship with the environment.

Bulblet – a small bulb.

Corm – enlarged fleshy base of a stem (Weber and Wittmann 2001).

Diploid – having two similar complements of chromosomes.

Ecoregions – large geographically-defined areas that integrate various environmental conditions (e.g., climate, geology) and that support distinctive groupings of species and ecological communities.

Edaphic – soil and the physical, chemical, and biological factors that influence organisms.

Geophyte – an herbaceous plant with an underground storage organ; in *Calochortus flexuosus* this organ is a bulb. This strategy evolved as a mechanism to help perennial plants survive adverse climatic conditions such as temperature extremes. The aerial portions of the geophyte die back, leaving only the storage organ in the soil until conditions are appropriate for aboveground growth.

Glabrous – lacking hair.

Gland – a group of one or more cells whose main function is to secrete a specific chemical substance or substances.

Lanceolate – lance-shaped; much longer than broad, widening above the base, and then tapering to the apex (Zomlefer 1994).

Metapopulation – discontinuous subpopulations that collectively exhibit certain population-like functions.

Monecious – species with male and female flowers on the same plant.

Perfect – Flowers that include both male and female structures; bisexual (Weber and Wittmann 2001).

Potential Conservation Area (PCA) – A best estimate of the primary area supporting the long-term survival of targeted species or natural communities. A PCA is circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2001).

Propagules – buds or shoots; any structure having the capacity to give rise to a new plant.

Quadrat – a small area used in an ecological survey to study the distribution and abundance of species in detail.

Ruderal – growing along roadsides or other waste places.

Sepal – one of the outer flower segments; one of the separate, usually green, parts forming the calyx of a flower.

Imperilment Ranks used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe.

Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**

G/S1	Critically imperiled globally/state-province because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.
G/S2	Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).
G/S4	Apparently secure globally/state-province, though it might be quite rare in parts of its range, especially at the periphery.
G/S5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GX	Presumed extinct.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but not verified for an extended period, usually.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not permanent residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliable identified, mapped, and protected.
SA	Accidental in the state or province.
SR	Reported to occur in the state or province, but unverified.
S?	Unranked. Some evidence that the species may be imperiled, but awaiting formal rarity ranking.

Notes: Where two numbers appear in a G or S rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

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