Oreoxis humilis Raf.
(Rocky Mountain alpineparsley):
A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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COVER PHOTO CREDIT

Oreoxis humilis (Rocky Mountain alpineparsley). Photograph by William Jennings. Reprinted with permission from the photographer.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *OREOXIS HUMILIS*

Status

Oreoxis humilis (Rocky Mountain alpineparsley) is a perennial forb endemic to Pikes Peak in Colorado occurring from 3,440 to 4,160 meters (11,280 to 13,650 feet) on granitic substrates in alpine and subalpine environments. Currently, there are approximately four known occurrences of this species, and all occur wholly or in part on the USDA Forest Service (USFS) Pike-San Isabel National Forest. This species is not listed on the USFS Rocky Mountain Region (Region 2) sensitive species list (USDA Forest Service 2003a) or the U.S. Fish and Wildlife Service threatened or endangered species list (U.S. Fish and Wildlife Service 2004). Because of its very small range, the global heritage status rank for *O. humilis* is G1 (critically imperiled), and the Colorado Natural Heritage Program (NHP) state heritage rank is S1 (critically imperiled) (NatureServe 2002).

Primary Threats

Oreoxis humilis is a species of concern because of its restricted geographic range, small number of documented occurrences, and possible vulnerability to human-related and environmental threats. Not enough abundance data or demographic information are available to conclude if occurrences of *O. humilis* are increasing, decreasing, or remaining stable. There is no evidence of drastic population declines at this time. Disturbances and land management activities may maintain suitable habitat for this species, or they may negatively impact existing occurrences, depending on the intensity, frequency, size, and type of disturbance and activity. Possible human-related threats to *O. humilis* include road erosion and construction, structure maintenance, and motorized and non-motorized recreational activities (Colorado Natural Heritage Program 2004). Possible environmental and biological threats to occurrences of *O. humilis* include environmental fluctuations, herbivory, genetic isolation, inadequate pollination, global climate changes, and exotic species invasion.

Primary Conservation Elements, Management Implications and Considerations

Oreoxis humilis is a species endemic to one area (Pikes Peak, Colorado) with a small number of recorded occurrences and potentially high vulnerability to human-related activities and environmental changes. Although all four occurrences are on National Forest System Lands in Region 2, this species is not specifically protected as a sensitive species by the USFS. The microhabitat needs of this species and the intensity, frequency, size, and type of disturbance optimal for its persistence are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual and vegetative reproductive potential, and genetic variability of this species makes it difficult to predict its long-term vulnerability. Surveying high probability habitat for new occurrences, protecting existing occurrences from direct damage, documenting and monitoring the effects of current land-use activities, and preventing non-native plant invasions are key conservation elements for this species. Priorities of future research include revisiting and mapping of the extent of existing occurrences in detail, surveying to locate additional occurrences within USFS Region 2, studying the taxonomic status, assessing imminent threats, investigating factors affecting spatial distribution (e.g., microhabitat characteristics), exploring biological and ecological limitations, and producing information related to demography and genetic structure.

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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). *Oreoxis humilis* (Rocky Mountain alpineparsley) is the focus of an assessment because it is a rare species with viability concerns due to its regional endemism, small number of documented occurrences, and possible human-related and environmental threats. A species of concern may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *O. humilis* throughout its entire range, all of which is in USFS Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation 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, conservation status, and management 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 background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications).

Scope and Information Sources

This assessment examines the biology, ecology, conservation status, and management of *Oreoxis humilis* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Where supporting literature used to produce this species assessment originated from investigations outside the region (e.g., studies of related species), this document placed that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *O. humilis* 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, we performed an extensive literature search to obtain all material focusing on *Oreoxis humilis*, as well as related information on the geographical and environmental contexts of this species. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), dissertations, data accumulated by resources management agencies (e.g., state NHP element occurrence records), and regulatory guidelines (e.g., USFS Manual). We did not visit every herbarium with specimens of this species, but we did incorporate specimen label information provided by herbarium staff and available in NHP element occurrence records. While the assessment emphasizes refereed literature because this is the accepted standard in science, non-refereed publications and reports are used extensively in this assessment because they provided information unavailable elsewhere. These unpublished, non-refereed reports were regarded with greater skepticism, and we treated all information with appropriate uncertainty.

Treatment of Uncertainty

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, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Because of a lack of experimental research efforts concerning *Oreoxis humilis*, this assessment report relies heavily on the personal observations of botanists and land management specialists from throughout the species' range. When information presented in this assessment is based on our personal communications with a specialist, we cite those sources as "personal communication." Unpublished data (e.g., NHP element occurrence records) were also important in estimating the geographic distribution and describing the habitat of this species. These data required special attention because of the diversity of persons and methods used in collection and the inability to verify historical information.

Because there is a paucity of knowledge specific to this species, we also incorporated information, where available, from other *Oreoxis* species or taxonomically related genera endemic to USFS Region 2 or adjacent states to formulate this assessment (e.g., *O. alpina*). However, information about this species (e.g., life history, population structure, longevity, dispersal, mortality, and seed biology) is also lacking (Handley et al. 2002, Johnston 2002). These comparisons are not meant to imply that *O. humilis* is biologically identical to these species, but they represent an effort to hypothesize about *potential* characteristics of this species. For example, studies on pollination of *O. alpina* in Colorado tundra habitats (Petersen 1977, Puterbaugh 1998) may provide helpful insights on important issues to consider when studying the biology and conservation of *O. humilis*. As a result, the biology, ecology, and conservation issues presented for *O. humilis* in USFS Region 2 are based on inference from these published and unpublished sources. We clearly noted when we were making inferences based on the available knowledge to inform our understanding of *O. humilis*.

Publication of Assessment on the World Wide Web

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

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Oreoxis humilis is a regional endemic species of Pikes Peak in Colorado and is known from four occurrences globally (**Figure 1**; Colorado Natural Heritage Program 2004). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this species.

Management and Conservation Status

Federal status

This species is not listed on the USFS Rocky Mountain Region sensitive species list (USDA Forest Service 2003a) or the U.S. Fish and Wildlife Service (USFWS) threatened or endangered species list (U.S. Fish and Wildlife Service 2004).

Heritage program ranks

Because of its very small range, the Global Heritage status rank for *Oreoxis humilis* is G1 (critically imperiled), and the Colorado NHP state heritage rank is S1 (critically imperiled) (NatureServe 2002). Heritage databases draw attention to species of special concern that potentially require conservation strategies for future success. However, these lists are not associated with specific legal constraints, such as limiting plant harvesting or restricting damage to critical habitats.

Oreoxis humilis is not known from Kansas, Nebraska, South Dakota, or Wyoming and is thus not currently listed or ranked in those states (Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002, Wyoming Natural Diversity Database 2003).

Existing Regulatory Mechanisms, Management Plans, and Conservation Practices

All of the *Oreoxis humilis* occurrences are wholly or partly within the USFS Pike-San Isabel National Forest in Colorado. Two occurrences are partially on private property owned by Colorado Springs Utilities (**Table 1**; Colorado Natural Heritage Program 2004). Thus, the majority of plants are on USFS lands, which are managed for multiple use, with an effort to prevent damage to occurrences of species of special concern.

Although *Oreoxis humilis* has been identified as a species of special concern by the Colorado NHP, this species is not currently listed as a USFWS threatened species or a USFS sensitive species. Therefore, there are no specific regulatory mechanisms at the federal level to regulate its conservation. This species may obtain protection from various general conservation strategies designed to protect plants and animals on USFS lands. While managing lands for multiple use, the USFS

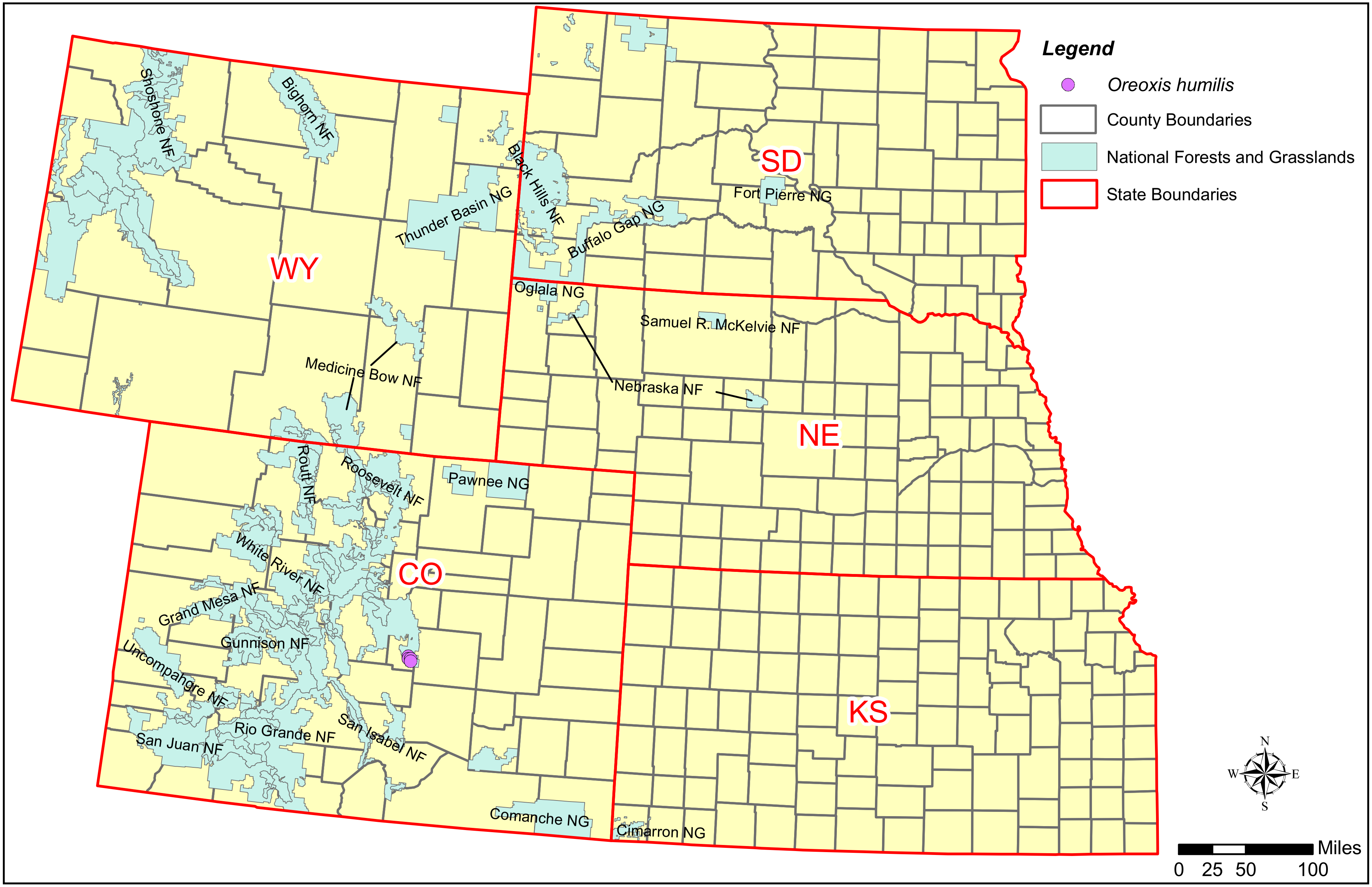

Figure 1. Map of US Forest Service (USFS) Region 2 illustrating distribution of four *Oreoxis humilis* occurrences in El Paso and Teller Counties, Colorado. Each occurrence may include one to several populations. Refer to document for abundance and distribution information. Sources: University of Colorado Herbarium (2003); Colorado Natural Heritage Program (2004); Colorado State University Herbarium (2004); Rocky Mountain Herbarium (2004).

Table 1. Information on four *Oreoxis humilis* occurrences in Colorado (USFS Region 2). Includes county, location, occurrence identifier, sub-occurrence identifier, dates of observation, estimated abundance, estimated area, element occurrence rank, and land management context. Estimated area is based on calculated attributes generated in ArcView GIS by the Colorado Natural Heritage Program. Key to element occurrence ranks: A – excellent estimated viability; C – fair estimated viability. Sources: University of Colorado Herbarium (2003); Colorado Natural Heritage Program (2004); Colorado State University Herbarium (2004); Rocky Mountain Herbarium (2004).

County	Location/ Occurrence Identifier	Sub-Occurrence Identifier	Date of Observations	Estimated Abundance	Estimated Area (hectares)	Element Occurrence Rank	Management Area/Owership
El Paso	Mount Garfield/Not Available (NA)	--	1901	Not Available (NA)	Not Available (NA)	Not Available (NA)	Pike-San Isabel National Forest
El Paso/ Teller	Pikes Peak/ 9187	--	1871, 1884, 1896, 1901, 1904, 1915, 1919, 1921, 1935, 1962, 1994, 1998, 2000	Common (1998); 2,000 (2000)	181.3	A	Pike-San Isabel National Forest; Private land
Teller	Sheep Mountain/ 7980	--	1998	Thousands; more expected	25.3	A	NA
Teller	Almagre Mountain/567	2492	1998	Hundreds; more expected	16.8	A	Pike-San Isabel National Forest
	Almagre Mountain/567	6692	1998	40; more expected	1.8	C	Pike-San Isabel National Forest

is directed to develop and implement management practices to ensure that species do not become threatened or endangered (USDA Forest Service 1995). The National Environmental Policy Act (U.S. Congress 1982) requires an assessment of the impacts of any significant USFS projects to natural environments.

Examples of specific management plans to reduce negative impacts to sensitive species in the Pikes Peak area include the *Pikes Peak Multi-Use Plan* (Design Workshop, Inc. 1999) and a drainage, erosion, and sediment control plan for the Pikes Peak highway (J. Hovermale personal communication 2004). The *Pikes Peak Multi-Use Plan* was developed by the USFS and Colorado Springs Utilities. It outlines the protection of natural resources within watersheds of the Pikes Peak area. While this plan does not specifically mention *O. humilis*, it does outline plans to pave the Pikes Peak toll road to reduce sedimentation and to minimize trail creation to reduce trampling impacts on fragile tundra communities (Design Workshop, Inc. 1999). Operation and maintenance of the Pikes Peak toll road is accomplished by the City of Colorado Springs under a special use permit with the USFS, and Pikes Peak Highway paving is associated with legal settlements and congressional mandates to protect watersheds in the Pikes Peak area (J. Hovermale personal communication. 2004). An environmental assessment examined the effects of the proposed sediment control actions, and a finding of no significant impact was signed in 2000 (J. Hovermale personal communication 2004). Paving of the Pikes Peak toll road started in 2001 and continues as part of a 12-year project (J. Hovermale personal communication 2004).

NHP databases draw attention to species of concern that potentially require conservation strategies for future success. In addition, based on element occurrence data, NHPs designate Potential Conservation Areas (PCA) that are important to the long-term survival of targeted species and natural communities. However, these species lists and PCAs are for planning purposes only and are not associated with specific legal constraints, such as restricting damage to habitats that support these plants. The Colorado NHP has designated the Pikes Peak PCA in the Pike-San Isabel National Forest as an area of outstanding biodiversity significance due to the presence of “every location of the Pikes Peak spring parsley (*Oreoxis humilis*) in the world”, as well as occurrences of at least six other rare plant species (Fayette and Grunau 1998, Colorado Natural Heritage Program 2001). In addition to the three occurrences that the Colorado NHP reports in the Pikes Peak PCA (occurrences on 9187, 7980, 567), there is also an additional occurrence outside the PCA (an occurrence on Mount Garfield, no occurrence identifier) (**Table 1**; Rocky Mountain Herbarium 2004).

Existing regulations do not appear to be adequate to conserve *Oreoxis humilis* over the long term, considering that the range of this species is extremely small, all occurrences may possibly be threatened by a variety of human-related or ecological threats, and this species is not considered a sensitive species by the USFS.

Biology and Ecology

Classification and description

Systematics and synonymy

Oreoxis humilis Rafinesque is in the genus *Oreoxis* of family Apiaceae (Carrot family), order Apiales, and group Dicotyledonae (dicots) of phylum Anthophyta (flowering plants) (NatureServe 2002). *Oreoxis humilis* was collected by E. James on July 14, 1820 (probably at Windy Point) and described by Rafinesque in 1830 (Rafinesque 1830, University of Colorado Herbarium 2003). In 1878, Gray described *Cymopterus alpinus* and considered *O. humilis* to be a synonym (Mathias 1930). Mathias (1930) produced a monograph of the genus *Cymopterus* with a discussion of related genera, including this species as *O. humilis*. One synonym for *O. humilis* is *C. humilis* (Raf.) Tidestrom and Kittell (Harrington 1954). Cronquist (1997) emphasized the close affinities among the genera *Cymopterus*, *Oreoxis*, *Pteryxia*, and *Pseudocymopterus*, and proposed treating *Oreoxis* species as *Cymopterus*. Harrington (1954) suggested that *O. humilis* was doubtfully distinct from *O. alpina*, and Weber and Wittmann (2001) echoed that, "The distinctions between these two species are not clearly stated in any descriptions…" R. Hartman has worked extensively with the Apiaceae family and suggested that *O. humilis* and *O. alpina* are distinct as a result of both morphological and chromosomal differences (i.e., *O. humilis* is diploid and *O. alpina* is tetraploid) (R. Hartman personal communication 2003). In addition, recent molecular studies to elucidate the phylogeny of western Apiaceae also support *O. humilis* and *O. alpina* as distinct species located in different clades (Sun et al. 2004). Overall, the phylogeny of perennial Apiaceae species endemic to the western U.S. is complex, and many genera (including *Oreoxis* and *Cymopterus*) are not monophyletic (Downie et al. 2002, Sun et al. 2004). Based on these preliminary findings, a complete reassessment of the limits of these genera is warranted (Sun et al. 2004).

This assessment treats this species as *Oreoxis humilis* Raf. as presented in the PLANTS database (USDA Natural Resources Conservation Service 2002), Integrated Taxonomic Information System database (Integrated Taxonomic Information System 2002), NatureServe database (NatureServe 2002), and Colorado NHP records (Colorado Natural Heritage Program 2004). Common names for *O. humilis* include Rocky Mountain alpine parsley (Weber and Wittmann 2001, USDA Natural Resources Conservation Service 2002) and Pikes Peak spring parsley (Colorado Natural Heritage Program 2004). The holotype specimen of *O. humilis* is housed at the New York Botanical Garden Herbarium (New York, NY). Within USFS Region 2, isotypes are housed at the University of Colorado Herbarium (Boulder, CO) and the Rocky Mountain Herbarium (Laramie, WY).

History of species

Oreoxis humilis was first collected in 1820 and has been considered in taxonomic treatments of Apiaceae (Rafinesque 1830, Coulter and Rose 1900, Mathias 1930, Mathias and Constance 1944, Cronquist 1997, Downie et al. 2002, Sun et al. 2003). No status assessment or detailed demographic, ecological, or biological studies of this species have been undertaken.

Morphological characteristics

Members of the family Apiaceae are characterized by ternately compound leaves with a sheathing petiole, umbellate flower clusters, fruits that separate into one-seeded units at maturity, and often a pungent odor or taste (Zomlefer 1994, Weber and Wittmann 2001). Flowers of these species are mostly uniform, with five minute sepals, five petals, five stamens, and an inferior ovary (Zomlefer 1994, Weber and Wittmann 2001).

The genus *Oreoxis* is endemic to the southern Rocky Mountains and is comprised of four species: *O. alpina* (Arizona, Colorado, Utah, Wyoming), *O. bakeri* (Colorado, New Mexico, Utah), *O. humilis* (Colorado), and *O. trotteri* (Utah) (Mathias and Constance 1944, Harrington 1954, Welsh and Goodrich 1985, Scott 1995). *Oreoxis* species are low (generally less than 10 centimeters [cm] tall), mat-forming, scapose, caespitose, acaulescent perennials from slender, elongated roots with once- to twice-pinnately compound leaves, white to yellow flowers in umbels, dimidiate involucel, and laterally flattened, winged fruits (Harrington 1954, Scott 1995, Weber and Wittmann 2001).

Oreoxis humilis is a perennial herb from 2 to 15 cm tall, with occasional puberulence at the base of the umbel and in the inflorescence (**Figure 2**; Mathias 1930, Harrington 1954). Weber (1976) suggested that this species is usually less than 5 cm tall. The leaves are 0.5 to 4.5 cm long and 0.5 to 1 cm wide (excluding the petioles, which are 1 to 4.5 cm long), singly or bi-pinnatisect, and with linear, acute end segments from 2 to 10 millimeters (mm) long and 1 to 2 mm wide. Weber (1976) stated that leaves of this species are usually 5 to 8 cm long, and the side pinnae are 5 to 10 mm long. The peduncles exceed the leaves, from 1 to 13 cm long; the umbels are several rayed, each ray 2 to 5 mm long; and the involucre is absent or rarely present as one inconspicuous linear bract. The yellow flowers are subtended by several linear involucel bractlets equaling the flowers. The fruits are oblong, boat-shaped, 3 to 5 mm long and 1.5 to 3 mm wide, with wings broadly linear in cross-section and mostly rounded at the apex. Oil tubes number 1 to 5 in the intervals and 3 to 6 on the commissure (Mathias 1930, Harrington 1954).

Oreoxis alpina is abundant on tundra in Colorado, but it is replaced by *O. humilis* on Pikes Peak (Weber and Wittmann 2001). *Oreoxis humilis* can be distinguished from *O. alpina* because the former has linear fruit wings and is mostly glabrous (Weber 1976, Colorado Natural Heritage Program 2004). The wings of *O. humilis* fruits are broadly linear in cross-section, whereas the wings of *O. alpina* fruits are obovate or ovate in cross-section (Harrington 1954). *Oreoxis alpina* is slightly puberulent, at least on the fruits, whereas *O. humilis* tends to be totally glabrous, occasionally puberulent near the inflorescence (Harrington 1954, Spackman et al. 1997, Weber and Wittmann 2001, Colorado Natural Heritage Program 2004). Weber (1976) also suggested that *O. humilis* tends to be generally larger in all respects compared to *O. alpina*. For example, the leaves of *O. humilis* tend to be 5 to 8 cm long, whereas the leaves of *O. alpina* are 5 cm long. However, both of these plants are very small (**Figure 2**), and the size of individual plants undoubtedly changes throughout the growing season, so size is likely not a reliable character for identification.

Oreoxis bakeri differs from *O. humilis* in that *O. bakeri* has broad, toothed, often purplish involucel bractlets (small bracts subtending the flowers) whereas *O. humilis* has linear, entire, and green bractlets (Kettler et al. 1993, Spackman et al. 1997). *Oreoxis humilis* differs from other Apiaceae species in the Front Range of Colorado by its tundra habitat, generally being much smaller (i.e., 5 cm high), and having a leafless flowering stem (Weber 1976).

Technical descriptions of *Oreoxis humilis* are presented in Mathias (1930), Mathias and Constance (1945), and Harrington (1954). A photograph and an illustration are available in Spackman et al. (1997).

Distribution and abundance

Oreoxis humilis is a regional endemic species found only on the Pike-San Isabel National Forest and Colorado Springs Utilities property on Pikes Peak in El Paso and Teller counties in Colorado (**Figure 1**, **Table 1**). This species is known from four occurrences within its range. An occurrence is any naturally occurring group of individuals of the same species that is separated by at least 1 mile across unsuitable habitat or 2 miles across suitable habitat that is not known to be occupied (Spackman 2000). Based on geographic information system (GIS) calculations by the Colorado NHP, the occurrences range from 1.8 to 181.3 hectares (ha) in size (**Table 1**). After performing multiple spot checks during a survey of the Pikes Peak area, Fayette and Grunau (1998) hypothesized that *O. humilis* can be expected anywhere above timberline in this area (Colorado Natural Heritage Program 2001).

Abundance estimates for the three occurrences observed in the last 10 years are: “2,000”, “thousands”, and “40 to hundreds” (**Table 1**; Colorado Natural Heritage Program 2004). The two populations of *O. humilis* that are partly on Colorado Springs Utilities property are estimated as “2,000” and “thousands” in the element occurrence record (**Table 1**; Colorado Natural Heritage Program 2004). Botanists estimate that the total abundance of this species could be up to tens of thousands of individuals (Colorado Natural Heritage Program 2004).

Element occurrence ranks based on observer judgment of *Oreoxis humilis* occurrence size and landscape context include three A-ranked occurrences (excellent likelihood of long-term viability, evidence of intact reproductive mechanisms, high quality habitat), one C-ranked occurrence (fair estimated viability, somewhat degraded habitat), and one unranked occurrence (Spackman 2000, Colorado Natural Heritage Program 2004).

(A)

Photograph by William Jennings. Reprinted with permission from the photographer.

(B)

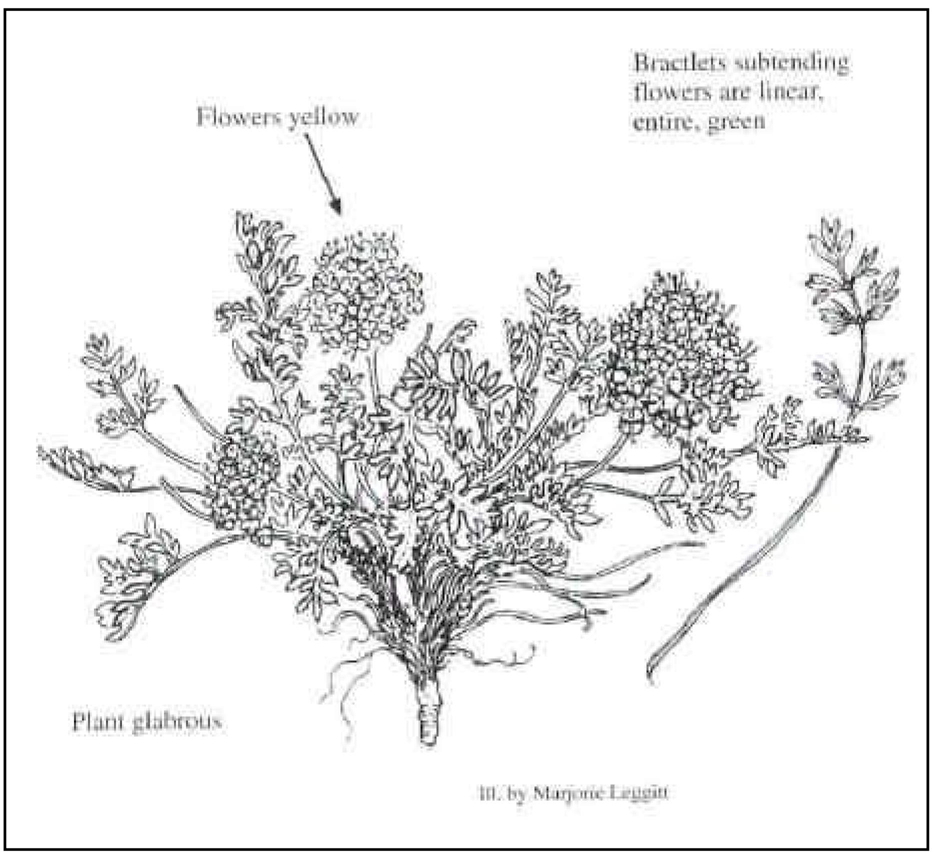

Illustration by Marjorie Leggitt. Reprinted with permission from the artist.

Figure 2. *Oreoxis humilis* (A) photograph in its natural habitat, and (B) illustration of the vegetative and reproductive structures.

Population trends

There are no data on population trends for *Oreoxis humilis*. Although population sizes have been estimated in some cases, multi-year population or demographic monitoring has not been initiated for any site. There is currently no evidence of drastic population declines. Surveys in 2001 led to the discovery of thousands of individuals, and this species is hypothesized to occur everywhere above timberline in the Pikes Peak area (Colorado Natural Heritage Program 2001).

Habitat characteristics

Oreoxis humilis is a perennial forb inhabiting granitic substrates in subalpine and alpine habitats from 3,290 to 4,270 m (10,800 to 14,000 ft.) on Pikes Peak (**Table 2**; Colorado Natural Heritage Program 2004). Existing populations occur from 3,440 to 4,240 m (11,280 to 13,900 ft). This species has been reported growing in: (1) alpine fellfields and meadows above treeline (e.g., *Kobresia myosuroides* Herbaceous Alliance V.A.5.N.h.15), (2) bristlecone pine-spruce (*Pinus aristata – Picea engelmannii*) krumholtz and tundra, and (3) below treeline in spruce-fir (*Picea engelmannii - Pseudotsuga menziesii*) forest with scattered bristlecone pine (e.g., *Picea engelmannii* Forest Alliance I.A.8.N.c.29) (**Table 2**; Grossman et al. 1998, Colorado Natural Heritage Program 2004). Spatial data from the USFS categorizes vegetation cover types at *O. humilis* locations as grassland, barren rock, shrubland, or spruce/fir, and classifies habitat structural stages at these locations as "unknown" (USDA Forest Service 2003b). Plant species associated with *O. humilis* include forbs, grasses, sedges, mosses, and lichen (Colorado Natural Heritage Program 2004); refer to **Table 2** for a list of associated plant species at each location.

Oreoxis humilis is generally found on summit alpine ridges, on large boulder outcrops, in alpine "rock gardens" (i.e., rocky areas), on stabilized talus slopes, and in grassy tundra (Colorado Natural Heritage Program 2004). The substrates of *O. humilis* microhabitats are generally coarse, comprised of gravel, rocks, or boulders weathered from granites of the Pikes Peak batholith. The parent material is a Precambrian core of old granites, such as Pikes Peak granite and the younger Windy Point granite (Wobus et al. 1976, Chronic 1980, Chumley 1998). Pikes Peak granite is pink to reddish tan, medium to coarsely crystalline biotite, hornblende-biotite, or quartz monzonite, and the Windy Point granite is gray to pink, fine to medium crystalline prophyritic granite or quartz monzonite (Wobus et al. 1976). The geology of the Pikes Peak area has created a unique habitat for *O. humilis*, and this species is limited to Pikes Peak and Windy Point granites (Fayette and Grunau 1998, Colorado Natural Heritage Program 2001). Information for occurrence 9187 indicated that some *O. humilis* plants were growing in xeric microsites, while other plants were growing in wet areas near melting snow streamlets. The slopes ranged from 0 to 60 degrees of all aspects (**Table 2**). Exposure was reported as full sun for occurrence 9187 and partial shade for sub-occurrence 6692. The only record of groundcover was at the forested site (sub-occurrence 6692), with an estimate of 60 percent vegetation cover, 30 percent litter cover, and 10 percent gravel cover (Colorado Natural Heritage Program 2004).

Reproductive biology and autecology

The biology of *Oreoxis humilis* has not been studied, and details concerning its reproductive system are largely unknown. In this and subsequent sections, we summarize available observations of *O. humilis* as well as present information, where available, from other Apiaceae species endemic to USFS Region 2 or adjacent states. These comparisons are not meant to imply that *O. humilis* necessarily reproduces in a similar manner, but they represent an effort to elucidate *potential* reproductive mechanisms for this species and suggest avenues for future research.

Reproduction

Oreoxis humilis produces an umbellate inflorescence with a cluster of small, perfect flowers (Petersen 1977, Puterbaugh 1998). This species flowers from June to August and fruits in August (Kettler et al. 1993, Spackman et al. 1997). The extent of sexual or vegetative reproduction is unknown, although this species is thought to be non-rhizomatous (R. Hartman personal communication 2003). It is also unknown if *O. humilis* relies on outcrossing, self-fertilization, or a combination; the details of the breeding system have not been studied. Members of the Apiaceae are generally equipped to attract pollinators and cross-pollinate; cross-pollination is probably promoted through protandry or protogyny (Zomlefer 1994). The extent of these characteristics in *O. humilis* is not known, and evidence from *O. alpina*, a closely-related species known from alpine habitats, provides conflicting evidence of whether these species are obligate outcrossers or self-compatible. A study of *O. alpina* by Petersen (1977) found that self-pollination does not occur readily; only 6 percent of covered flowers set any seed (Petersen

Table 2. *Oreoxis humilis* habitat characteristics. Includes location, occurrence and sub-occurrence identifiers, elevation, general habitat description, associated plant species, substrate, slope, and aspect. Sources: University of Colorado Herbarium (2003); Colorado Natural Heritage Program (2004); Colorado State University Herbarium (2004); Rocky Mountain Herbarium (2004).

County	Location/ Occurrence Identifier	Elevation Range (meters)	General Habitat Description	Associate Plant Species	Substrate	Slope (degrees)	Aspect
El Paso	Mount Garfield/Not Available (NA)	3,850	Not Available (NA)	Not Available (NA)	Not Available (NA)	Not Available (NA)	Not Available (NA)
El Paso/ Teller	Pikes Peak/ 9187	3,566 to 4,237	Gravelly tundra, stabilized talus, xeric alpine fellfield, wet and dry meadows, above timberline	Forbs, grasses, and mosses; *Allium* spp., *Androsace chamaejasme* ssp. *carinata, Artemisia* spp., *Bistorta* spp., *Castilleja* spp., *Ciliaria montana, Cirsium scopulorum, Claytonia* spp.,*Eritrichium aretioides, Geum* spp., *Hirculus platysepalus* ssp. *crandallii, Mertensia alpina, Micranthes rhomboidea, Noccaea* spp., *Paronychia pulvinata, Pedicularis* spp., *Phlox* spp., *Polemonium viscosum, Primula* spp., *Selaginella* spp., *Sibbaldia* spp., *Stellaria* spp., *Telesonix jamesii, Trifolium* spp., and *Trifolium nanum*.	Pikes Peak and Windy Point granite; rocky soil, little soil development	0 to 60	South and southeast
Teller	Sheep Mountain/ 7980	3,566 to 3,755	Summit of alpine ridges, large boulder outcrops, rock gardens, grassy tundra	Forbs, grasses, sedges, and lichen; *Achillea lanulosa, Allium* spp., *Artemisia* spp., *Bistorta* spp., *Campanula* spp., *Geum* spp., *Hymenoxys grandiflora, Mertensia* spp., *Pentaphylloides* spp., *Potentilla* spp., *Sedum* spp., *Stellaria* spp., *Telesonix jamesii,* and *Trifolium* spp.	Granite gravel	0 to 60	All aspects, west
Teller	Almagre Mountain/567 (2492 and 6692)	3,536 to 3,697	Bristlecone pine and Engelmann spruce krummholtz and tundra	Forbs and grasses; *Artemisia* spp., *Bistorta* spp., *Castilleja* spp., *Erigeron pinnatisectus, Gentiana* spp., *Geum* spp., *Kobresia* spp., *Mertensia alpina, Penstemon* spp., *Phlox* spp., *Potentilla* spp., *Rhodiola integrifolia, Stellaria* spp., *Telesonix jamesii,* and *Trifolium* spp.	Boulders, rocks, granite gravel, little soil development	0 to 40	NA
		3,438	Below treeline in spruce-fir forest with scattered bristlecone pine	Forbs and grasses; *Geum* spp., *Pentaphylloides* spp., *Potentilla* spp., *Rhodiola integrifolia, Sedum lanceolatum, Solidago* spp., *Stellaria* spp.	NA	NA	NA

1977). Self-fertilization was presumably discouraged because stigmas mature and protrude from the flowers while anthers are still held within tightly closed petals (Petersen 1977). In contrast, Puterbaugh (1998) hypothesized that *O. alpina* may have autogamous seed set, based on pollination studies of this species in the Park Range of Colorado. Petersen (1977) hypothesized that *O. alpina* was not agamospermous, as flowers with stigmas removed did not set seed, but Puterbaugh (1988) did not rule out the possibility for agamospermy in *O. alpina*. *Oreoxis humilis* may or may not be agamospermous or cross-fertilizing; there have been no pollination or reproduction studies of this species.

One element occurrence record of *Oreoxis humilis* noted that reproductive mechanisms were intact because a large proportion (up to 75 percent) of the population had flowers and there was evidence of multiple size/age classes. However, the number of fruits per plant or the production of viable seed was not studied, and more detailed descriptions of size classes were not provided. Other records simply noted that there was a mixture of vegetative and reproductive individuals (Colorado Natural Heritage Program 2004). Refer to the following sections for further information: Life history and strategy, Pollinators and pollination ecology, and Dispersal mechanisms.

Life history and strategy

There have been no studies on the life history, demographic rates, fecundity, or longevity of *Oreoxis humilis*. It is a perennial forb growing with a slender taproot in alpine habitats. This species may be considered an S-selected, or stress-tolerant species, because of its perennial life history, ability to withstand relatively unpredictable and unproductive conditions, and capability to access resources with a taproot (Grime 1979, Barbour et al. 1987). The hypothesized life cycle of this perennial plant is depicted in **Figure 3**.

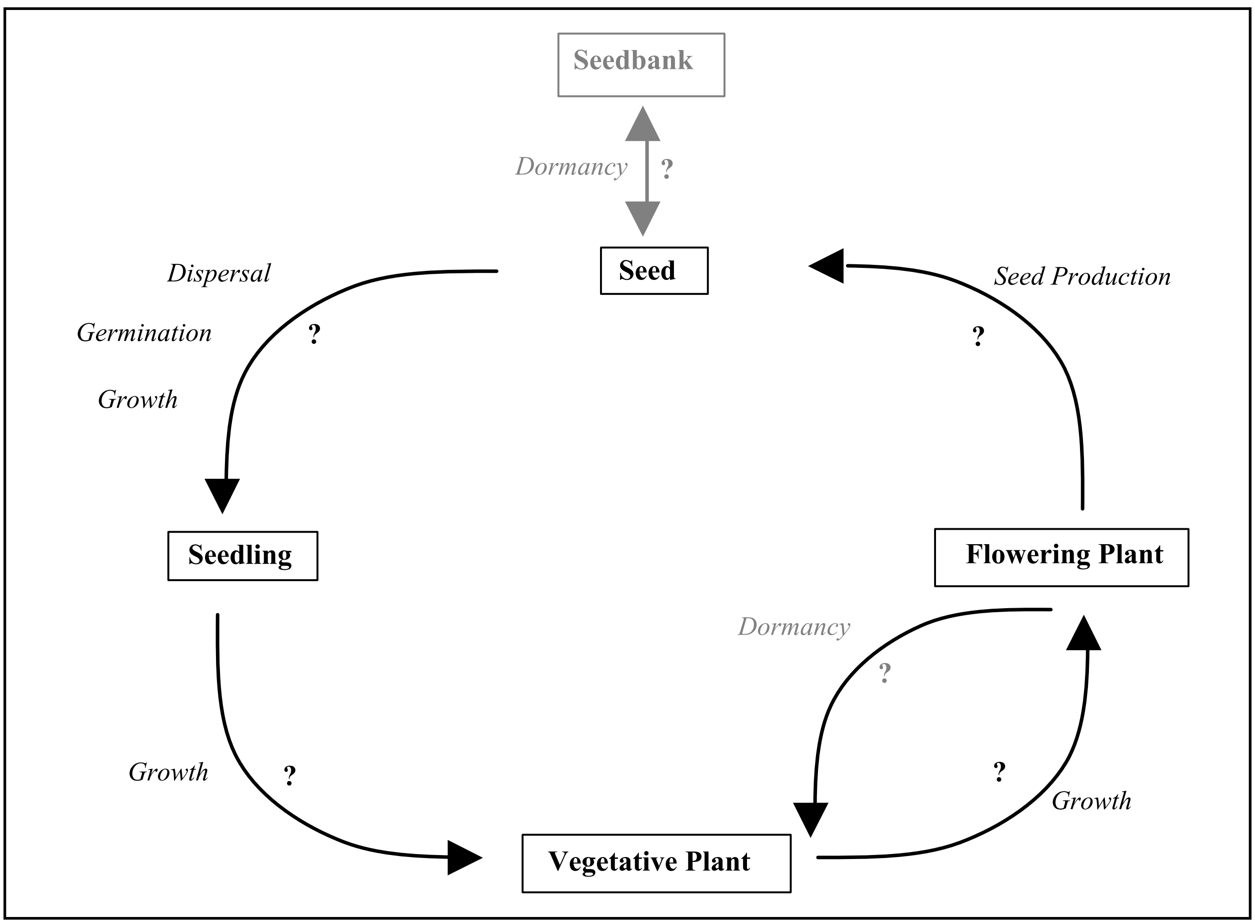

Figure 3. Schematic representation of the hypothesized life cycle of *Oreoxis humilis*. Rates of recruitment, growth, dormancy, fecundity, and dispersal are unknown and are indicated by "?". The presence of a seedbank is also unknown for this species. The existence of clonal growth has not been studied, but this species is thought to be non-rhizomatous. Death at each stage and mortality rates are not indicated on this figure. Figure adapted from Grime (1979).

Many alpine plants share similar strategies and adaptations to harsh environmental conditions and a short growing season (Grime 1979, Zwinger and Willard 1996). Many alpine plants, including *Oreoxis humilis*, have a perennial life history because the short growing season precludes annual plants from producing stems, leaves, flowers, and fruit in a few months. Using food reserves stored underground in roots allows alpine perennials to flower early in the season and to take advantage of the short summer heat to ripen seeds. In addition, many alpine plants have extended growth patterns where it may take many years for a plant to grow, produce buds, and eventually flower and set seed.

The morphology of *Oreoxis humilis* and other alpine plants also helps to increase survival in harsh conditions such as cold temperatures, desiccating winds, intense solar radiation, and low moisture (Grime 1979, Zwinger and Willard 1996). These conditions are especially intense in *O. humilis* habitat, which can include fellfields, boulder outcrops, and gravelly slopes with dry soils and sparse plant cover. When growing in exposed areas, this species must contend with environmental conditions such as high water runoff, intense solar radiation, and strong winds. A study of *O. alpina* found that this species is capable of withstanding harsh winds and prolonged snow cover in alpine habitats (Petersen 1977). Puterbaugh (1998) also found that *O. alpina* occurred in alpine fellfields, which are typically rocky, windy, and dry year-round as a result of low snow accumulation. The low growth and small size of *O. humilis* and *O. alpina* presumably keep individuals out of harsh winds, reduce plant tissue growth needs, create less distance to transport water, allow interception of both solar radiation and ground-reflected radiation, and afford protection to the inner parts of the plant. Many alpine plants also grow extensive roots in order to anchor them in strong winds and to exploit precious moisture (Zwinger and Willard 1996).

Pollinators and pollination ecology

Pollination biology and specific pollination mechanisms for *Oreoxis humilis* have not been studied. Members of the Apiaceae family are well-equipped to attract pollinators with open flowers and easily accessible nectar secreted by the disc at the ovary apex (Zomlefer 1994). Possible pollinators for these small flowers within dense inflorescences include small flies, bees, beetles, moths, and other insects (Zomlefer 1994). Petersen (1997) studied the morphological characteristics of *O. alpina* in an alpine habitat on the Front Range of Colorado and hypothesized that ants (Hymenoptera: Formicidae) play a large role in pollination for this species. *Oreoxis alpina* has characteristics common to ant-pollinated plants, such as nectaries accessible to short-tongued insects, short stems, dense stands in impoverished plant communities, few synchronously blooming flowers, sessile flowers, small and few pollen grains, few seeds per flower, flowers less than 4 mm in diameter, and small quantities of nectar (Petersen 1997). Small, plain flowers with small amounts of nectar are generally unattractive to flying pollinators with high energy requirements. In addition, ants are important pollinators in alpine tundra habitats, where high winds and cold temperatures discourage other pollinators (Petersen 1977). Although *O. alpina* was commonly visited by species of flies (Diptera: *Philygra*) and other insects, ants (Hymenoptera: *Formica* and *Leptothorax*) represented 75 percent of the visitation. In addition, 80 percent of the ants captured near *O. alpina* individuals were carrying its pollen on their bristles (Petersen 1977). Puterbaugh (1998) also found high ant visitation on *O. alpina* in the Park Range of Colorado, where ants frequently visited umbels, carried numerous pollen grains, regularly contacted reproductive structures on the plants, and often moved between umbels (i.e., possible cross-pollination). However, Puterbaugh (1998) found that seed set in *O. alpina* appeared to be unaffected by this ant activity, possibly because this species is not limited by pollen or because it is autogamous or agamospermous (as indicated by high seed set for covered flowers). Thus, the role of ant pollination and the extent of self-fertilization for *O. alpina* are not clear.

Oreoxis humilis is similar to *O. alpina* in morphology and habitat, and ants may or may not play a role in the pollination of this species. Important issues related to the pollination of rare plants that have yet to be researched for *O. humilis* include the extent of self-pollination, the identification of effective pollinators, the effect of plant density on pollination, genetic implications of pollination, and the effect of environmental fluctuations on pollination.

Dispersal mechanisms

Details of seed dispersal mechanisms in *Oreoxis humilis* or related species have not been studied. This species has wings on the seeds that presumably facilitate wind dispersal, and windy weather is common at high elevations. Water movement (e.g., sheets of rain, snow meltoff), soil movement (e.g., erosion), and animal vectors (e.g., ants) could also disperse the seeds. Presumably, dispersal success of *O. humilis* may depend on wind and precipitation patterns, substrate characteristics, animal activities, topographic heterogeneity, and the availability of suitable "safe" sites.

Seed viability and germination requirements

No information is available concerning the fertility, seed viability, and germination requirements of *Oreoxis humilis* or related species.

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in height, leaf size, flowering time, or other attributes, with change in light intensity, latitude, elevation, or other site characteristics. An element occurrence record for an occurrence of *Oreoxis humilis* that spanned an elevation range noted that plants were in fruit at lower elevations and in flower at higher elevations (Colorado Natural Heritage Program 2004). This is most likely the result of a longer growing season at lower elevations. There were no notes about the existence of other morphological variations.

Cryptic phases

No information regarding cryptic phases of *Oreoxis humilis* or related species is available. Seed dormancy can be an important adaptation for plant populations to exploit favorable conditions in a harsh environment (Kaye 1997). It is not known whether a persistent seed bank exists or what the extent of seed dormancy is for *O. humilis*. Details of seed longevity, patterns of seed dormancy, and factors controlling seed germination for *O. humilis* have not been studied.

Mycorrhizal relationships

The existence of mycorrhizal relationships with *Oreoxis humilis* or related species was not reported in the literature.

Hybridization

There is no reported evidence of hybridization with *Oreoxis humilis*. The genetic differences or evolutionary relationship between *O. humilis* and closely-related *O. alpina* have not been studied. *Oreoxis alpina* is a polyploid species, with a diploid chromosome count of approximately 44 (Crawford and Hartman 1972). Other Apiaceae species are generally 2n = 22 (Crawford and Hartman 1972), and *O. humilis* is also thought to be 2n = 22 (R. Hartman personal communication 2003).

Demography

Little is currently known about population demographics in *Oreoxis humilis*. However, as discussed previously, research on other related Apiaceae species, where available, may provide insights into some of the ecological, spatial, and genetic considerations for *O. humilis* demography.

Life history characteristics

There is no information regarding population parameters or demographic features of *Oreoxis humilis*, such as metapopulation dynamics, life span, age at maturity, recruitment, and survival. Although this species has a perennial habit and has been noted to produce flowers, specific information is not available to develop a quantitative life history model.

Refer to **Figure 4** and **Figure 5** for envirograms outlining resources and malentities potentially important to *Oreoxis humilis*. An envirogram is a schematic diagram, first introduced by Andrewartha and Birch (1984) for animal species, that depicts the relationships between a target organism and environmental conditions. The centra are the main categories (i.e., resources and malentities) that directly affect the target species, and the web outlines the factors that indirectly influence the centra. The web depicts the most distal to most proximal factors using linear, one-way branches. Because there is a paucity of ecological information about this species, the envirograms outline hypothesized resources and malentities that are *potentially* important for *O. humilis*. Additional information would be needed to create more comprehensive and specific envirograms.

Life cycle diagram and demographic matrix. Life cycle diagram and demographic matrix. A life cycle diagram is a graphical model that represents the dominant life history stages for a species and the transitions between those stages or vital rates. The diagram consists of a series of nodes that represent the different life stages connected by various arrows for vital rates (i.e., survival rate, fecundity). Demographic parameters, such as recruitment and survival rates, are not currently available for *Oreoxis humilis*, and so there are no definitive data regarding the vital rates that contribute to species fitness. Although stage-based models based on population matrices and transition

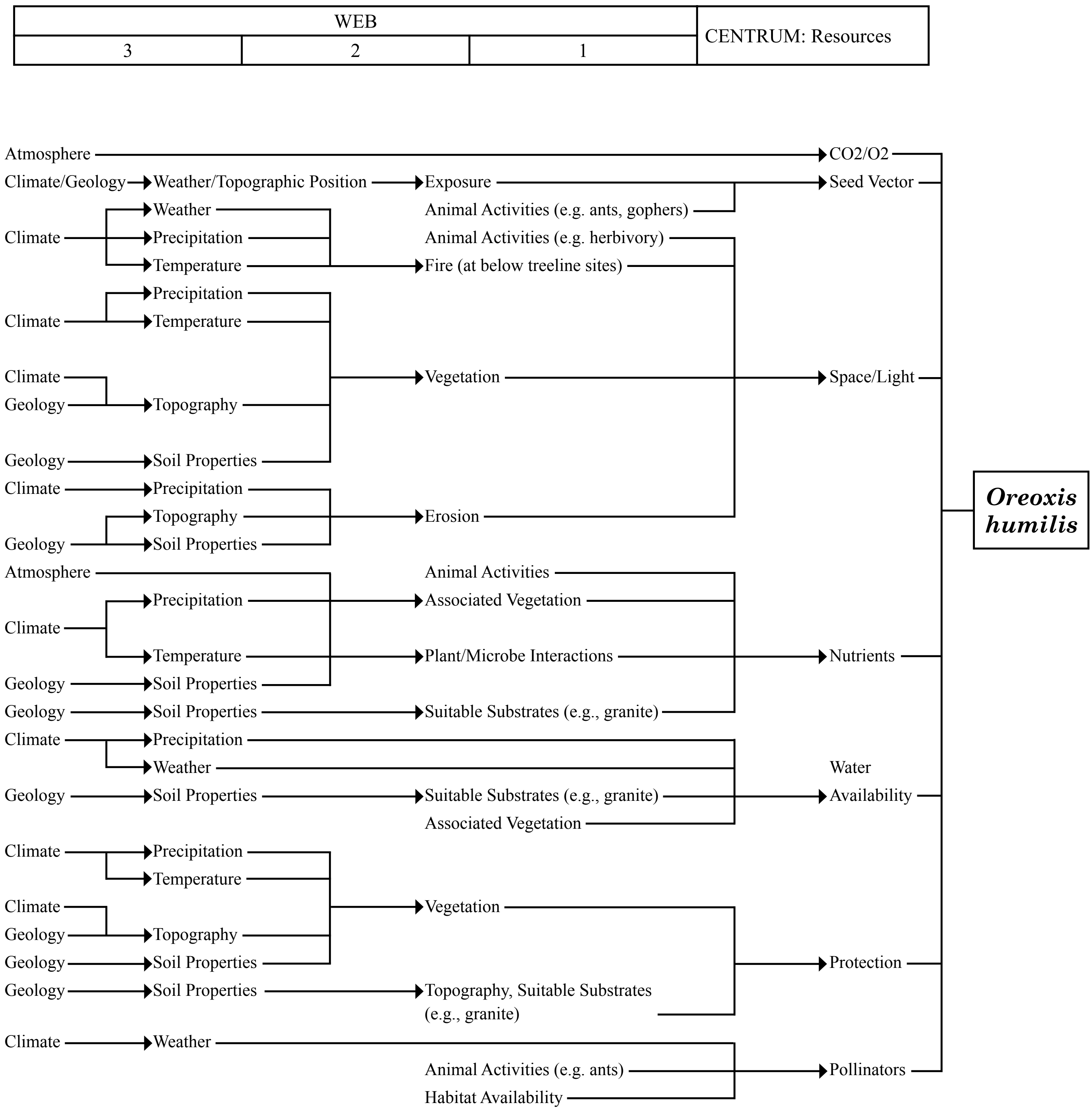

Figure 4. Envirogram outlining potential resources for *Oreoxis humilis*. An envirogram depicts direct and indirect factors that may influence a species. The centrum includes the most proximate factors and the web includes more distal factors.

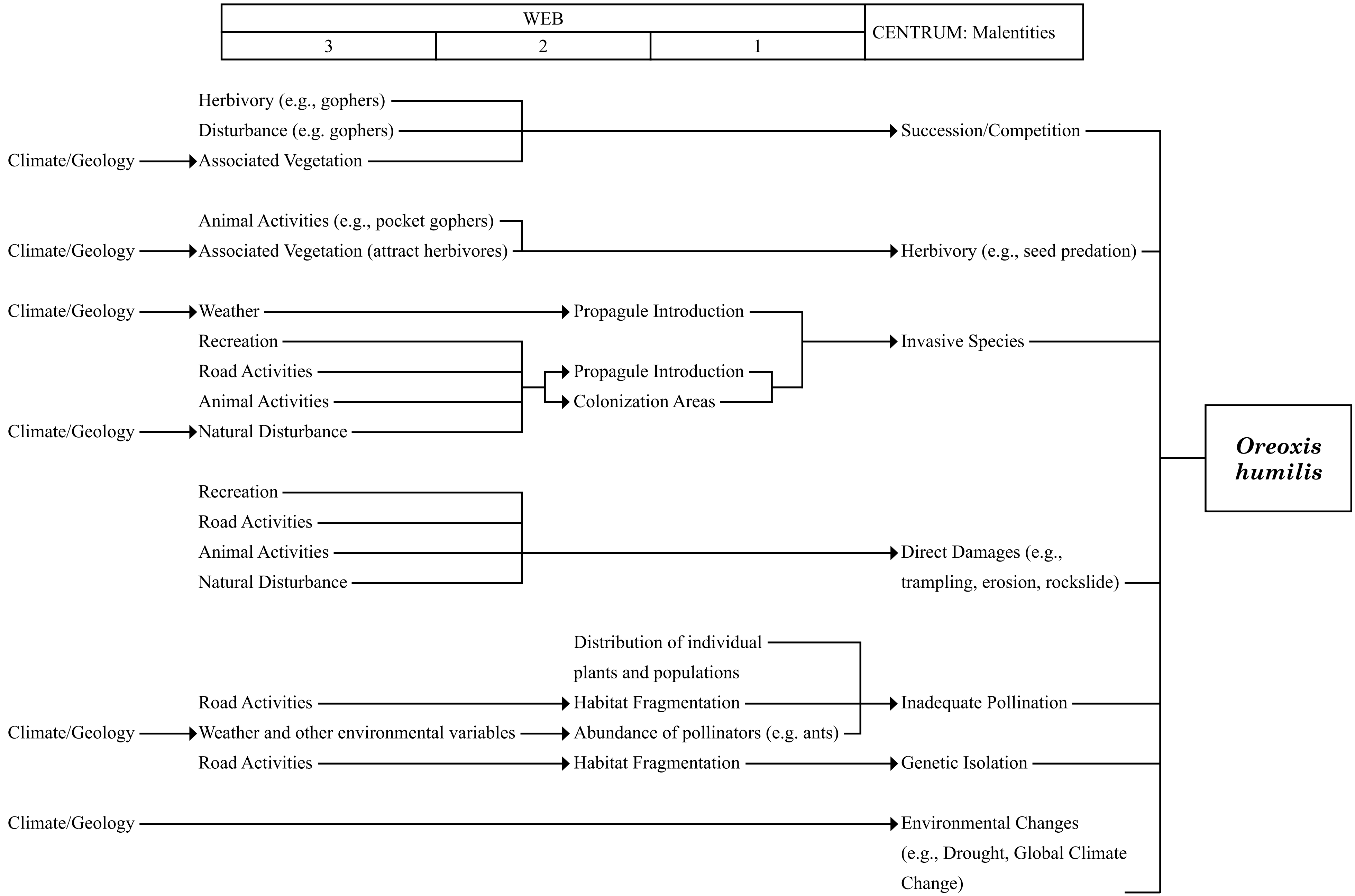

Figure 5. Envirogram outlining malentities to *Oreoxis humilis*. An envirogram depicts direct and indirect factors that may influence a species. The centrum includes the most proximate factors, and the web includes more distal factors.

probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model. For *O. humilis*, the stages that could potentially be incorporated into a demographic matrix include seed, seedling, vegetative individuals, and reproductive adults (**Figure 3**).

Presumably, seeds of *Oreoxis humilis* are dispersed to suitable locations. The probability of germination and subsequent establishment depends on the longevity of these propagules and whether appropriate environmental conditions exist for germination and growth. Seeds that germinate can grow into seedlings, assimilate resources, and mature into reproductive individuals. Growth rates may be influenced by the intensity and frequency of disturbance and the availability of resources, such as space, light, moisture, and nutrients. Successful seed set will depend on the rate of pollen and ovule formation, pollination, fertilization, and embryo development. Fecundity rates depend on the production of seeds and the percentage of those seeds that survive to germination in subsequent years.

Population viability analysis. In order to initiate a population viability assessment for *Oreoxis humilis*, the rates of germination, fecundity, survival, and other important parameters require additional study.

Ecological influences on survival and reproduction

Germination, growth, seed production, and long-term persistence of *Oreoxis humilis* most likely depend on a range of ecological influences over many years, including climatic fluctuations, microsite conditions, herbivory, disturbance patterns, interspecific competition, seed predation, and pollinator activities. Refer to **Figure 4** for an envirogram outlining resources potentially important to *O. humilis*. There is little information on the capabilities of *O. humilis* to disperse, colonize, and establish new populations around the landscape. The establishment of new populations most likely depends on barriers to dispersal and the availability of suitable germination sites and conditions. The rate of population growth may also be influenced by factors that would affect sexual reproduction, such as pollinator limitations.

It is also unclear what type, size, intensity, or frequency of disturbance regime is important for *Oreoxis humilis*. Disturbances in mountainous environments can include erosion/deposition, fire, blowdowns, frost heaving, wind-scouring, herbivore activity, environmental fluctuations, and human influences (Zwinger and Willard 1996). These disturbances could either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on the location and intensity of the disturbance. For example, *O. humilis* occurrences on talus slopes could be extirpated by erosion or rockslide, or new suitable habitat could be created for future populations. Fayette and Grunau (1998) noted that substrates of Pikes Peak granite are highly erodible and that vegetation may not be able to survive accelerated erosion rates from poorly managed roads or off-road activity. Most occurrences of *O. humilis* are unlikely to be directly affected by blowdowns or fire because they generally occur above treeline in rocky areas with minimal ground fuels. However, *O. humilis* is known from one occurrence below treeline and potentially could be affected by the direct or indirect effects of fire.

Spatial characteristics

The spatial distribution of *Oreoxis humilis* has not been studied. Puterbaugh (1998) found that *O. alpina* attained maximum densities of 29 flowering rosettes per meter squared in alpine fellfields of the Park Range, but the density of *O. humilis* has not been recorded. The range of *O. humilis* is restricted, and the extent to which gene flow occurs between individuals and populations is unknown. Characteristics that could influence the spatial distribution of this rare species may include habitat availability, snowpack characteristics, seed dispersal patterns, competition with other vegetation, landscape and microsite heterogeneity, and disturbance patterns.

Genetic characteristics and concerns

Genetic concerns, such as the amount of genetic variability between and within the four occurrences, have not been studied for *Oreoxis humilis*. Issues related to gene flow, inbreeding, and genetic isolation could affect the demography, ecology, management considerations, and long-term persistence for this species. Assessing the genetic variability of populations is also important for establishing conservation plans to protect genetic diversity and to design reintroduction plans.

Factors limiting population growth

There is insufficient knowledge about *Oreoxis humilis* or related species to determine factors limiting population growth. The rate at which colonization and establishment of new populations occurs is unknown. Population growth or establishment of *O. humilis* could possibly be limited by competition with other species (e.g., invasive species), ineffective pollination, environmental changes (e.g., changes to snowpack characteristics or temperature regime), inadequate genetic variability for long-term persistence, or reduced habitat availability as a result of human-related changes or environmental fluctuations.

Community ecology

Herbivores and relationship to habitat

The extent or effects of herbivory on *Oreoxis humilis* are unknown. *Oreoxis humilis* could possibly be affected by grazing or trampling disturbances by herbivores such as large ungulates (e.g., elk, deer, bighorn sheep, mountain goats), small mammals (e.g., pika, marmots, gophers, hares), or insects (e.g., ants, beetles). One of the largest bighorn sheep populations in Colorado occurs on Pikes Peak (Fitzgerald et al. 1994), but the possible effects of sheep on *O. humilis* or its habitat have not specifically been studied. Mountain goats have become common in other mountainous areas of Colorado (i.e., Mount Evans) and could potentially "invade" the Pikes Peak area as well (W. Weber personal communication 2004). The palatability of *O. humilis* to herbivores is largely unknown. Kufeld (1973) studied the diets of Rocky Mountain elk and categorized *O. alpina* as a highly valuable food item for elk during the summer. *Oreoxis humilis* is presumably also a palatable food source for elk. Herbivory and burrowing actions of gophers can also affect alpine plant species (e.g., Thomson et al. 1996), but the effects of gophers on *O. humilis* have not been studied. Ants may play a role in the pollination of tundra plant species, but they can also damage flowers while seeking lipids in the flower tissues (Puterbaugh 1998).

Competitors and relationship to habitat

The interactions of *Oreoxis humilis* within the plant community are not well known. The severity of competition for resources is not known, but it is likely to be minimal at sparsely vegetated, harsh, rocky sites and more significant in grassy meadows. Plants co-occurring with *O. humilis* could compete for available resources or possibly facilitate the accumulation of organic material and moisture. Succession tends to be a slow process in alpine environments, but historical evidence demonstrates that, over a long time, cushion plants of fellfields can be outcompeted by taller grasses and sedges to form alpine meadows (Zwinger and Willard 1996). The characteristics of the natural fire regime and the response of *O. humilis* to fire have not been studied. Fuel loads in alpine habitats are probably minimal and patchily distributed, resulting in spot fires with low temperatures that would not kill deep-rooted perennials. Fire may play a larger role for *O. humilis* at the below-treeline site.

Element occurrence records do not specifically note that exotic species are a potential threat to *Oreoxis humilis*. The introduction of exotic species can be a secondary effect of trail and road construction, and in some instances, exotic species can outcompete or replace native plants by using space, nutrients, and water. Potential montane, subalpine, and alpine non-native invasive plant species in Colorado include *Cirsium arvense* (Canada thistle), *Carduus nutans* (musk thistle), *Chrysanthemum leucanthemum* (ox-eye daisy), *Linaria vulgaris* (yellow toadflax), *Matricaria perforata* (scentless chamomile), *Phleum pratense* (timothy grass), *Taraxacum officinale* (dandelions), and *Trifolium repens* (white clover) (Chumley 1998). Fayette and Grunau (1998) recorded the presence of *Linaria vulgaris* on the Pikes Peak tollway and along the cog railroad but noted that it had not yet moved into the natural vegetation. In 2003, S. Tapia (personal communication 2003) reported that *L. vulgaris* in subalpine areas had spread significantly from roadside areas and was encroaching populations of other rare native plant species. The relationship (i.e., nearness) of these invasions to existing occurrences of *O. humilis* is not known. The threat of exotic species to *O. humilis* most likely differs from site to site depending on geographic location, elevation, distance from weed hotspots (e.g., roads and trails), dispersal mechanisms, and other factors related to disturbance factors. In addition, the competitive abilities of *O. humilis* compared to those of non-native species have not been studied.

Parasites and disease

Evidence for parasites or diseases on *Oreoxis humilis* or related species was not reported in the reviewed literature. However, W. Weber noted (personal communication 2004) that the only alpine Rocky Mountain plant he knows of without a specific fungus rust is *Chionophila* spp.

Symbiotic interactions

Insect pollination of flowering plants is an example of an important symbiotic interaction. Plants lure insects to a pollen or nectar reward, and the insects carry pollen to other flowers, thus helping to cross-fertilize the plants. Specific details concerning pollination ecology of *Oreoxis humilis* are largely unknown. The positive interactions between other associated plant or microbial species and *O. humilis* are also unknown.

Habitat influences

Oreoxis humilis appears to be edaphically endemic to exposed granitic substrates on Pikes Peak and Windy Gap granite. Within areas with suitable substrates, *O. humilis* inhabits a variety of microhabitats, ranging from rocky outcrops to stabilized talus slopes to grassy meadows, with different slopes and aspects (Colorado Natural Heritage Program 2004). The availability and quality of suitable microsites may depend on heterogeneity in topography, environmental fluctuations, disturbance factors, and competition with other species.

CONSERVATION

Threats

Threats to the long-term persistence of *Oreoxis humilis* in USFS Region 2 are mostly unknown because of the lack of species understanding and specific research. The information presented in this section is primarily based on observations in occurrence records (Colorado Natural Heritage Program 2001, Colorado Natural Heritage Program 2004) and personal communications with resource management specialists and botanists (J. Hovermale personal communication 2004, S. Olson personal communication 2004, W. Weber personal communication 2004). *Oreoxis humilis* populations and habitat throughout its range, including USFS Region 2 lands, are potentially threatened by human-related actions and environmental changes. These factors are summarized in an envirogram outlining malentities potentially important to *O. humilis* (centrum) and the indirect variables affecting those centrum factors (**Figure 5**). It is important to note that the malentities outlined on the envirogram are possible threats to be researched and they are not definite threats that have been identified as causing population declines.

Populations of *Oreoxis humilis* could potentially be threatened by a variety of human-related activities (e.g., road-related impacts, recreation), or ecological changes (e.g., global climate changes, invasive species introduction). The specific threats will likely vary for each occurrence or group of individuals, depending on the landscape context. For example, *O. humilis* could occur anywhere above timberline on Pikes Peak (Colorado Natural Heritage Program 2001), and recreational activities occur predominantly in certain high-use areas. While individuals near trailheads or tourist viewpoints could suffer intense impacts from direct trampling, road dust, associated erosion and deposition, individuals located a distance away from these areas may not experience the same threats. In addition, human-related activities and other disturbances can either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on the frequency, intensity, size, and location of the disturbance. For example, one element occurrence record indicated that a large group of individuals was located in an area with evidence of past disturbance (Colorado Natural Heritage Program 2004); however, the timing of the disturbance in relation to colonization by the species is not known. Direct impacts could either damage the existing individuals or reduce reproductive success, available habitat, establishment of new occurrences, or other factors important for the long-term persistence of the species.

Oreoxis humilis occurrences are all located in the Pikes Peak area, which is near urban population centers along the Front Range area of Colorado and is popular with recreationalists (J. Hovermale personal communication 2004, S. Olson personal communication 2004). Direct or indirect negative impacts to *O. humilis* populations or habitat by human-related activities could occur from motorized and non-motorized recreation, trail or road construction and maintenance, invasive species introduction, structure construction and maintenance, or crystal collecting (Fayette and Grunau 1998, Colorado Natural Heritage Program 2004). Those occurrences closest to roads, trails, rock-climbing areas, or other human-related structures (e.g., radio towers) are likely at the most risk.

Disturbances associated with roads (e.g., trampling, erosion/sedimentation, introduction of non-native seeds) may be the most significant potential threat to *Oreoxis humilis*. All of the occurrences of *O. humilis* are potentially near trails, roads, or railroads (Colorado Natural Heritage Program 2004). The Pikes Peak toll road is creating substantial and significant erosion and sedimentation issues for the surrounding landscape (Fayette and Grunau 1998, Colorado Natural Heritage Program 2001, Colorado Natural Heritage Program 2004). Significant erosion and sedimentation washes away or degrades habitat for this species (Colorado Natural Heritage Program 2001) and could affect existing individuals of *O. humilis* found downslope from roads. Element occurrence records for this species indicate that the Pikes Peak Highway impacts occurrences of this plant in numerous locations (Spackman 2000, Colorado Natural Heritage

Program 2001). Paving of the Pikes Peak road will continue over the next several years (J. Hovermale personal communication 2004). The paving and use of sedimentation control structures will presumably reduce the risk of erosion/deposition to *O. humilis* in the future, but individuals of this plant near the existing road could be impacted by construction processes. One of the authors of this assessment noted that the coarser, denser rock material used as railroad ballast for the Pikes Peak Cog Railroad does not appear to cause the same sedimentation problems as the toll road because it is not as erodible. Roads and trails are also often associated with the spread of invasive plants that could possibly compete with *O. humilis* for resources. However, the competitive abilities of *O. humilis* compared to those of non-native species have not been studied.

Motorized vehicles and foot traffic near roadsides, road pullouts, and trailheads have the potential to trample *Oreoxis humilis* occurrences located near those areas. One of the authors of this assessment noted that trampling by people was clearly occurring near *O. humilis* individuals at the Windy Point area on Pikes Peak, especially because trails are not delineated and it is not clear where it is acceptable to walk or not to walk. Colorado NHP (2001) also notes that "trampling is having limited impacts on this species in areas of high visitation." However, the amount of trampling specifically affecting *O. humilis* at that site and the amount of trampling that this species can tolerate are not known. In general, surface disturbances in alpine habitats can take much longer to restore (Zwinger and Willard 1996). Off-highway vehicle (OHV) use on the USFS Pike-San Isabel National Forest in the areas with occurrences of *O. humilis* is generally restricted to existing roads and is prohibited in wilderness areas (S. Olson personal communication 2004). One occurrence of *O. humilis* occurs on the southern flank of Pikes Peak in an area where private land (i.e., reservoirs owned by Colorado Springs Utilities) is interspersed with USFS land. Thus, any occurrences of *O. humilis* on these private land parcels could be affected by any additional structure construction, reservoir expansion, or road maintenance activities. Public activity is excluded from the private land areas around the reservoirs, which reduces the number of visitors to the area (J. Hovermale personal communication 2004). There are also some radio towers located on USFS land near *O. humilis* occurrences, and numerous two-track roads run through the USFS habitat in that area (Colorado Natural Heritage Program 2004). One occurrence record noted that an occurrence of about 40 *O. humilis* individuals found below treeline was located near a road used by vehicles and motorbikes and some campsites (Colorado Natural Heritage Program 2004). Both motorized vehicles and hikers have the potential to directly trample *O. humilis* populations found in these more accessible habitats.

Recreational activities (e.g., hiking, camping, wildlife watching, sight-seeing, rock climbing, crystal collecting) are popular activities in areas of the Pike-San Isabel National Forest with *Oreoxis humilis* occurrences. Although *O. humilis* occurrences on cliff faces and in boulderfields are less likely to be affected by road-specific activities, these less accessible occurrences could still be affected by off-road and off-trail recreational activities. *Oreoxis humilis* occurrences on rocky outcrops and talus slopes may be less impacted by recreational activities. Rock climbing is a popular activity in the Pikes Peak area and rock climbing could possibly negatively impact *O. humilis* plants along climbing access trails or at the bases of cliffs. The juxtaposition of climbing areas and *O. humilis* occurrences is not known. Similarly, crystal collectors or "rockhounds" could also trample plants.

The effects of land management activities or environmental fluctuations on *Oreoxis humilis* have not been studied. In general, land management activities or other environmental disturbances (e.g., succession, fire, drought, rockfall, flash flood, global warming, erosion, blowdown, or timber harvest) can either create suitable habitat throughout a landscape or directly impact existing individuals, depending on the frequency, intensity, size, and location of the disturbance. Erosion, rockslide, and other disturbances have affected the friable Pikes Peak area for millennia (W. Weber personal communication 2004). *Oreoxis humilis* occurs at high elevations on steep slopes, rocky outcrops, and other areas with exposed bedrock and low productivity and would likely not be affected by thinning, timbering, prescribed burning, or grazing activities (S. Olson personal communication 2004).

Possible environmental and biological threats to occurrences of *Oreoxis humilis* include environmental fluctuations (e.g., changes in snowpack characteristics), genetic isolation, succession, inadequate pollination, global climate changes, or changes to the natural disturbance regime. *Oreoxis humilis* may rely on wind and water erosion to reduce competition and to maintain available substrate, but existing occurrences could be damaged during soil or water movement. *Oreoxis humilis* is known from only four occurrences in a small range; the amounts of gene flow, genetic variability, and inbreeding are unknown for this species. Pollinators for this species, and the factors that may affect pollinator densities and behavior, are also not known.

Changes to existing climatic and precipitation patterns, perhaps as a result of global climate change, could also impact *Oreoxis humilis*. For example, average temperatures are projected to increase, and precipitation is generally expected to increase over western North America (U.S. Environmental Protection Agency 1997, Watson et al. 2001). A document about regional climate changes in Colorado by the U.S. Environmental Protection Agency reports that average temperatures have increased by 4.1 ºF and precipitation has decreased by up to 20 percent in some areas of Colorado over the last century (U.S. Environmental Protection Agency 1997). Over the next century, climate models predict that temperatures in Colorado could increase by 3 to 4 ºF (with a range of 1 to 8 ºF) in the spring and fall and by 5 to 6 ºF (with a range of 2 to 12 ºF) in the summer and winter. Precipitation is estimated to increase by 10 percent in the spring and fall, increase by 20 to 70 percent in the winter, and create more thunderstorms in the summer (without a significant change in precipitation total) (U.S. Environmental Protection Agency 1997). Climate change and other potential changes to a suite of environmental variables could affect plant community composition by altering establishment, growth, reproduction, and death of plants. For example, model projections predict that tree lines could shift upslope in alpine ecosystems (U.S. Environmental Protection Agency 1997). In addition, environmental stochasticity can affect pollinator activity and behavior.

Overall, the most imminent threats to *Oreoxis humilis* on USFS Region 2 lands probably pertain to individuals existing near high-use areas and general threats to alpine flora as a whole (e.g., global climate changes).

Conservation Status of the Species in USFS Region 2

Oreoxis humilis is of special concern because it is a highly geographically limited plant with a small number of occurrences and potential threats to existing occurrences and habitat. The viability of this species within USFS Region 2 is difficult to ascertain because the full abundance is unknown and demographic parameters have not been studied. Road effects, structure construction, motorized and non-motorized recreation, exotic species invasion, and environmental fluctuations potentially threaten this species. However, this species is found in abundance within suitable habitat away from heavily used areas, and this species is probably not at risk of drastic population declines (W. Weber personal communication 2004). Although *O. humilis* is comprised of a large number of individuals in a restricted geographic area (i.e., Pikes Peak), the Pikes Peak area is large and has significant topographic heterogeneity. It is unlikely that one catastrophic disturbance (e.g., rockslide) could destroy all of the occurrences, but changes in environmental conditions (e.g., global climate change) could possibly affect all of the occurrences. Much information is lacking on the abundance and biology of *O. humilis*. It is difficult to predict the ability of this species to tolerate environmental stochasticity and any future environmental or management changes. *Oreoxis humilis* is found mainly on USFS Region 2 lands, but it is not protected as a sensitive species.

Population declines

Based on the existing estimates of abundance, we are unable to conclude that the distribution or abundance of *Oreoxis humilis* is declining, maintaining, or expanding throughout its range. There is no evidence of a drastic population decline at this time. Abundance estimates ranged from 40 to thousands per site, with an estimated total of thousands to tens of thousands of individuals (Colorado Natural Heritage Program 2004). There have been no detailed status reports or intensive surveys for this species. After performing multiple spot checks during a survey of the Pikes Peak area, Fayette and Grunau (1998) hypothesized that *O. humilis* can be expected anywhere above timberline in this area (Colorado Natural Heritage Program 2001). There is also speculation that the range of this species could possibly be underestimated due to misidentification with a more common species (i.e., *O. alpina*) or otherwise overlooked by botanists (Colorado Natural Heritage Program 2004). Element occurrence records suggest that additional individuals may exist over the entire summit of the mountain, and undiscovered populations may occur below treeline.

Habitat variation and risk

Although *Oreoxis humilis* appears to be edaphically restricted to exposed substrates of Pikes Peak and Windy Point granites, this species inhabits a range of microhabitats, such as rocky outcrops, talus slopes, fellfields, and grassy meadows. The microhabitat requirements for *O. humilis* are largely undefined. The optimal type, size, frequency, and intensity of disturbances required to sustain populations of *O. humilis* are not known. Disturbances play a beneficial role to create suitable habitat for *O. humilis* but could also be detrimental to existing individuals depending on location and intensity. Potential risks within the habitats could include competition from surrounding vegetation, lack of suitable germination sites, inadequate pollinator habitat, barriers to gene flow, conditions too harsh for adequate growth and development (e.g., sedimentation, trampling), and other fluctuations in disturbance processes that could affect existing occurrences or creation of habitat. Erosion and sedimentation from the Pikes Peak tollway has caused habitat to wash away or to become otherwise degraded, and this has been identified as a significant risk for *O. humilis* habitat in these areas (Colorado Natural Heritage Program 2001). It is difficult to predict the spread of non-native invasive plants and the potential risk of alteration to plant communities, but high alpine habitats are at less risk for serious invasion by non-native plants than lower elevation areas. Specific individuals could be at a greater risk than others, depending on the landscape context, such as proximity to roads and microhabitat characteristics. The inaccessibility of some *O. humilis* occurrences in steep, rocky, alpine terrain may help to protect occurrences from human and herbivore impacts. Overall, *O. humilis* is considered to be fairly resistant to human disturbance because it is small-statured, heavy-rooted, and covered with snow most of the year (W. Weber personal communication 2004). However, trampling of *O. humilis* plants has been noted at high-use areas (Colorado Natural Heritage Program 2001).

Potential Management of the Species in USFS Region 2

Quantitative demographic monitoring and detailed biological and ecological studies of *Oreoxis humilis* populations and its habitat on USFS Region 2 lands have not occurred. Based on the available information, we can only hypothesize how changes in the environment may affect the abundance, distribution, and long-term persistence of this species.

Management implications

Oreoxis humilis occurrences and habitat may be at risk as a result of management activities within its range. Possible human-related threats to existing individuals of this species include off-road (or off-trail) motorized and non-motorized activities, road maintenance and sedimentation, structure maintenance, and introduction of non-native species. *Oreoxis humilis* is not likely to be affected by thinning, timbering, prescribed burning, or grazing activities (S. Olson personal communication 2004). The long-term persistence of this species may rely on monitoring the effects of current USFS Region 2 land-use practices in order to reduce human-related threats to existing occurrences and to learn about the effects of these actions to help inform future management decisions. For example, creating clearly-demarcated and well-constructed trails in popular recreational areas may reduce the effects of direct trampling and erosion/deposition on *O. humilis* (Fayette and Grunau 1998, Colorado Natural Heritage Program 2001). Despite the existing recreational and touristic development on Pikes Peak, this species has persisted (W. Weber personal communication 2004). This species may not require specific management actions, but it will benefit from management tactics that reduce further degradation of Pikes Peak habitats (W. Weber personal communication 2004).

Potential conservation elements

Oreoxis humilis is a species endemic to one mountain area with a small number of recorded occurrences and potentially high vulnerability of some individuals to human-related activities and environmental changes. The microhabitat needs of this species and the intensity, frequency, size, and type of disturbance optimal for its persistence are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual and vegetative reproductive potential, or genetic variability of this species makes it difficult to predict its long-term vulnerability. Surveying high probability habitat for new occurrences, protecting existing occurrences from direct damage, documenting and monitoring the effects of current land-use activities, and preventing non-native plant invasions are key conservation elements for this species on USFS Region 2 lands.

Features of *Oreoxis humilis* biology that may be important to consider when addressing its conservation (i.e., key conservation elements) include its small stature, edaphic specialization on Pikes Peak granitic substrates, alpine habitat, and relatively abundant occurrences in a small geographic area. *Oreoxis humilis* is a small-statured, heavy-rooted perennial that is likely covered by snow most of the year (W. Weber personal communication 2004), which helps makes it resistant to the effects of human trampling. This species is not showy and is probably not targeted for horticultural collection. This species appears to be limited to Pikes Peak and Windy Point granites, and the unique lithology of the area is clearly important in the endemism of this species (Fayette and Grunau 1998, Colorado Natural Heritage Program 2001, W. Weber personal communication 2004). Because this species inhabits an alpine area, it may be more susceptible to global climate changes but possibly less susceptible to environmental changes such as non-native plant invasion. Although *O. humilis* is only known from the Pikes Peak area, it is found in relative abundance, and population sizes are probably underestimated.

Tools and practices

There are no existing population monitoring protocols for *Oreoxis humilis*, and very little is known about its biology, ecology, taxonomy, and spatial distribution. Thus, additional habitat surveys, quantitative species monitoring, taxonomic analyses, and ecological studies are priorities for constructing a current status assessment and conservation plan.

Species inventory and habitat surveys

Current reports of existing *Oreoxis humilis* occurrences provide a useful base of information, but the distribution and total abundance of this species are not sufficiently known to formulate conservation strategies on USFS Region 2 lands. Spot checks performed during general surveys of the Pikes Peak area led researchers to suggest that *O. humilis* may be found anywhere above timberline (Fayette and Grunau 1998, Colorado Natural Heritage Program 2001); this hypothesis could be verified through more systematic surveys. A status report on the distribution of *O. humilis* over its range is a necessity. Researchers could visit all documented sites to ascertain both current distribution and population status. These sites could be regularly revisited for update reports. Ascertaining the current abundance of this species would help to monitor the effects of human activities and environmental fluctuations.

Additional surveys of habitat are needed to discover any other locations of *Oreoxis humilis*, such as possible below-treeline locations, and to document the full spatial extent of this species. Researchers could identify areas of potential habitat in the Pikes Peak area using topographic maps, geologic maps, land status maps, and aerial or satellite images. *Oreoxis humilis* is known from areas with exposed Pikes Peak and Windy Point granites. Within areas of suitable parent material, this species is known from topographic landforms such as ridges, outcrops, and scree slopes. New surveys could also use existing occurrences as a starting point because similar habitat and topography may extend along slopes, drainages, or topographical formations. Locations downslope or downwind from existing occurrences could be surveyed because *O. humilis* seeds are possibly wind, water, and gravity dispersed.

The size and extent of existing occurrences could be mapped and recorded using global positioning system (GPS) and GIS technology. The extent of occurrences in inaccessible areas may only be estimated. Mapping the extent of each known occurrence of *Oreoxis humilis* will maintain consistency for future observations and help in making estimates of density and abundance over time. Mapping exercises will also elucidate the spatial distribution of occurrences and provide a framework for creating research studies. Occurrences in areas slated for various management, maintenance, or disturbance activities could be readily identified.

Population monitoring and demographic studies

Additional information is needed to gain an understanding of the life cycle, demography, and population trends of *Oreoxis humilis*. Information is lacking on longevity, germination requirements, seed survival, extent of asexual reproduction, factors affecting flower development, pollination ecology, role of a seed bank, and gene flow between populations. This type of species-specific information would be useful in assessing threats to this species and in estimating species viability. For example, studies of germination needs in the field might elucidate potential limiting factors for the establishment of new individuals.

No data are available on population trends for this species, and no long-term demographic monitoring has been initiated. Long-term monitoring studies could yield helpful information, such as temporal and spatial patterns of abundance and dormancy; environmental factors that influence abundance; whether occurrences are increasing, decreasing, or remaining stable; and the minimum number of plants necessary to perpetuate the species. In addition, further studies on the genetic differences between and among populations will clarify metapopulation dynamics. Further genetic studies would also elucidate the relationship between *Oreoxis humilis* and *O. alpina*.

Understanding certain aspects of demography is a priority in order to provide basic population information, as indicated by these questions:

- What are the rates of survival, longevity, and recruitment?
- What are the population fluctuations from year to year?
- What are the effects of disturbances on demographics?

- ❖ What are the role, status, and longevity of the seed bank?
- ❖ What is the age structure of the population?
- ❖ What is the age at which individuals become reproductive?
- ❖ What is the extent of vegetative and sexual reproduction?
- ❖ What is the gene flow among populations?
- ❖ What are the genetic differences between *Oreoxis humilis* and *O. alpina*?

Long-term monitoring programs are required to answer these kinds of questions, but it may take decades for a clear pattern to emerge. Several groups have developed protocols for monitoring population and demographic trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in USFS Region 2. For example, Hutchings (1994) and Elzinga et al. (1998) are general references that provide concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. Austin et al. (1999) and Bonham et al. (2001) provide helpful protocols specifically designed for federal agencies monitoring plants on public lands. In addition, population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and identifying the most critical feature of the species' life history (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are used as powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998).

Habitat monitoring and management

The general habitats of *Oreoxis humilis* have been identified, but there are too many unknowns regarding microhabitat requirements and basic population dynamics to know which factors are critical in maintaining or restoring habitat for these species. This species appears to be limited to Pikes Peak and Windy Point granites, and the unique lithology of the area is clearly important in the endemism of this species (Fayette and Grunau 1998, W. Weber personal communication 2004). Studies exploring *O. humilis*' specialization on granite would help to understand the role of edaphic characteristics in the life history and survival of this species (e.g., Kruckeberg 2002). It is currently not known what types, intensities, or frequencies of disturbance create and maintain habitat and are tolerated by existing occurrences of this species. The effects of land-use activities on *O. humilis* and its habitats have not been studied or monitored. Documenting land management and monitoring habitat could occur in conjunction with population monitoring efforts in order to associate population trends with environmental conditions.

Some examples of management practices that would protect *Oreoxis humilis* habitat include restricting off-road vehicle traffic, reducing sedimentation from roads, encouraging hikers to use trails, and preventing the spread and establishment of non-native invasive species. Habitat management could also consider issues related to the surrounding landscape, such as pollinator habitat needs, herbivore movement patterns, and trail proximity and position in relation to population locations.

Biological and ecological studies

Much of the information regarding habitat requirements, establishment, reproduction, dispersal, relationship with herbivores, competition with other species, and overall persistence has not been studied for *Oreoxis humilis*. The response of *O. humilis* to habitat changes is not known in sufficient detail to evaluate the effects of changes in disturbance patterns. Research studies to evaluate the effects of erosion and sedimentation, non-native plant species, succession, global climate changes, and other environmental fluctuations would provide valuable input to the development of conservation strategies and management programs. The types of monitoring studies required to understand how this species responds to environmental fluctuations, changes in the disturbance regime, or natural succession would be complex and could take decades. For example, precipitation fluctuations have the potential to affect erosion rates, germination success, pollinator population trends, timing of flowering, and/or growth of surrounding vegetation. It will be difficult to determine to what extent disturbances are necessary to create habitat and/or to maintain an occurrence, what disturbance intensity and frequency may be most appropriate, and what factors would result in local extirpation of an occurrence.

Availability of reliable restoration methods

There are too many unknowns regarding habitat preferences and basic population dynamics to know what factors are critical in restoring habitat for *Oreoxis humilis*. No information was found regarding the germination of this species in a greenhouse setting or the availability of propagules for use in a restoration program. A study of turf transplants at an alpine restoration site in Colorado found that the cover of *O. alpina* was significantly higher in control plots than in transplant plots (Conlin and Ebersole 2001). This work suggests that if restoration of *O. humilis* is warranted, then preliminary research would need to be performed before transplanting this species.

Information Needs and Research Priorities

Based on our current understanding of *Oreoxis humilis*, we can identify research priorities where additional information will help to develop management objectives, to initiate monitoring and research programs, and to inform a conservation plan. To address these data gaps, information can be obtained through surveys, long-term monitoring plans, and extended research programs. There is so little known about the biology and ecology of this species that there are a large number of research projects that could be implemented.

Revisiting all occurrences, estimating current abundance, assessing imminent threats, studying taxonomic status, and determining ecological needs and limitations are of primary importance to further the understanding of *Oreoxis humilis* in USFS Region 2. The following types of studies are priorities to supplement basic knowledge regarding this species:

- ❖ Revisiting and mapping existing occurrences in detail
- ❖ Surveying for new occurrences
- ❖ Addressing imminent threats to known occurrences
- ❖ Characterizing microhabitat
- ❖ Documenting and monitoring current land management practices
- ❖ Assessing taxonomic status and relationship to *Oreoxis alpina*
- ❖ Studying reproductive biology, including pollinator surveys, germination trials, vegetative reproduction, dispersal capabilities, mycorrhizal associations, and seedbank analyses
- ❖ Performing genetic analyses to assess gene flow and variability throughout range

Additional research and data that may be useful but are not incorporated into this assessment include aspects related to managing data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. The Colorado NHP and NatureServe have developed databases and GIS components to assist in information storage and habitat modeling (D. Anderson personal communication 2004). Such a database should be integrated with GIS and allow queries and activities such as the following:

- ❖ Efficient incorporation of data in the field
- ❖ Generation of location and habitat maps
- ❖ Identification of occurrence locations
- ❖ Characterization of associated habitat types
- ❖ Identification of population trends over time
- ❖ Identification of data gaps that require further information gathering
- ❖ Ease of database modification as additional information becomes available.

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DEFINITIONS

Acaulescent — With a stem so short that leaves are clustered in a basal rosette.

Agamospermous — Capable of asexually producing seeds without fertilization.

Annual — A plant that completes its entire life cycle in one growing season.

Anther — Part of the flower reproductive structure (stamen) that bears pollen.

Asexual reproduction — Any form of reproduction not involving the union of gametes.

Autogamous — Capable of self-fertilizing.

Bract — Reduced, modified leaf associated with flowers.

Bractlet — Small, secondary bract.

Caespitose — Grows in tufts; in low-branching pattern from near base.

Calyx — The collective name for sepals.

Carpel — The plant organ that bears the ovules.

Commissure — The face by which two carpels cohere.

Corolla — Portion of flower comprised of petals.

Demographics — The study of fecundity and mortality parameters that are used to predict population changes.

Dimidiate — Appearing as if one half of an otherwise symmetrical structure were wanting.

Dormancy — A period of growth inactivity in seeds, buds, bulbs, and other plant organs even when environmental conditions normally required for growth are met.

Endangered — Defined in the Endangered Species Act as a species, subspecies, or variety likely to become extinct in the foreseeable future throughout all or a significant portion of its range.

Endemic — A population or species with narrow physiological constraints or other restrictions, which limit it to a special habitat or a very restricted geographic range, or both.

Fellfield — Alpine community characterized by rocky ground, dry soils, and cushion plants.

Fertility — Reproductive capacity of an organism.

Fitness — Success in producing viable and fertile offspring.

Fruit — The ripened, seed-containing reproductive structure of a plant.

G1 ranking — Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction (NatureServe).

G2 ranking — Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe).

G3 ranking — Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction (NatureServe).

G4 ranking — Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

G5 ranking — Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

Genotype — Genetic constitution of an organism.

Herbaceous — Characteristic of an herb (plant with no aboveground persistent woody stem).

Hybridization — The result of a cross between two interspecific taxa.

Inferior ovary — Ovary appearing to be below the perianth.

Inflorescence — The flowering part of a plant, usually referring to a cluster of flowers.

Interspecific competition — Competition for resources between individuals of different species.

Involucel — Secondary involucre.

Involucre — Series of bracts surrounding or subtending a flower or inflorescence.

Metapopulation — Group of populations that are linked through migration of individuals.

Mycorrhiza — Symbiotic association between a fungus and the root of a higher plant.

Nectary — Nectar-secreting gland.

Ovary — The enlarged portion of the female reproductive structure (pistil) that contains the ovules and develops into the fruit.

Peduncle — Stalk of an inflorescence.

Perennial — A plant that lives for three or more years and can grow, flower, and set seed for many years; underground parts may regrow new stems in the case of herbaceous plants.

Perfect flower — Flower with both "male" (stamens) and "female" (pistils) reproductive organs.

Perianth — Part of flower consisting of calyx and corolla, usually used when these structures are incomplete or modified.

Petiole — Leaf stalk.

Phenotype — The external visible appearance of an organism.

Phenotypic plasticity — When members of a species vary in height, leaf size or shape, flowering (or spore-producing time), or other attributes, with changes in light intensity, latitude, elevation, or other site characteristics.

Pinnate — Having parts or branches arranged on either side of a midrib.

Pinnatisect — Divided pinnately nearly to the midrib.

Pistil — The seed-producing organ of a flower, consisting of a stigma, style, and ovary.

Pollen — The male spores in an anther.

Polyploidy — Having more than two complete sets of chromosomes per cell.

Population Viability Analysis — An evaluation to determine the minimum number of plants needed to perpetuate a species into the future, the factors that affect that number, and current population trends for the species being evaluated.

Propagule — A reproductive body, usually produced through asexual or vegetative reproduction.

Protandry — Development of male organs before female organs to avoid self-fertilization.

Protogyny — Development of female organs before male organs to avoid self-fertilization.

Puberulence — Minute, soft, curling hairs.

Pubescent — Bearing hairs.

Racemose — With stalked flowers or small flower clusters arranged along an elongated central axis.

Recruitment — The addition of new individuals to a population by reproduction.

Rhizomatous — Bearing rhizomes.

Rhizome — Prostrate stem growing beneath the ground surface, usually rooting at the nodes.

S1 ranking — Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction (NatureServe).

S2 ranking — Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe).

S3 ranking — Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction (NatureServe).

S4 ranking — Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

S5 ranking — Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

Scape — A leafless peduncle arising from the ground-level in acaulescent plants.

Scapose — With the flowers on a scape.

Schizocarp — A fruit that slips into separate carpels at maturity.

Scree — Accumulation of small rock debris (generally smaller than talus), often at base of cliff or steep slope.

Sensitive species — A species whose population viability is a concern due to downward trends in population numbers, density, or habitat capability, as identified by a regional forester (USFS).

Sepals — A segment of the calyx.

Sessile — Lacking a stalk.

Sexual reproduction — Reproduction involving the union of gametes.

Stamen — The pollen-producing structures of a flower; the “male” part of a flower.

Succession — The orderly process of one plant community replacing another.

Symbiosis — An intimate association between two dissimilar organisms that benefits both of them.

Sympatric — Occupying the same geographic region.

Talus — Accumulation of coarse rock debris (generally larger than scree), often at base of cliff or steep slope.

Taproot — Main, central root growing straight down, often stouter than other roots.

Ternately — In threes.

Threatened — Defined in the Endangered Species Act as a species, subspecies, or variety in danger of becoming endangered throughout all or a significant portion of its range.

Umbel — A racemose inflorescence with an abbreviated axis and elongated pedicels; the inflorescence is composed of several branches that radiate from almost the same point and are terminated by single flowers or secondary umbels.

Umbellate — Of an umbel.

Vegetative reproduction — A form of asexual propagation whereby new individuals develop from specialized multicellular structures that often detach from the mother plant.

Viability — The capability of a species to persist over time. A viable species consists of self-sustaining and interacting populations that have sufficient abundance and diversity to persist and adapt over time.

Xeric — Characterized by extremely dry habitat.

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