Delphinium robustum Rydb. (Wahatoya Creek larkspur): A Technical Conservation Assessment

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

July 26, 2004

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Peer Review Administered by
Center for Plant Conservation

Beatty, B.L., W.F. Jennings, and R.C. Rawlinson (2004, July 26). *Delphinium robustum* Rydb. (Wahatoya Creek larkspur): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/delphiniumrobustum.pdf [date of access].

Acknowledgements

We acknowledge several botanists and land management specialists for providing helpful input and document review, including Gay Austin, Beth Burkhart, Dean Erhard, David Inouye, Steve Olson, Mary Price, Bob Sivinski, Jon Stewart, and Nickolas Waser. Natural heritage programs and herbaria within USFS Region 2 supplied current occurrence records of this species from their databases and collections. We thank Jon Stewart for permission to use his *Delphinium robustum* images. Funding for this document was provided by USDA Forest Service, Rocky Mountain Region (Region 2) contract 53-82X9-2-0112.

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Cover Photo Credit

Delphinium robustum (Wahatoya Creek larkspur). Photographs by Jon Stewart. Reprinted with permission from the photographer.

List of Errata

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *DELPHINIUM ROBUSTUM*

Status

Delphinium robustum (Wahatoya Creek larkspur) is a perennial forb inhabiting canyon bottoms and aspen groves from 2,135 to 3,400 meters (m) (7,000 to 11,200 feet) in the mountains of southcentral Colorado to northcentral New Mexico (Colorado State University Herbarium 2003, NatureServe 2003, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). Based on brief descriptions of locations, up to seven of the nine known occurrences of this species in Colorado may occur on lands managed by the USDA Forest Service (USFS). This species is not listed on the USFS Rocky Mountain Region sensitive species list (USDA Forest Service 2003) or the U.S. Fish and Wildlife Service threatened or endangered species list. The Global Heritage status rank for *D. robustum* is G2? (imperiled globally, with uncertainty), and within USFS Region 2, the Colorado Natural Heritage Program (NHP) state heritage rank is S2? (imperiled in state, with uncertainty) (NatureServe 2003). This species is also documented from six occurrences in New Mexico, where it is currently not ranked (SNR) by the New Mexico NHP (Sivinski 1999, New Mexico Natural Heritage Program 2002).

The taxonomy of *Delphinium* species in Colorado and New Mexico, including *D. robustum*, is being studied for possible revision, mainly as a result of the largely similar morphology, habitat, and overlapping ranges (e.g., Jennings 1998a). It is possible that *D. robustum* and other *Delphinium* species from Colorado and New Mexico (i.e., *D. ramosum*, *D. sapellonis*, *D. novo-mexicanum*, and *D. sierrae-blancae*) are not separable (Jennings 1998b), which affects the interpretation of the distribution and abundance of these species. In this assessment we evaluate *D. robustum* as a species distinct from these other species, as designated in the PLANTS database (USDA Natural Resources Conservation Service 2002). Not enough abundance data or demographic information is available to conclude whether occurrences of *D. robustum* are increasing, decreasing, or remaining stable. Until 1998, *D. robustum* sites in Colorado had not been re-visited since their original discoveries over thirty years ago. Efforts by one of the authors of this assessment (W. Jennings) to revisit most of the *D. robustum* occurrences in 1998 failed to find any individuals of this species at six of the nine reported locations in Colorado (Jennings 1998a). At several of these sites, though, W. Jennings did find individuals of *D. ramosum*. Thus, either environmental conditions in 1998 were not suitable for the growth of *D. robustum*, or this species has been extirpated in Colorado, or these individuals had been previously misidentified as *D. robustum*.

Primary Threats

Delphinium robustum is vulnerable because of its endemic distribution, small number of documented occurrences, possible population declines, and potential human-related and environmental threats. Although seven occurrences may be on USFS Region 2 lands, this species is not protected as a sensitive species.

Threats to the long-term persistence of *Delphinium robustum* in USFS Region 2 are mostly unknown because of a lack of species knowledge and research. Possible human-related threats to *D. robustum* include motorized and non-motorized recreation, structure construction, road construction and maintenance, erosion and sedimentation related to roads, livestock trampling, and changes to natural disturbance regimes (e.g., fire suppression). The extent of these activities near existing occurrences of *D. robustum* or in suitable *D. robustum* habitat is unknown. Disturbances and land management activities, such as burning, thinning, or grazing, may maintain suitable habitat for this species or negatively impact existing occurrences, depending on the disturbance intensity, frequency, and type. Possible environmental and biological threats to occurrences of *D. robustum* include environmental fluctuations (e.g., drought), non-native species invasion, extensive herbivory, succession, genetic isolation, hybridization, inadequate pollination, and global climate changes.

Primary Conservation Elements, Management Implications and Considerations

The distribution, abundance, and ecological range of *Delphinium robustum* and the intensity, frequency, size, and type of disturbance optimal for the persistence of this species are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual and asexual reproductive potential, and

genetic variability of this species makes it difficult to predict its long-term vulnerability. *Delphinium robustum* has not been observed in USFS Region 2 in over 30 years. Studying taxonomic relationships with closely-related species (e.g., *D. ramosum*, *D. sapellonis*), assessing current distribution and abundance, protecting any existing occurrences from direct damage, surveying high probability habitat for new occurrences, documenting and monitoring the effects of current management activities, and preventing non-native plant invasions are key conservation elements for this species on USFS Region 2 lands. Priorities of future research studies include studying its taxonomic status; re-visiting and mapping the extent of any existing occurrences in detail; assessing imminent threats; surveying to locate additional occurrences within USFS Region 2; investigating factors that affect spatial distribution (e.g., microhabitat characteristics); exploring biological and ecological limitations; and producing information related to reproductive mechanisms, 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). *Delphinium robustum* 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, possible population declines, and potential 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 *D. robustum* throughout its range in USFS Region 2 although its range extends outside Region 2. This introduction outlines the scope of the assessment and describes the process used in producing the assessments.

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. Rather it provides the ecological background upon which management must be based, and it focuses on the consequences of changes in the environment that result from management (i.e., management implications). Additionally, the assessment cites management recommendations proposed elsewhere and examines the success of those that have been implemented.

Scope and Information Sources

This assessment examines the biology, ecology, conservation status, and management of *Delphinium robustum* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature on the species may originate from field investigations outside the region, this document places 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 *D. robustum* 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 this assessment, we performed an extensive literature search to obtain material focusing on *Delphinium robustum*, as well as related information on the geographical and environmental context 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., Natural Heritage Program [NHP] element occurrence records), and regulatory guidelines (e.g., USFS Forest Service Manual). We did not visit every herbarium with specimens of this species but 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 for 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. These scientific tools are to be used in concert with the most complete species status data to produce a robust analysis. The data and analyses presented in this assessment on *Delphinium robustum* in the Rocky Mountain Region address all information and records produced as documentation of its distribution and biology. The strength of evidence for particular interpretations or ideas is noted, and alternative explanations are described when appropriate.

Because of a lack of experimental research efforts concerning *Delphinium robustum*, this assessment 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 and herbarium 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 because of the unverified historical information. Information about possible taxonomic revisions of this species is based on the unpublished research of W. Jennings from 1998 (i.e., Jennings 1998a, Jennings 1998b).

"The ecology of the species is almost wholly unknown and only a single collection with follicles has been seen." (Ewan 1945). Because there is a paucity of knowledge specific to this species, we also incorporated information, where available, from other *Delphinium* species or taxonomically related genera endemic to USFS Region 2 or adjacent states to formulate this assessment. These comparisons are not meant to imply that *D. robustum* is biologically identical to these species, but they represent an effort to hypothesize about *potential* characteristics of this species. Although the reproductive biology of *Delphinium* species has been the subject of preliminary investigative study (Waser and Price 1979, Waser and Price 1985, Waser 1988, Inouye 1991, Graham and Jones 1996, Bosch et al. 1998, Bosch and Waser 1999, Williams 1999, Williams and Waser 1999, Bosch et al. 2001, Bosch and Waser 2001, Johnson 2001, Koontz et al. 2001, Schulke and Waser 2001, Simon et al. 2001, Williams et al. 2001, Dodd and Helenurm 2002), details concerning the reproductive biology of *D. robustum* are inferred or unknown. Ongoing studies on the conservation genetics of other *Delphinium* species (Waser and Price 1985, Bosch et al. 1998, Williams and Waser 1999, Simon et al. 2001, Dodd and Helenurm 2002) provide helpful insights on important issues to consider when studying the biology and conservation of *D. robustum*. As a result, biology, ecology, and conservation issues presented for *D. robustum* in USFS Region 2 are based on inference from these published and unpublished sources. In many cases we refer to studies on *D. nuttallianum* (synonymous with *D. nelsonii*) and *D. barbeyi*, because information about species more closely-related to *D. robustum*, such as *D. ramosum* and *D. sapellonis*, are also not available. *Delphinium robustum* is likely to be at least somewhat similar to other delphiniums in the Rocky Mountains (M. Price and N. Waser personal communication 2004). We clearly noted when we were making inferences based on the available knowledge to inform our understanding of *D. robustum*.

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 facilitated 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

Delphinium robustum is a regional endemic species of Colorado and New Mexico and is known from approximately nine occurrences in Colorado and six occurrences in New Mexico (**Figure 1**, **Table 1**; Rydberg 1901, Ewan 1945, Sivinski 1999, Colorado State University Herbarium 2003, Kathryn Kalmbach Herbarium 2003, New Mexico Natural Heritage Program 2003, Rocky Mountain Herbarium 2003, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this species.

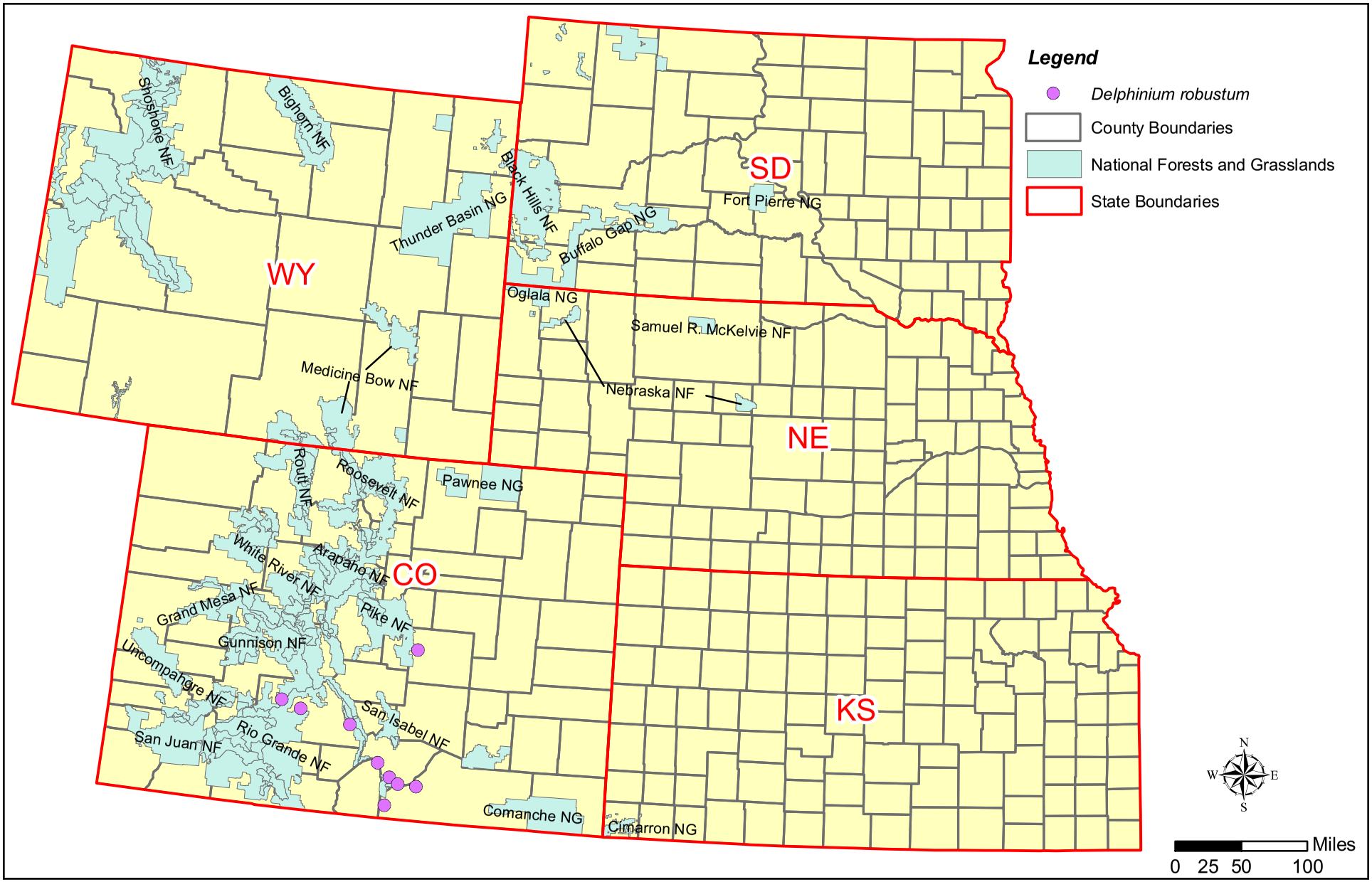


Figure 1. Map of U.S. Forest Service Region 2 illustrating distribution of nine *Delphinium robustum* occurrences in El Paso, Huerfano, Las Animas, and Saguache counties, Colorado. There are additional occurrences outside USFS Region 2 in New Mexico. Refer to document for abundance and distribution information. Sources: Ewan (1945), Sivinski (1999), Colorado State University Herbarium (2003), Rocky Mountain Herbarium (2003), University of Colorado Herbarium (2003), Colorado Natural Heritage Program (2004).

Table 1. Information on nine *Delphinium robustum* occurrences in Colorado (USFS Region 2). Includes county, number of occurrences, dates of observation, estimated abundance, land management context, habitat characteristics, and associated plant species.

County (number of occurrences)	Date of Observations	Estimated Abundance	Management Area/Ownership[1]	Elevation (m)	General Habitat Description	Associated Plant Species
El Paso (1 site)	1895; 1998	1895: Not Available (NA); 1998: 0 plant	Pike-San Isabel National Forest (?); City of Colorado Springs (?); **Private (?)**	2,135	Not Available (NA)	Not Available (NA)
Huerfano (3 sites)	1900; 1998	1990: NA; 1998: 0 plant	Pike-San Isabel National Forest - Spanish Peaks Wilderness (?); **Private (?)**	2,300	NA	NA
	1934; 1998	1934: Infrequent; 1998: 0 plant	Pike-San Isabel National Forest (?); Colorado BLM (?); State of Colorado (?); **Private (?)**	2,310	In the valley, near irrigation ditch	NA
	1964; 1998	1964: NA; 1998: 0 plant	Colorado BLM (?); **State of Colorado (?); Private (?)**	2,310	In thickets	NA
Las Animas (2 sites)	1901	NA	Colorado BLM (?); State of Colorado (?); Private (?)	NA	NA	NA
	1969; 1998	1969: NA; 1998: 0 plant	Pike-San Isabel National Forest (?); Colorado BLM (?); State of Colorado (?); **Private (?)**	2,591 to 2,932	NA	NA
Saguache (3 sites)	1939; 1998	1939: NA; 1998: 0 plant	Rio Grande National Forest (?); **Colorado BLM (?);** State of Colorado (?); Private (?)	2,591	Moist opening in forest	NA
	1943	NA	Rio Grande National Forest - Sangre de Cristo Wilderness (?); Colorado BLM (?); Private (?)	NA	NA	NA
	1959	NA	Gunnison National Forest (?); State of Colorado (?)	NA	NA	*NA*

[1](?) – indicates uncertainty; bold face font indicates the most probable ownership based on fieldwork by one of the authors of the assessment (W. Jennings). Sources: Ewan (1945); Jennings (1998b); Kathryn Kalmbach Herbarium (2003); Rocky Mountain Herbarium (2003); University of Colorado Herbarium (2003); Colorado Natural Heritage Program (2004).

Management and Conservation Status

Federal status

Delphinium robustum is not listed on the U.S. Fish and Wildlife Service (USFWS) threatened or endangered species list, the USFS Rocky Mountain Region (Region 2) sensitive species list (USDA Forest Service 2003), the Colorado Bureau of Land Management (BLM) sensitive species list (Bureau of Land Management 2000), or the New Mexico BLM sensitive species list (BLM). *Delphinium robustum* is listed on the USFS Region 3 sensitive species list (New Mexico Natural Heritage Program 2004).

Heritage program ranks

The Global Heritage status rank for *Delphinium robustum* is G2? (imperiled globally, with uncertainty), and within USFS Region 2, the Colorado NHP state heritage rank is S2? (imperiled in state, with uncertainty) (NatureServe 2003). Outside USFS Region 2, the New Mexico NHP state heritage rank for *D. robustum* is SNR (rank not yet assessed) (NatureServe 2003). 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 harvest or restricting damage to critical habitats. The New Mexico Rare Plant Technical Committee also ranks species with an R-E-D ranking system, where R=rarity, E=endangerment, and D=distribution. Each element in the R-E-D code has three levels of concern, from 1 to 3, where 3 is the highest level of concern. The R-E-D rank for *D. robustum* is 1 for rarity (rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low for the foreseeable future), 1 for endangerment (not endangered), and 2 for distribution (rare outside New Mexico).

Delphinium robustum is not known from Kansas, Nebraska, South Dakota, or Wyoming and is thus not currently listed or ranked in those states (Fertig and Heidel 2002, 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

The majority of information about *Delphinium robustum* is contained within brief descriptions associated with herbarium specimens, often with very little specific location information. Therefore, there is considerable uncertainty regarding the exact location of many *D. robustum* sites and the existence of occurrences on USFS lands; inferences are made from location descriptions, mapping exercises, fieldwork by one of the authors of this assessment (W. Jennings), and conversations with USFS botanists (D. Erhard personal communication 2003, S. Olson personal communication 2003, G. Austin personal communication 2004). Element occurrence records for this species (Colorado Natural Heritage Program 2004) also provide information about possible land ownership in the vicinity of an occurrence based on the available location information and GIS analysis. Of the nine occurrences of *D. robustum* in USFS Region 2, four occurrences may be on or near the Pike-San Isabel National Forest, two occurrences may be on or near the Rio Grande National Forest, and one occurrence may be on or near the Gunnison National Forest (**Figure 1**, **Table 1**). Because this species is not listed as a sensitive species in USFS Region 2, USFS botanists for the pertinent national forests were not familiar with *D. robustum* and could not verify its presence or absence on USFS lands (D. Erhard personal communication 2003, S. Olson personal communication 2003, G. Austin personal communication 2004). Occurrences may also be on or near Colorado BLM lands, State of Colorado lands, City of Colorado Springs lands, or private lands (**Table 1**). For example, *D. robustum* is reported to occur along a road in Huerfano County, Colorado (Colorado Natural Heritage Program 2004). However, without additional information (e.g., location along road, distance from road, extent of occurrence, elevation), it is difficult to state with certainty if this species occurs within the highway right-of-way, or on nearby Colorado BLM, USFS, or private lands. One of the authors of this assessment (W. Jennings) believes that it is most likely that the species would be close to a road (i.e. highway right-of-way) where it would be easy to see and collect, and less likely to occur on the BLM or USFS lands off the road. In another example, location information for *D. robustum* indicates that the plant may have been collected from the Spanish Peaks area of Pike-San Isabel National Forest. Based on fieldwork performed by W. Jennings, it is likely that the specimens were collected from private lands just outside those boundaries. However, it is still possible that these occurrences could extend to nearby lands. Thus, **Table 1** incorporates uncertainty by listing possible land management contexts with a "?". The table also includes bold font to indicate the most likely management context based on W. Jennings' field and research work.

Although *Delphinium robustum* has been identified as a species of special concern by the Colorado and New Mexico NHPs, there are few specific regulatory mechanisms at the federal level to regulate its conservation. *Delphinium robustum* is not currently listed as a USFWS threatened species, a USFS Region 2 sensitive species, or a BLM sensitive species. In New Mexico, this species is on the USFS Region 3 sensitive species list.

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 is directed to develop and implement management practices to ensure that species do not become threatened and endangered (USDA Forest Service 1995). The National Environmental Policy Act (NEPA) requires an assessment of the impacts of any significant federal project to natural environments (U.S. Congress 1982). However, *D. robustum* may not be specifically targeted in surveys and evaluations in Colorado because it is not listed as a sensitive species (D. Erhard personal communication 2003). USFS travel management plans protect rare species by restricting vehicle use to established roads only (USDA Forest Service and Bureau of Land Management 2000), and wilderness areas have restrictions on motorized travel (Office of the Secretary of the Interior 1964). The USFS prohibits the collection of sensitive plant species without permit (USDA Forest Service 1995).

Existing regulations do not appear to be adequate to conserve *Delphinium robustum* in USFS Region 2 over the long term, considering that the abundance and distribution of this species is largely unknown, specific occurrences may be threatened by human-related and ecological threats, and this species is not considered a sensitive species by the USFS or the BLM in Colorado.

Biology and Ecology

Classification and description

Systematics and synonymy

Delphinium robustum Rydberg is in the genus *Delphinium* of family Ranunculaceae (Buttercup family), order Ranunculales, and group Dicotyledonae (dicots) of phylum Anthophyta (flowering plants) (NatureServe 2003). In Weber and Wittmann (2001), the family Helleboraceae includes former members of the Ranunculaceae that have follicles or berries rather than achenes, and includes the genus *Delphinium* (Jennings 1998a, Jennings 1998b). The genus *Delphinium* is a group of about 300 species found worldwide, with approximately 61 North American species (Warnock 1997). Ewan (1945, 1951) summarized and revised the North American *Delphinium* species based on previous work by Gray (1887), Huth (1895), and Davis (1900), and informally divided the genus into subgeneric groups. Warnock (1993, 1995, 1997) has also surveyed the genus further to elucidate taxonomic relationships. The relationships of species in the genus *Delphinium* are complex and continue to be the subject of botanical and taxonomical work (Jennings 1998a, Jennings 1998b, Sivinski 1999).

Ewan (1945) placed *Delphinium robustum* in the Ceratophylloid group, made up of seven species in the area from the Sierra Madre Occidental of Mexico along the southern Rocky Mountain cordillera. The species in this group, *D. tenuisectum*, *D. novomexicanum*, *D. scopulorum*, *D. ramosum*, *D. robustum*, *D. sapellonis*, and *D. andesicola*, each occupy a discrete area of this montane area as a narrow endemic, and these species are characterized by finely palmatisect leaves with numerous comb-like segments. Warnock (1993) identified the southern Cordilleran complex from the subsection Exaltata of the genus *Delphinium* as *D. andesicola*, *D. novomexicanum*, *D. robustum*, *D. sapellonis*, and *D. valens*. He considered that the patterns of variation and differences within and among the members of the subsection are largely determined by the degree and length of isolation in the various mountain ranges. The taxonomy of these southern Cordilleran species is undergoing revision, mainly as a result of the largely similar morphology and overlapping ranges and habitats of the species within the group (e.g., Jennings 1998a, Jennings 1998b). Sivinski (1999, personal communication 2003) also emphasized that the *Delphinium* species of New Mexico are "taxonomically ambiguous and need additional study." Considerable field surveys and herbarium studies were performed by one of the authors of this assessment (W. Jennings) to help elucidate the taxonomy of *D. robustum* and its relationship with other Colorado and New Mexico species (Jennings 1998a, Jennings 1998b). On the basis of these studies, W. Jennings proposed that *D. robustum* may not be separable from other *Delphinium* species of Colorado and New Mexico, such as *D. ramosum*, *D. sapellonis*, *D. novo-mexicanum*, and *D. sierrae-blancae*. R. Sivinski (personal communication 2003) echoed these thoughts on the basis of his observations of *Delphinium* species in New Mexico. W. Jennings provided explanations of proposed revisions to *Delphinium* taxonomy and nomenclature in a letter to R.L. Hartman at the Rocky Mountain Herbarium, WY (Jennings 1998a) and also prepared an identification key

and descriptions of *Delphinium* species in Colorado for a Colorado Native Plant Society workshop (Jennings 1998b). The Colorado Vascular Plant Specimen Database (University of Colorado Herbarium 2003) and A Checklist of the Vascular Plants of Colorado (Hartman and Nelson 2001) both consider *D. robustum* to be synonymous under *D. ramosum* (the older of the two names).

This species assessment treats this species as *Delphinium robustum* Rydberg as presented in the PLANTS database (USDA Natural Resources Conservation Service 2002), Integrated Taxonomic Information System (2002), NatureServe database (NatureServe 2003), and Colorado NHP records (Colorado Natural Heritage Program 2004). Common names for *D. robustum* include Wahatoya Creek larkspur (USDA Natural Resources Conservation Service 2002, Integrated Taxonomic Information System 2002, NatureServe 2003, Colorado Natural Heritage Program 2004) and robust larkspur (Warnock 1997). The type specimen of *D. robustum* is housed at the New York Botanical Garden Herbarium (New York, NY), and an isotype is housed at Rocky Mountain Herbarium (Laramie, WY). Within USFS Region 2, additional specimens are located at the University of Colorado Herbarium in Boulder, CO and at the Colorado State University Herbarium in Fort Collins, CO.

History of species

Delphinium robustum was first collected in 1840 by Abert in New Mexico, and the type specimen of *D. robustum* was collected by Rydberg and Vreeland near Wahatoya Creek below the Spanish Peaks in 1900 in Colorado (Rydberg 1901). This species has since been considered in taxonomic treatments of *Delphinium* (Ewan 1945, Warnock 1995, Warnock 1997, Jennings 1998a, Jennings 1998b). None of the *D. robustum* sites in Colorado had been re-visited since their original discovery over thirty years ago. In 1998, efforts by one of the authors of this assessment (W. Jennings) to revisit most of the *D. robustum* occurrences in Colorado failed to find any individuals of this species at these locations (Jennings 1998a). No other status assessment or detailed demographic, ecological, or biological studies of this species or its close-relative *D. ramosum* have been undertaken.

Morphological characteristics

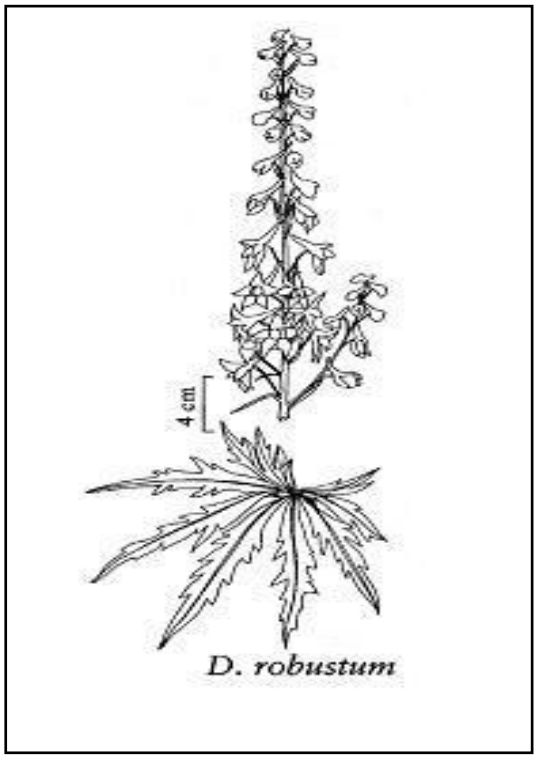
Members of the family Ranunculaceae are characterized as herbaceous plants often with rhizomes or tuberous roots, compound or dissected leaves with sheathing petiole bases, a perianth of showy petaloid sepals and reduced petals, and sap with alkaloids or other secondary compounds (Zomlefer 1994). The genus *Delphinium* is generally distinguished from other members of the Ranunculaceae family by its flowers with spurred sepals and petals (Zomlefer 1994).

Delphinium robustum is a tall, perennial herb from 100 to 250 cm tall with a very heavy, woody rootstock (**Figure 2**; Ewan 1945, Harrington 1954, Warnock 1993, Warnock 1997, Sivinski 1999). One herbarium specimen noted that the *D. robustum* individual was 10 ft (305 cm) tall (University of Colorado Herbarium 2003). The stem of *D. robustum* is simple, hollow, stout, and has been described as finely puberulent to glabrous and glaucous. The 12 to 22, pale olive-green leaves are cauline with petioles 5 to 13 cm long and round to pentagonal leaf blades 7 to 12 cm wide and 10 to 20 cm long. The leaves are palmately dissected to the base into five to seven main lobes, and each lobe is further dissected into additional lobes or teeth that are rounded at the apex or acute with a blunt tooth. The ultimate lobes of the leaves are 6 to 30 mm wide with blunt or short acute tips. The leaves are generally absent (withered) from the proximal fifth of the stem at anthesis. The elongate, loosely paniculate raceme inflorescences have a puberulent pedicel 0.5 to 2 cm long and 40 to 90 (up to 180) flowers. The inflorescences of larger specimens can be paniculately branched at the base. The linear, puberulent bracteoles are green to purple and 5 to 8 mm long. The flowers have azure to bluish purple to pale lavender (rarely pink) sepals that are uniformly puberulent, glabrous, or have a band of puberulence on the back. The lateral sepals are more or less forward pointing, up to 15 mm long and 8 mm wide, and broadly ovate to acute in shape. The upper sepals are extended basally into a spur. The dark blue spurs are straight to slightly decurved, 30 to 45 degrees above horizontal, and 10 to 13 mm long. The lower petals are included, sparsely bearded with yellow to white hairs, and are 5 to 7 mm long with clefts 2 to 3 mm long. The upper petals are entire or crisped. R. Sivinski (personal communication 2003) noted that the *D. robustum* individuals that he has observed have had pink or lavender flowers, rarely blue. The fruits are 13 to 18 mm long, puberulent, and three to four times longer than wide. The ovoid, tawny seeds have smooth surfaces, narrow wings on the margins, and are 2 to 2.5 mm long (Ewan 1945, Harrington 1954, Warnock 1993, Warnock 1997, Sivinski 1999).

(A)

Photographs by Jon Stewart, courtesy of New Mexico Rare Plants Technical Council, Albuquerque, NM. Reprinted with permission from the photographer.

(B)



Adapted from Warnock, M.J. 1997. *Delphinium*. In: Flora of North America North of Mexico, Volume 3. Flora of North America Association, Oxford University Press: New York, NY.

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

Delphinium robustum can supposedly be distinguished from other *Delphinium* species of the subsection *Exaltata* by its size, sepal characteristics, and/or puberulence (Warnock 1993, Warnock 1997, Sivinski 1999, Weber and Wittmann 2001). For example, *D. robustum* differs from *D. alpestre* because *D. robustum* is generally over 100 cm tall, and *D. alpestre* is less than 30 cm (Warnock 1997). *Delphinium robustum* is reported to have sepals 11 to 15 mm long and branched racemes, whereas *D. ramosum* has shorter sepals from 8 to 10 mm long, unbranched racemes, and is usually less than 100 cm tall (Warnock 1997, Sivinski 1999). *Delphinium barbeyi* is glandular and has longer, yellow hairs on the pedicels, dark blue flowers with acuminate lower sepals, and broad leaf segments in contrast to the short hairs on the pedicels, lighter blue flowers with ovate lower sepals, and narrow leaf segments of *D. robustum* (Warnock 1997, Sivinski 1999). *Delphinium sapellonis* has dull yellowish or brownish-purple flowers and strong glandular pubescence distinguished from the blue flowers and non-glandular puberulence in *D. robustum* (Ewan 1945, Sivinski 1999). However, as discussed earlier, one of the authors of this assessment (W. Jennings) observed flowers of these closely related species in the field and on herbarium specimens and found that the morphological characteristics presented in Rydberg (1901), Ewan (1945), and Warnock (1997) were not always present (Jennings 1998a, Jennings 1998b). As a result, W. Jennings has created a new key to *Delphinium* species in Colorado, which includes *D. ramosum* and *D. robustum* together as *D. ramosum* (Jennings 1998b). In addition, W. Jennings also believes that other closely related species, such as *D. sapellonis*, may not be separable from *D. robustum/D. ramosum*.

Technical descriptions of *Delphinium robustum* are presented in Ewan (1945), Harrington (1954), and Warnock (1993, 1997). An illustration is available in Warnock (1997), photographs of the type specimen are available in Ewan (1945) and New York Botanical Garden (2003), and a photograph of this species in its natural habitat is available in Sivinski (1999).

Distribution and abundance

Delphinium robustum is a regional endemic species known from southcentral Colorado and northcentral New Mexico (Rydberg 1901, Wooton and Standley 1915, Ewan 1945, Warnock 1997, Sivinski 1999, Durkin 2002, San Juan College Herbarium 2002, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). Within USFS Region 2, there are approximately nine occurrences of this species within El Paso, Huerfano, Las Animas, and Saguache counties in Colorado (**Figure 1**, **Table 1**; Ewan 1945, Warnock 1997, Durkin 2002, Colorado State University Herbarium 2003, Rocky Mountain Herbarium 2003, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). Areas with this species include the Spanish Peaks, Cuchara Valley, La Garita Hills, Cochetopa Hills, west side of the Sangre de Cristo Mountains, and Colorado Springs.

As discussed earlier, there is taxonomic confusion regarding *Delphinium robustum* and other *Delphinium* species in Colorado and New Mexico (e.g., *D. ramosum*); this can affect interpretation of the distribution and abundance of these species. Although all of the *D. robustum* specimens at the University of Colorado Herbarium and Rocky Mountain Herbarium were annotated to *D. ramosum* by W. Jennings in 1998 (Jennings 1998a, Jennings 1998b), this possible taxonomic change has not yet been published for acceptance by the general taxonomic community. Therefore, **Figure 1** includes nine occurrences of *D. robustum* that have been described in treatments of the genus previous to 1998. Occurrences described by Ewan (1945) and Warnock (1993, 1997), in element occurrence records compiled by the Colorado NHP (2004), and represented by herbarium specimens (Colorado State University Herbarium 2003, Rocky Mountain Herbarium 2003, University of Colorado Herbarium 2003) are presented in **Figure 1**. Thus, herbarium specimens still identified as *D. robustum* as of 1998, even though they were annotated by W. Jennings or J. Koontz as *D. ramosum* in 1998 or 2000, are included on the figure. Herbarium specimens originally identified as *D. robustum* and annotated by Ewan as *D. ramosum* in 1945 are not included on the figure because these were considered to be *D. ramosum* before 1998. For example, the occurrence of *D. robustum* near Camp Creek in El Paso County near Colorado Springs is possibly a misidentification, as it is very near the type locality of *D. ramosum* and the location of numerous other *D. ramosum* specimens (Jennings 1998b). Jennings (1998b) suggested that it is unlikely that two such closely-related species would be blooming in the same place at the same time. However, the Camp Creek occurrence is on **Figure 1** because it was included in Ewan's 1945 treatment and not annotated by Jennings until 1998.

If further analysis proves that *Delphinium robustum* and *D. ramosum* are not separable, then the range of this species in the wide sense would still be restricted to Colorado and northern New Mexico, but it would stretch from Larimer County to northeastern New Mexico (Jennings 1998a). Jennings (1998a) has

observed specimens of *D. ramosum* or *D. robustum* from three distinct areas in Colorado: the Eastern Slope area in Larimer, Boulder, Gilpin, Clear Creek, Jefferson, Park, Teller, and El Paso counties; the San Juans and Cochetopa Hills area in Saguache, Hinsdale, and Mineral counties; and the Spanish Peaks/Culebra Range area in Costilla, Huerfano, and Las Animas counties (Jennings 1998a).

As discussed above, the majority of information about *Delphinium robustum* is contained within brief descriptions, and there is considerable uncertainty regarding the exact location of many sites and the existence of occurrences on USFS lands. Of the nine occurrences of *D. robustum* in USFS Region 2, four occurrences may be on the Pike-San Isabel National Forest, two occurrences may be on the Rio Grande National Forest, and one occurrence may be on the Gunnison National Forest (**Figure 1**, **Table 1**). Because this species is not listed as a sensitive species in USFS Region 2, USFS botanists for the pertinent national forests were not familiar with *D. robustum* and could not verify its presence or absence on USFS lands (D. Erhard personal communication 2003, S. Olson personal communication 2003, G. Austin personal communication 2004). Occurrences may also be on or near Colorado BLM lands, State of Colorado lands, City of Colorado Springs lands, or private lands (**Table 1**). **Table 1** incorporates uncertainty by listing possible land management contexts with a "?". The table also includes bold font to indicate the most likely management context based on W. Jennings' field and research work. For example, the elevation listed for one of the sites in Saguache County suggests that it would be on BLM land, rather than the slightly higher-elevation USFS land. However, it is still possible that these occurrences could extend to nearby lands.

Outside USFS Region 2, *Delphinium robustum* is reported from six occurrences in Colfax, Rio Arriba, Sandoval, and Taos counties in New Mexico, within the Jemez, San Antonio, San Juan, San Pedro, and Sangre de Cristo mountains (Wooton and Standley 1915, Warnock 1997, Sivinski 1999, San Juan College Herbarium 2002, R. Sivinski personal communication 2003). Tidestrom and Kittell (1941) list the distribution of *D. robustum* as Montana to northern New Mexico; however, no other references include Montana as part of the range of this species. Sivinski (1999) pointed out that only Colfax and Taos counties are represented by specimens at the University of New Mexico Herbarium, and most of this species' range is likely in the southern Sangre de Cristo range (R. Sivinski personal communication 2003).

Abundance estimates for *Delphinium robustum* are lacking (Sivinski 1999, Durkin 2002, NatureServe 2003). Our knowledge of this species is based mainly on historical records (i.e., herbarium specimens) that do not report counts of individuals. One herbarium record noted that this species was "infrequent" in 1934 (University of Colorado Herbarium 2003). Ewan (1945) suggested that *D. robustum* colonies are always small and are widely scattered along Front Range canyons of the Arkansas River catchment basin. In addition, it appears that individuals are not common and tend to be scattered within appropriate habitat (Ewan 1945). Ewan (1945) searched for *D. robustum* in the Wet Mountains and around West Spanish Peak and was unable to find it in the field. In New Mexico, R. Sivinski (1999, personal communication 2003) reported that *D. robustum* is fairly scattered and rare in geographic distribution but may be locally abundant although population sizes have never been quantitatively assessed. R. Sivinski (personal communication 2003) has observed one site with this species in New Mexico where scattered plants occur for about a mile along a road. J. Stewart (personal communication 2003) found only a few plants at the site where he observed this species. The "rarity" status for this species as designated by Sivinski (1999) is 1, indicating that it is rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low. In contrast, W. Jennings performed extensive field surveys in 1998 to assess the current status of all reported occurrences of *D. robustum* in Colorado, but he did not find any individuals, except those that he considered as *D. ramosum* (Jennings 1998a, Jennings 1998b). Thus, environmental conditions in 1998 were not suitable for the growth of *D. robustum*, this species had been extirpated in Colorado, or these individuals had been previously misidentified as *D. robustum*. R. Sivinski (personal communication 2003) also stated that as he understood it (based on conversations with W. Jennings), the extant populations of this species are all found in New Mexico; there are no existing populations in Colorado due either to extirpation or taxonomic confusion. If *D. ramosum* and *D. robustum* are not separable, then the abundance of this species in the wide sense would be greater than for *D. robustum* in the strict sense, as *D. ramosum* has more occurrences and is ranked as G4 (apparently secure globally) (NatureServe 2003). However, it is important to note that even if these taxa are a single species, it still would not be a common species with a large geographic range or with large populations within that range (M. Price and N. Waser personal communication 2004).

Thus, there is a significant lack of knowledge about the current distribution and abundance of *Delphinium robustum* throughout its range and on USFS Region 2 lands. In addition, the abundance and distribution of this species cannot be accurately estimated until taxonomic issues are settled.

Population trends

Delphinium robustum occurrence sizes have not been estimated, and multi-year population or demographic monitoring has not been initiated for any site. As discussed earlier, this species was not found during a 1998 survey of most of the reported sites by one of the authors of this assessment (W. Jennings; Jennings 1998a, Jennings 1998b). Thus, either environmental conditions in 1998 were not suitable for the growth of *D. robustum*, or this species has been extirpated in Colorado, or these individuals had been previously misidentified as *D. robustum*.

Habitat characteristics

Habitat characteristics have not been extensively described for *Delphinium robustum*; all available notes from herbarium specimen labels and element occurrence records are reproduced in **Table 1** for occurrences within USFS Region 2 (Colorado State University Herbarium 2003, Kathryn Kalmbach Herbarium 2003, Rocky Mountain Herbarium 2003, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). *Delphinium robustum* is a perennial forb inhabiting canyon bottoms and aspen groves from 2,135 to 3,400 meters (m) (7,000 to 11,200 ft.) in the mountains of southcentral Colorado to northcentral New Mexico (**Table 1**; Wooton and Standley 1915, Ewan 1945, Harrington 1954, Warnock 1997, Sivinski 1999, Weber and Wittmann 2001, Durkin 2002, NatureServe 2003, Rocky Mountain Herbarium 2003, R. Sivinski personal communication 2003, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). The reported elevation for the nine Colorado occurrences ranges from 2,135 to 2,591 m (**Table 1**). Although one herbarium specimen reported this species occurring at 2,591 m, mapping exercises by the Colorado NHP indicate that the actual elevation of the location described in that specimen label is approximately 2,932 m in elevation (Colorado Natural Heritage Program 2004).

In USFS Region 2, *Delphinium robustum* has been reported growing in broad canyon bottoms, shaded woods, open woods, borders of aspen woodlands, edges of meadows, and near an irrigation ditch (**Table 1**; Ewan 1945, Harrington 1954, Weber and Wittmann 2001, University of Colorado Herbarium 2003, Colorado Natural Heritage Program 2004). Plant species associated with *D. robustum* have not been described; not enough information is available to describe vegetation communities associated with *D. robustum* using the classifications of Grossman et al. (1998).

Outside USFS Region 2, *Delphinium robustum* occurs in valley bottoms, riparian woodlands, subalpine meadows, and aspen groves in lower and upper montane coniferous forests. Microhabitats can include dense forest, open woods, woodland edges, meadows, meadow edges, and roadsides (Wooton and Standley 1915, Sivinski 1999, Durkin 2002, San Juan College Herbarium 2002, NatureServe 2003, R. Sivinski personal communication 2003, J. Stewart personal communication 2003). R. Sivinski (personal communication 2003) noted that *D. robustum* in New Mexico tended to occur in more mesic areas, such as valley bottoms, as opposed to drier areas, such as valley sides.

The closely related *Delphinium ramosum* also occurs in meadows, aspen woodlands, and *Artemisia* spp. scrub (Warnock 1997). At many of the reported locations for *D. robustum*, one of the authors of this assessment (W. Jennings) actually found occurrences of what he considered to be *D. ramosum*. Based on these findings, the two species either have similar habitat or the species are not taxonomically distinct. Jennings (1998a) estimates that the elevational range of these species in Colorado, based on specimens of *D. robustum* and *D. ramosum*, is 2,225 to 3,231 m (7,300 to 10,600 ft.), mostly 2,560 to 2,745 m (8,400 to 9,000 ft.), and averaging 2,713 m (8,900 ft.).

Reproductive biology and autecology

Although the reproductive biology of *Delphinium* species has been the subject of preliminary investigative study (Waser and Price 1979, Waser and Price 1985, Waser 1988, Inouye 1991, Graham and Jones 1996, Bosch et al. 1998, Bosch and Waser 1999, Williams 1999, Williams and Waser 1999, Bosch et al. 2001, Bosch and Waser 2001, Johnson 2001, Koontz et al. 2001, Schulke and Waser 2001, Simon et al. 2001, Williams et al. 2001, Dodd and Helenurm 2002), details concerning the reproductive biology of *D. robustum* are largely inferred or unknown. In this and subsequent sections, we summarize available observations of *D. robustum* as well as present information from other related *Delphinium* species endemic to USFS Region 2 or adjacent states. In many cases we refer to studies on *D. nuttallianum* and *D. barbeyi*, because information

about species more closely-related to *D. robustum*, such as *D. ramosum* and *D. sapellonis*, are also not available. These comparisons are not meant to imply that *D. robustum* necessarily reproduces in a similar manner, but they may help to elucidate *potential* reproductive mechanisms for this species and suggest avenues for future research. *Delphinium robustum* is likely to be at least somewhat similar to other delphiniums in the Rocky Mountains (M. Price and N. Waser personal communication 2004).

Reproduction

Delphinium robustum is a tall larkspur that grows up to 250 cm tall (and up to 10 ft. [305 cm] as noted on one herbarium specimen) and produces dense inflorescences with up to 180 lavender to blue flowers (Colorado Natural Heritage Program 2004). This species is reported to flower over a long period of time, from early July to September (Ewan 1945, Warnock 1997).

The species in the genus *Delphinium* tend to be predominantly outcrossers with some self-compatibility, but the extent of self-incompatibility and autogamy varies throughout the genus (Bosch et al. 2001, Williams et al. 2001). It is unknown if *D. robustum* relies on outcrossing, self-fertilization, or a combination; details of the breeding system have not been studied. There is no information concerning the extent of vegetative reproduction for this species. Some *Delphinium* species do not reproduce vegetatively (e.g., *D. nuttallianum*), while others are known to be rhizomatous (e.g., *D. bolossii*) (Bosch et al. 2001, Williams et al. 2001). The ability of *D. robustum* individuals to remain dormant during unsuitable conditions, similar to other *Delphinium* species, is also unknown (Koontz et al. 2001). There have also been no studies on other vital aspects of *D. robustum* reproduction, such as which insect or hummingbird species are effective pollinators, germination requirements and success, demographic parameters (e.g., average fruit set or seeds per fruit), or genetic aspects of reproduction.

Life history and strategy

There have been no studies on the life history, demographic rates, fecundity, or longevity of *Delphinium robustum*. The competitive relationships, ecological limitations, and reproductive biology are not adequately known to assess the life history and strategy of *D. robustum*. Stress-tolerant or "S-selected" species have a perennial life history, an ability to withstand harsh and unproductive environments, and a capability to access resources with well-developed roots (Grime 1979, Barbour et al. 1987). Ruderal or "R-selected" species can exploit low stress, high disturbance environments by minimizing vegetative growth and maximizing reproductive output (Grime 1979, Barbour et al. 1987). Good competitors, or "C-selected" species, are usually robust, perennial plants that tend to maximize resource capture in relatively undisturbed conditions and allocate resources to growth (Grime 1979, Barbour et al. 1987). The robust growth, substantial rootstock, and large inflorescence of *D. robustum* suggest that this species may possibly be a successful competitor for some resources (e.g., light) compared to other species (e.g., short-statured herbs). However, the competitive ability of this species has not been studied. The ability of this plant to colonize disturbed environments is unknown. The hypothesized life cycle of this perennial plant is depicted in **Figure 3**.

Pollinators and pollination ecology

Pollination biology and specific pollination mechanisms for *Delphinium robustum* have not been studied. Members of the family Ranunculaceae are well-equipped to attract insect pollinators with their conspicuous flowers, but details of the pollination mechanisms depend on floral and pollinator morphology (Zomlefer 1994, Graham and Jones 1996). Species with open flowers attract a variety of insects, whereas species with more elaborate flowers with spurs, like *D. robustum*, tend to attract insects with long proboscises or hummingbirds (Zomlefer 1994). Pollinators of other *Delphinium* species in Colorado (e.g., *D. barbeyi*, *D. nuttallianum*) are bumblebees (*Bombus appositus* and *B. flavifrons*), hummingbirds (*Selasphorus platycercus* and *S. rufus*), and solitary bees (Williams and Waser 1999, Williams et al. 2001, M. Price and N. Waser personal communication 2004). One of the authors of this assessment (W. Jennings) also observed a sphinx moth (*Hyles lineata*) visiting *D. scopulorum* in New Mexico and unidentified flies on *D. ramosum* in Huerfano County. The use of *D. robustum* by these or other species is not known. In addition, the extent of self-pollination or cross-pollination for *D. robustum* is unknown. Williams et al. (2001) discovered that *Delphinium* species with multiple, large inflorescences (e.g., *D. barbeyi*) tend to have higher intraplant pollen transfer and higher rates of self-fertilization than plants with a single, small inflorescence (e.g., *D. nuttallianum*).

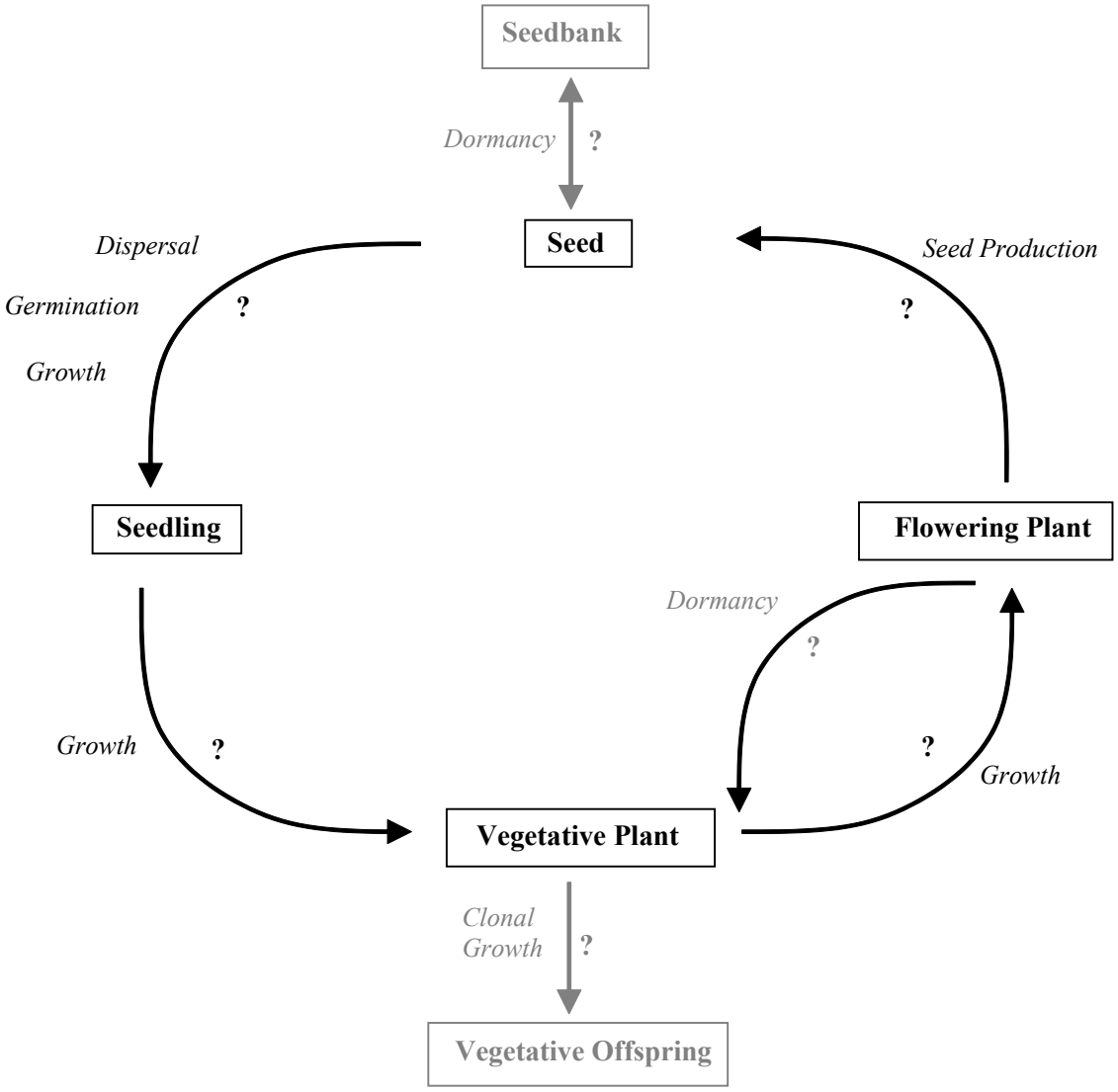


Figure 3. Schematic representation of the hypothesized life cycle of *Delphinium robustum*. Rates of recruitment, growth, dormancy, fecundity, and dispersal are unknown and are indicated by "?". The extent of asexual reproduction and presence of a seedbank are also unknown for this species and are indicated by gray lines. Death at each stage and mortality rates are not indicated on this figure. Figure adapted from Grime (1979).

Important issues related to the pollination of rare plants that have yet to be researched for *Delphinium robustum* include the extent of asexual and sexual reproduction, the identity of effective pollinators, the effect of plant density on pollination, any genetic implications of pollination, and the effects of environmental fluctuations on pollination. For example, Schulke and Waser (2001) found that pollinators of *D. nuttallianum* traveled up to 400 m among scattered individuals and populations in naturally fragmented landscapes, and this has implications for the gene flow within a metapopulation and conservation genetics of this species. Bosch and Waser (1999, 2001) hypothesized that the reproductive success of some *D. nuttallianum* individuals was limited by poor environmental conditions rather than pollinator limitations.

Dispersal mechanisms

Details of seed dispersal mechanisms in *Delphinium robustum* have not been studied. In general, *Delphinium* seeds lack wings and are probably gravity-dispersed or possibly ant-dispersed (Turnbull et al. 1983, M. Price and N. Waser personal communication 2004). *Delphinium robustum* is a very tall larkspur species; one herbarium specimen noted that an individual plant

was 10 ft (305 cm) tall. It is likely that seeds drop to the ground near the parent plant when jostled by the wind or animals. Seeds on the ground could be dispersed downslope or downwind by water movement, soil movement, or animal vectors. In addition, it is possible that any seeds or seedheads that fall from inflorescences to the snowpack could be dispersed by wind across the surface of the snow or the movement of snowmelt water (D. Inouye personal communication 2004). The ability of *D. robustum* seeds to float and disperse by water is not known (M. Price and N. Waser personal communication 2004).

Williams and Waser (1999) documented that seed dispersal of *Delphinium nuttallianum* is primarily passive, and seeds generally drop an average of 10 cm away from the parent plant. Presumably, dispersal success of *D. robustum* may depend on wind and precipitation patterns, substrate characteristics, animal activities, topographic heterogeneity, and the availability of suitable "safe" sites. Durkin (2002) suggested that fragmentation of canyon bottoms due to livestock disturbances and residential development may reduce the availability of suitable habitat for this species and subsequently reduce its dispersal capabilities.

Seed viability and germination requirements

No information is available concerning the fertility, seed viability, and germination requirements of *Delphinium robustum* in natural environments. *Delphinium* species are extensively grown in cultivation, and notes on cultivated *Delphinium* species suggest that these species are easy to grow in pots or gardens in well-drained, open, sunny locations (Nicholls 2002). Seed sown in the autumn generally germinates the following spring (Nicholls 2002). In contrast, Williams and Cronin (1968) found that native *Delphinium* species in Colorado (*D. barbeyi*, *D. occidentale*, and *D. nuttallianum*) were difficult to germinate, and seedlings tended to grow slowly for the first two years. Seeds of these montane and subalpine species germinated under the snow, provided there was enough snow insulation and adequate moisture. M. Price and N. Waser (personal communication 2004) also noted that *D. nuttallianum* was difficult to germinate in the lab, but germinated well when pots with seeds were dug into the ground in the field.

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in height, leaf size, flowering time, or other attributes, with a change in light intensity, latitude, elevation, or other site characteristics. *Delphinium robustum* occurs at a range of elevations and in a variety of microhabitat contexts (e.g., open meadow, wooded thicket), and it is possible that characteristics such as flowering time, height, and leaf size could vary with these different microenvironments. The identification and taxonomy of *D. robustum* and other *Delphinium* species has proven to be problematic, and these issues could be further confounded if these species tend to be phenotypically plastic in key identifying characteristics (e.g., height, sepal length, flower color, puberulence).

Cryptic phases

No information regarding cryptic phases of *Delphinium robustum* is available. Seed dormancy can be an important adaptation for plant populations to exploit favorable conditions in a harsh and unpredictable environment (Kaye 1997). Details of seed longevity, patterns of seed dormancy, and factors controlling seed germination for *D. robustum* have not been studied. Williams and Cronin (1968) found that the seed of three *Delphinium* species (*D. barbeyi*, *D. occidentale*, and *D. nuttallianum*) in Colorado either germinated or disintegrated during the first year under field conditions, and no viable seed existed during the second year. Williams and Waser (1999) and M. Price and N. Waser (personal communication 2004) documented that there is no dormant soil seed bank for *D. nuttallianum* in Colorado. The status of a seed bank for *D. robustum* is not known. It is also unknown whether mature individuals of *D. robustum* can go dormant during suboptimal conditions, storing resources in the persistent caudex. M. Price and N. Waser (personal communication 2004) have noted that *D. nuttallianum* adults may go dormant seasonally and for a few seasons after a year with a large reproductive effort. *Delphinium robustum* may or may not have similar strategies and characteristics to these other Colorado delphiniums.

Mycorrhizal relationships

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

Hybridization

Natural hybridization regularly occurs among members of the genus *Delphinium*, although hybrids are usually limited to a small percentage of the parent species' population (Warnock 1989, Warnock 1997, Dodd and Helenurm 2002). Hybridization has been

reported between *D. robustum* and *D. sapellonis*, as well as between other pairs of *Delphinium* species from Colorado and New Mexico (e.g., *D. ramosum* x *D. barbeyi*, *D. ramosum* x *D. glaucum*) (Warnock 1993, Warnock 1997). *Delphinium sapellonis* is closely related to *D. robustum* and replaces *D. robustum* in the higher elevations of the southern Sangre de Cristo Mountains east of Santa Fe (Ewan 1945, Warnock 1993). The role of hybridization in the evolution of *D. robustum* or issues related to genetic variability are unknown.

Demography

Little is currently known about population demographics in *Delphinium robustum*. Research on other *Delphinium* species, where available, provides insights into some of the ecological, spatial, and genetic considerations for *D. robustum* demography, as discussed in the following sections.

Life history characteristics

There is no information regarding population parameters or demographic features of *Delphinium robustum*, such as metapopulation dynamics, life span, age at maturity, recruitment, and survival. Refer to **Figure 4** and **Figure 5** for envirograms outlining resources and malentities potentially important to *D. robustum*. An envirogram is a schematic diagram, first introduced by Andrewartha and Birch (1984) for animal species, that depicts 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 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 *D. robustum*. Additional information would be needed to create more comprehensive and specific envirograms.

Life cycle diagram and demographic matrix. A life cycle diagram is 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 *Delphinium robustum*, and so there are no definitive data regarding the vital rates that contribute to individual fitness. Although stage-based models based on population matrices and transition probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model. For *D. robustum*, the stages that could potentially be incorporated into a demographic matrix include seed, seedling, vegetative individuals, and reproductive adults (**Figure 3**).

Presumably, seeds of *Delphinium robustum* are dispersed to suitable locations. The probability of germination and subsequent establishment depend 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.

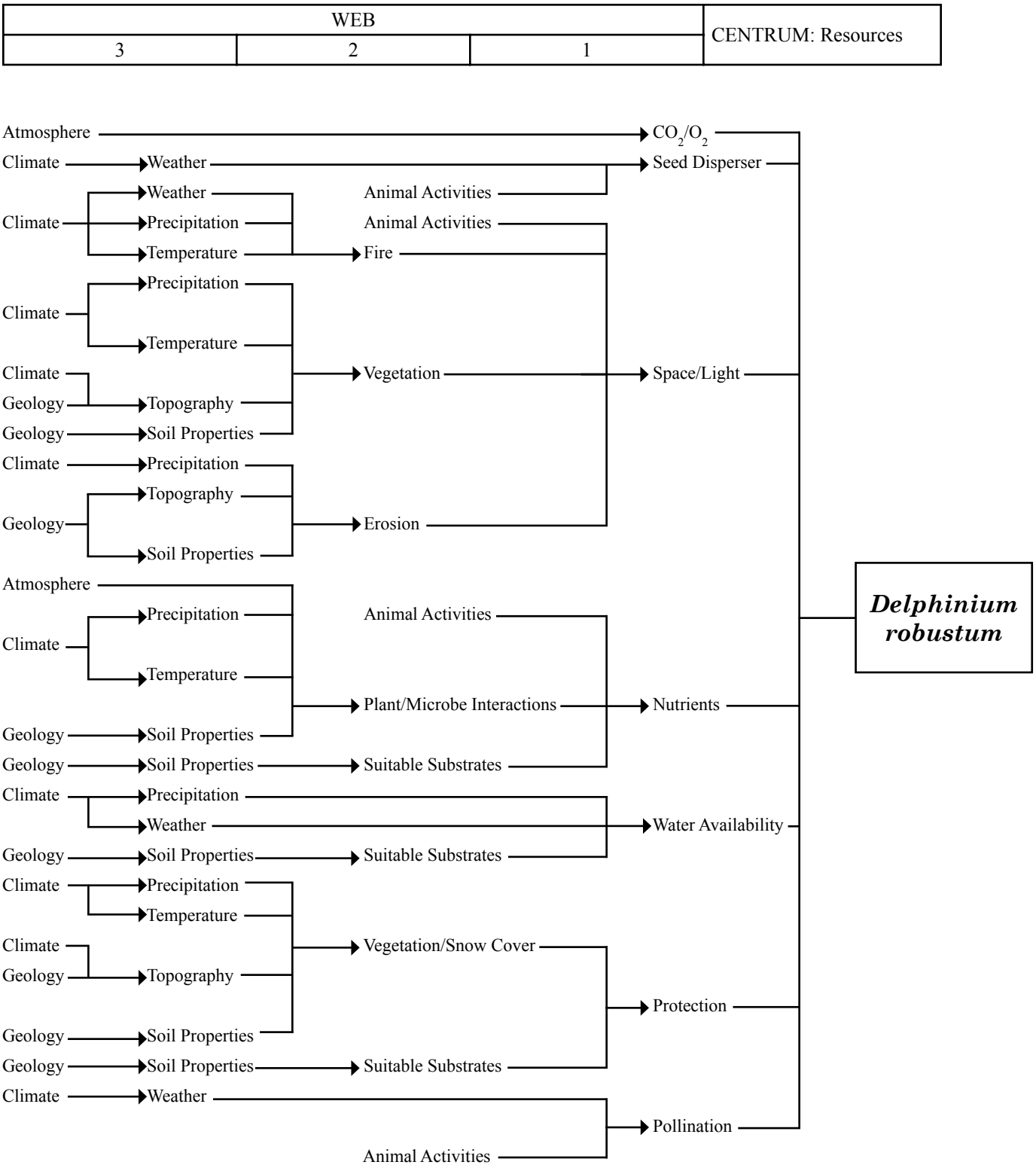


Figure 4. Envirogram outlining potential resources for *Delphinium robustum*. An envirogram depicts direct and indirect factors that may influence a species. The centrum includes the most proximate factors and the web includes more distal factors.

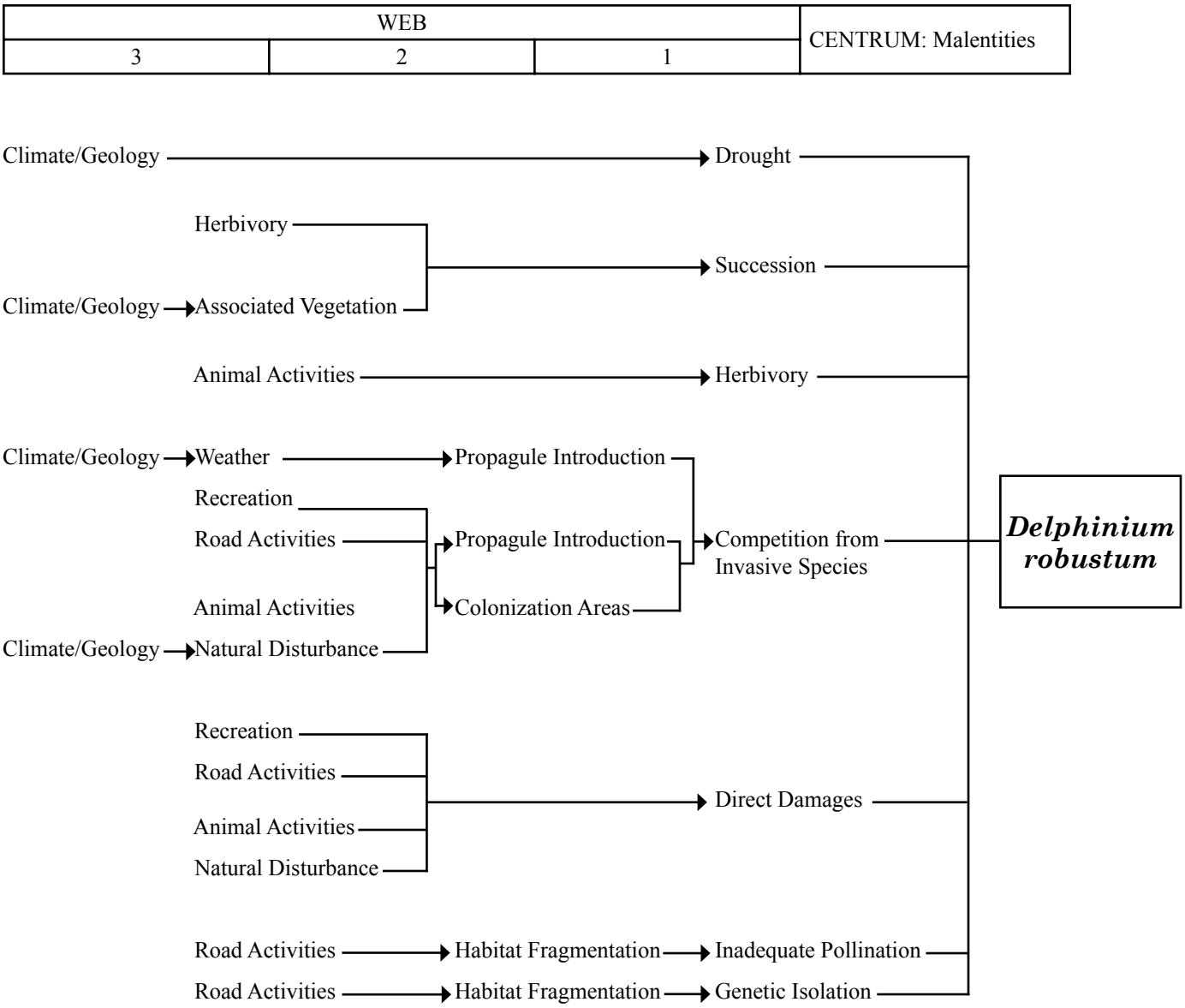


Figure 5. Envirogram outlining malentities to *Delphinium robustum*. An envirogram depicts direct and indirect factors that may influence a species. The centrum includes the most proximate factors and the web includes more distal factors.

Population viability analysis. In order to initiate a population viability analysis for *Delphinium robustum*, 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 *Delphinium robustum* 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 *D. robustum*. Ralphs and Gardner (2001) hypothesized that deep-rooted *Delphinium* species can grow throughout the summer in areas with summer monsoonal precipitation patterns (e.g., southern Colorado) without being limited by soil moisture. Inouye and McGuire (1991) and Inouye (1991) studied the effect of climate fluctuations on *D. nuttallianum* in

subalpine meadows of Colorado. They found that years with lower annual snowfall were correlated with lower reproductive output, possibly as a result of reduced insulative properties, exposure to colder temperatures, and less early-season water. In addition, the timing and abundance of flowering in *D. barbeyi* is also highly correlated with snowpack conditions (Inouye et al. 2002). M. Price and N. Waser (personal communication 2004) also noted that their studies of short delphiniums with bulbs or corms have found that these species rely on snowmelt for water. Jennings (1998b) hypothesized that because *D. robustum* and *D. ramosum* are found at lower elevations than *D. barbeyi*, these two species likely rely more on monsoonal thunderstorm moisture than on spring snowmelt like *D. barbeyi*. There is little information on the capabilities of *D. robustum* 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 could 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 *Delphinium robustum*. 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 their intensity and location. For example, existing *D. robustum* individuals could be impacted by a prescribed burn or wildfire, or new suitable habitat could be created for future growth or germination. The habitat characteristics of *D. robustum* are not well known, but it is possible that it may require periodic fires to open the understory and canopy of its woodland habitats. The optimal fire return intervals for persistence of *D. robustum* are not known, but the cycles most likely vary for different habitat types and elevations. It is possible that small mammal burrowing activities may affect *D. robustum* by creating suitable germination sites through soil turnover or by damaging or feeding on adult plants or seeds (M. Price and N. Waser personal communication 2004). *Delphinium robustum* has been observed along roadsides (R. Sivinski personal communication 2003, J. Stewart personal communication 2003), but the effect of disturbances associated with road activities (e.g., erosion/sedimentation, trampling, weed control activities) is unknown.

Spatial characteristics

The spatial distribution of *Delphinium robustum* at local and regional scales has not been studied. This species appears to be scattered over a variety of elevations and habitat types within its restricted range in southwestern Colorado and northeastern New Mexico. The scattered distribution may represent ecological limitations and habitat heterogeneity, dispersal barriers perhaps as a result of highly variable topography or habitat fragmentation, or it may reflect "holes" in the distribution due to incomplete inventory efforts. The spatial configuration of metapopulations or the extent to which gene flow occurs between local and distant populations is unknown for *D. robustum*. The size and density of populations and the distribution of individual plants within the population have not been described or studied. Characteristics that could influence the spatial distribution of this species may include habitat availability, seed dispersal patterns, competition with other vegetation, landscape and microsite heterogeneity, or effects of disturbances (e.g., small mammal activities, livestock activities, fire).

Genetic characteristics and concerns

Genetic concerns, such as the amount of genetic variability between and within populations, have not been studied for *Delphinium robustum*. The chromosome count for other *Delphinium* species is reported as n=8 (Ewan 1945, Bosch et al. 1998); however, we do not know if this holds for *D. robustum*. In addition, the genetic distinctiveness of this species and relationships with other closely related species have not been assessed. 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 (Koontz et al. 2001). Studies of genetic variability and population structure have been performed for other *Delphinium* species (Waser and Price 1985, Bosch et al. 1998, Williams and Waser 1999, Koontz et al. 2001, Simon et al. 2001, Williams et al. 2001, Dodd and Helenurm 2002), and these studies provide a framework for developing similar studies for *D. robustum*. For example, Williams and Waser (1999) failed to detect large genetic differences between populations of *D. nuttallianum* separated by up to 3,250 m and the researchers hypothesized that significant long-distance pollination facilitated gene flow between these populations. Williams et al. (2001) discovered that *D. barbeyi* had significant genetic

differentiation between populations, perhaps as a result of high rates of self-pollination. Dodd and Helenurm (2002) found that insular populations of *D. variegatum* were not genetically depauperate compared to mainland varieties of this species, suggesting that population isolation had not caused a loss of genetic diversity. Koontz et al. (2001) assessed the genetic status of wild and cultivated populations of *D. luteum* and determined that cultivated populations contain a significant portion of the genetic diversity present in wild populations and could possibly be used for reintroduction. Bosch et al. (1999) determined that low levels of genetic variability, low heterozygosity, disturbed pollinator activity, and declining population sizes are contributing to the endangered status of *D. bolosii*. We have included mention of these studies for completeness. *Delphinium robustum* could have similar or different genetic issues based on any differences in reproductive biology, breeding system, plant morphology, pollination, spatial distribution, plant density, and habitat types.

Factors limiting population growth

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

Community ecology

Herbivores and relationship to habitat

The extent or effects of herbivory on *Delphinium robustum* are unknown. In general, herbivores can cause direct damage to plants (e.g., consume individuals), cause indirect damage (e.g., reduce seed production and thus reproductive success), or facilitate a species (e.g., preferentially consume other species, aerate the soil, create favorable microsites for germination) depending on the circumstances (Thomsom et al. 1996, M. Price and N. Waser personal communication 2004).

The exact locations of *Delphinium robustum* occurrences are largely unknown, and the details of management activities at those areas are thus difficult to ascertain. *Delphinium robustum* may possibly occur on the Rio Grande, Gunnison, and/or Pike-San Isabel national forests (**Table 1**); the definite occurrence of this species on USFS land has not been verified. Light to moderate cattle grazing does occur on those areas of the national forests with possible *D. robustum* occurrences, but the potential direct or indirect effects of cattle on this species are unknown (D. Erhard personal communication 2003, S. Olson personal communication 2003, G. Austin personal communication 2004). R. Sivinski (personal communication 2003) and J. Stewart (personal communication 2003) did not note livestock activity near the species, nor did they observe any signs of grazing damage on any individuals. Being such a tall species, *D. robustum* is probably not affected by trampling, although it could be knocked down by the activities of animals moving though riparian areas or possibly affected by soil compaction caused by trampling. Based on observations of *D. nuttallianum*, it is also possible that some grazing regimes could facilitate *D. robustum*, by preferentially consuming competitors or reducing competitors through trampling (M. Price and N. Waser personal communication 2004). In Colorado, M. Price and N. Waser (personal communication 2004) observed decreases in the density of *D. nuttallianum* in places where grazing was reduced or removed.

Delphinium species are known to contain complex diterpenoid alkaloids that can be poisonous to cattle and other livestock, depending on the amount and rate of ingestion. Poisoning by *Delphinium* species has been implicated as a major cause of death for livestock in both plains and mountainous environments (Ewan 1945, Ralphs et al. 1989, Ralphs et al. 1998, Ralphs and Gardner 2001, Pfister et al. 2002). Despite toxicity, *Delphinium* species are still considered palatable because cattle and other livestock do select and eat these species. The amount of toxicity in plants and the possible effects on cattle will depend on plant developmental stage, season, weather changes, sun exposure, nitrogen availability, soil moisture (and other environmental conditions), part of plant eaten, cattle behavior (e.g., appetite), and availability and condition of other forage (Ralphs et al. 1989, Ralphs and Gardner 2001, Pfister et al. 2002). For example, Ralphs and Gardner (2001) found high alkaloid concentrations in *D. occidentale* and *D. barbeyi* plants growing in southern Colorado where the summer monsoonal precipitation patterns allowed plants to grow throughout the season without soil moisture limitations. In contrast, water stress can also increase the alkaloid concentration in a plant (Ralphs et al. 1989). In general, cattle tend to eat *Delphinium* species after the flowers are formed, then they eat the flowering racemes, followed by leaves and seed pods as the plant matures (Ralphs et al. 1989). Studies on poisoning by *Delphinium* species have concluded that 1) cattle

are likely to be more at risk for poisoning than horses because horses usually do not eat enough to endanger them, 2) sheep do not appear to be affected, 3) toxicity is not directly correlated with total alkaloid concentration, and 4) antidotes are available (Ewan 1945, Ralphs et al. 1989). The alkaloid concentrations in *D. robustum* have not been quantified. Ranchers can take a variety of steps to reduce cattle poisoning by *Delphinium* species, such as cultural controls (e.g., conditioned training, mineral supplementation), chemical controls (e.g., selective herbicide control in dense patches), and biological controls (e.g., grazing sheep before cattle, introducing biological control insects) (Ralphs et al. 1989, Ralphs et al. 1998, Pfister et al. 2002). If ranchers delay introducing livestock to an area until after *Delphinium* species have set seed and cattle consume other species preferentially, then grazing practices could possibly have a positive effect on those *Delphinium* species (M. Price and N. Waser personal communication 2004).

The toxicity and palatability of *Delphinium robustum* to livestock and native herbivores, such as large ungulates (e.g., elk, deer), small mammals (e.g., gophers, hares, other small mammals), or insects (e.g., ants, beetles), and the effects of eating this species on these herbivores are unknown. There is evidence of herbivory of other *Delphinium* species with significant implications for the demography of the species in some cases. Inouye and McGuire (1991) noted that some early-flowering *Delphinium* species are important sources of early-season nectar for queen bees and hummingbirds. Bosch et al. (1998) recorded herbivory by insect nectar robbers perforating the spurs of *Delphinium* flowers, and Simon et al. (2001) reported caterpillars feeding on the seeds of *D. montanum*, a European species. Flowers of *D. nuttallianum* and *D. barbeyi* harbor various insect larvae in the nectaries and developing fruits (M. Price and N. Waser personal communication 2004). Gophers tend to eat the tubers of *D. nuttallianum* and other small mammals eat the flowers and fruit (M. Price and N. Waser personal communication 2004). Significant herbivory by Pyrenean chamois caused a 97 percent reduction in fecundity for *D. montanum* (Simon et al. 2001). Thomson et al. (1996) observed that gopher herbivory and burrowing actions significantly affected the demography of glacier lilies, and M. Price and N. Waser (personal communication 2004) have also observed similar interactions for *D. nuttallianum* individuals growing in deep soils. Thus, the direct and indirect effects of herbivores on *D. robustum* warrant further study.

Competitors and relationship to habitat

The interactions of *Delphinium robustum* within the plant community are not well known. General habitat characteristics or the successional or competition dynamics in these habitats and the full range of tolerances of *D. robustum* have not been studied. In addition, the response of this species to forest fire or prescribed burns has not been studied (Sivinski 1999, Durkin 2002).

There are no reports of non-native invasive species specifically affecting *Delphinium robustum*, and there was no discussion of invasive species in literature sources for other *Delphinium* species. One herbarium specimen for *D. ramosum* in northern Colorado noted the presence of *Cirsium arvense* (Canada thistle) (Rocky Mountain Herbarium 2003). 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. Invasive species, such as *Poa pratensis* (Kentucky bluegrass), *Bromus japonicus* (Japanese brome), *Bromus inermis* (smooth brome), *Linaria vulgaris* (yellow toadflax), *Acroptilon repens* (Russian knapweed), *Kochia scoparia* (kochia), *Salsola iberica* (Russian thistle), *Ambrosia artemisiifolia* (ragweed), and *Melilotus officianalis* (biennial yellow sweet clover) have been recorded in the Arkansas River watershed (Arkansas Headwaters Recreation Area 2001). Weeds have invaded this area as a result of soil disturbance related to road construction, recreation site development, increased recreation use, and off-highway vehicle (OHV) use (Arkansas Headwaters Recreation Area 2001). Some of these noxious species can invade disturbed or undisturbed sites, reproduce vegetatively, form dense, monospecific stands, and outcompete native species. The extent of non-native plant invasions near existing occurrences of *D. robustum* is not known. If *D. robustum* is a good competitor, then perhaps it could tolerate or outcompete invasive species. However, the competitive ability of *D. robustum* is not known. The threat of exotic species to *D. robustum* most likely depends 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 potential effects of weed control tactics on this species have not been discussed.

Parasites and disease

Evidence for parasites or diseases on *Delphinium robustum* or on other *Delphinium* species was not reported in the reviewed literature.

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. Specific details concerning pollination ecology of *Delphinium robustum* are largely unknown. The positive interactions between other associated plant or microbial species and *D. robustum* are also unknown.

Habitat influences

Delphinium robustum appears to be geographically restricted, but the causes of endemism are unknown. The full range of environmental conditions tolerated by this species has not been studied. The availability and quality of suitable habitat most likely varies from area to area, depending on heterogeneity in associated species, topography, substrate, disturbance factors, and competition with other species. The ability of this species to colonize disturbed areas is unknown.

CONSERVATION

Threats

Threats to the long-term persistence of *Delphinium robustum* in USFS Region 2 are mostly unknown because of the lack of species knowledge and research. The information presented in this section is primarily based on preliminary assessment by Durkin (2002), field work by one of the authors of this assessment (W. Jennings), and hypotheses by botanists (D. Erhard personal communication 2003, S. Olson personal communication 2003, R. Sivinski personal communication 2003, G. Austin personal communication 2004). *Delphinium robustum* occurrences and habitat throughout its range, including USFS Region 2 lands, could potentially be threatened by human-related activities or environmental factors. These factors are summarized in an envirogram outlining malentities potentially important to *D. robustum* (centrum) and the indirect variables affecting those centrum factors (**Figure 5**).

Of the nine occurrences of *Delphinium robustum* in USFS Region 2, seven occurrences are possibly on or near National Forest System lands. Most of the occurrences that might be on USFS lands may be in areas managed for multiple uses and two occurrences may be in wilderness areas (**Table 1**). *Delphinium robustum* may also occur on state lands, Colorado BLM lands, or private lands. As discussed earlier, this species does not receive protection as a sensitive species in USFS Region 2 or Colorado BLM. Management or protection of occurrences of *D. robustum* on state or private lands is not known.

Occurrences of *Delphinium robustum* 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 from occurrence to occurrence, depending on the landscape context. Estimating the numbers of occurrences potentially threatened by certain activities (e.g., road activity) is associated with considerable uncertainty because descriptions of the occurrences and their landscape context are sparse. For example, an occurrence may be "near a road" and could subsequently suffer intense impacts from direct trampling, road maintenance activities, road dust, associated erosion and deposition, or alternatively it could suffer minimal effects if the road is not heavily traveled or the occurrence is some distance from the road. In addition, human-related activities and other disturbances can either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on frequency, intensity, size, and location. Direct impacts could either damage the existing individuals or reduce reproductive success, available habitat, establishment of new occurrences, or other factors important for long-term persistence of the species.

Possible human-related threats to *Delphinium robustum* include motorized and non-motorized recreation, trail or road construction and maintenance, erosion and sedimentation related to roads, structure construction and maintenance, livestock grazing, non-native species invasion, and changes to natural disturbance regimes (e.g., fire suppression). The extent of these activities near existing occurrences of *D. robustum* or in suitable *D. robustum* habitat is unknown. Those occurrences closest to roads, trails, or other human-related structures are likely at the most risk. Overutilization of *D. robustum* for educational, scientific, or horticultural purposes is also unknown.

Recreational activities (e.g., hiking, camping, biking, motorized activity) are popular in national forests with *Delphinium robustum* occurrences.

Disturbances associated with roads (e.g., trampling, erosion/sedimentation, introduction of non-native seeds, road maintenance activities) may be a significant threat to *D. robustum*. Motorized vehicles, mountain bikers, and hikers have the potential to trample *D. robustum* occurrences occurring in accessible habitats. Any plants found along roadsides could be directly damaged by vehicles pulling off the road, foot traffic, or road maintenance activities such as herbicide spraying. Roads can be associated with significant erosion and sedimentation issues for the surrounding landscape that could affect any occurrences of *D. robustum* found downslope from roads. Roads and trails are also often associated with the spread of invasive plants that could compete with *D. robustum* for resources or otherwise alter *D. robustum* habitat. *Delphinium robustum* could be affected by herbicide spraying along roadsides, or it may even be targeted for poisonous weed control by those trying to reduce the exposure of livestock to toxic *Delphinium* species (Durkin 2002). There are numerous two-track roads and trails running through USFS and BLM lands; all of the occurrences of *D. robustum* possibly on National Forest System lands are potentially near trails or roads. Although OHV use is generally restricted to existing roads and trails by travel management plans and it is prohibited in wilderness areas (D. Erhard personal communication 2003, S. Olson personal communication 2003, G. Austin personal communication 2004), there still might be impacts of OHVs through prohibited off-trail use, erosion/sedimentation, and introduction of non-native seeds. Up to two occurrences may occur in USFS wilderness areas where motorized travel and construction are prohibited (S. Olson personal communication 2003). One *D. robustum* occurrence possibly in the Pike-San Isabel National Forest may also occur near a USFS campground along the lower reaches of a stream, but the effects of hiking or camping activity on the plants in that area are unknown (S. Olson personal communication 2003).

The effects of land management activities or environmental fluctuations on *Delphinium robustum* have not been studied. In general, land management activities or other environmental disturbances (e.g., succession, fire, drought, flash flood, global warming, erosion, blowdown, or timber harvest) 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. *Delphinium robustum* could possibly benefit from land management activities that open up the overstory and reduce competition within its habitat; however, this is a hypothesis because the competitive abilities of this species have not been studied. Alternatively, these activities could cause direct damage or indirect changes to the habitat (e.g., reduction in soil moisture) that could negatively impact this plant. For example, a low-intensity fire may positively affect *D. robustum* individuals by removing shade cover, whereas a high-intensity fire may cause increased surface water runoff and increased soil erosion and deposition that could negatively impact *D. robustum* individuals. The specific fire history in these areas is unknown, but presumably fire played a role to create suitable aspen habitat in these areas (S. Olson personal communication 2003). Fire suppression activities could potentially alter community dynamics and reduce potential habitat for this species. Where *D. robustum* occurs in canyon bottoms and other mesic sites, this species may be less affected by wildfires or prescribed burning activities (R. Sivinski personal communication 2003). Surface-disturbing activities, such as natural resource development, structure construction, or road maintenance, could damage existing occurrences and potential habitat for *D. robustum*. The extent of surface disturbing activities at these sites is unknown.

The extent or effects of herbivory on *Delphinium robustum* are unknown. Livestock grazing occurs in habitats with *D. robustum* in the Rio Grande, Gunnison, and Pike-San Isabel national forests, but the extent of grazing near *D. robustum* individuals or the effects of grazing practices on this species are not known (D. Erhard personal communication 2003, S. Olson personal communication 2003, G. Austin personal communication 2004). For example, the area where *D. robustum* is reported to occur in the Gunnison National Forest is in an active grazing allotment grazed with 50 head of heifer; the possible effects of grazing on *D. robustum* have not been studied (G. Austin personal communication 2004). Similarly, moderate cattle grazing occurs in areas of the Rio Grande National Forest with possible occurrences of this species, but the effects of grazing on *D. robustum* there are unknown (D. Erhard personal communication 2003). In general, herbivores can cause direct damage to plants (e.g., consume individuals), cause indirect damage (e.g., reduce seed production and thus reproductive success), or facilitate a species (e.g., preferentially consume other species, aerate the soil, create favorable microsites for germination) depending on the circumstances (Thomsom et al. 1996, M. Price and N. Waser personal communication 2004). Canyon bottoms and riparian areas can have heavy livestock activity, and *D. robustum* individuals have the potential to be trampled by this intense activity. Durkin (2002) emphasized that riparian habitat and wet meadow habitat in the Rocky

Mountain Region are highly vulnerable to human disturbance and are often fragmented by livestock that tend to concentrate in these areas. In contrast, grazing practices could possibly have a positive effect on *Delphinium* species (M. Price and N. Waser personal communication 2004).

Possible environmental and biological threats to occurrences of *Delphinium robustum* include non-native species introductions, environmental fluctuations, genetic isolation, succession, excessive herbivory, inadequate pollination, global climate changes, hybridization, and changes to the natural disturbance regime (e.g., fire suppression). Disturbances can either create suitable habitat throughout a landscape or directly impact an existing occurrence, depending on frequency, intensity, size, and location. The environmental tolerances (e.g., soil moisture) of *D. robustum* are not known. Hybridization has been reported between *D. robustum* and *D. sapellonis*, as well as between other pairs of *Delphinium* species from Colorado and New Mexico. The effect of hybridization on conservation of *D. robustum* is unknown. The extent of non-native plant species invasions at sites with *D. robustum* is unknown. Non-native invasive species possess the potential to compete with *D. robustum* for resources, especially for occurrences along trails, roads, and other disturbed areas. The effects of native herbivores on *D. robustum* have not been assessed. The extent of landscape fragmentation in areas with this species has not been studied or quantified.

Changes to existing climatic and precipitation patterns, perhaps as a result of global climate change, could also impact this species. 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 EPA 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 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 associated changes to a suite of environmental variables could have the potential to affect plant community composition by altering establishment, growth, reproduction, and death of plants (Inouye and McGuire 1991), although changes may be slow in montane environments (Price and Waser 2000). For example, model projections predict that tree lines could shift upslope in alpine ecosystems (U.S. Environmental Protection Agency 1997). Studies at subalpine sites in Colorado have found strong correlations between climate and snowpack conditions and the timing and abundance of flowering in *D. barbeyi* and *D. nuttallianum* (Inouye et al. 2002, Saavedra et al. 2003). Because global climate change may alter snowpack and other environmental conditions, flower production and demography of these subalpine delphiniums and associated pollinators may also be affected. The possible effects of global climate change on *D. robustum* have not been studied.

Environmental stochasticity can also affect pollinator activity and behavior. If *Delphinium robustum* largely depends on outcrossing for maximum seed set, then any reductions in pollinator efficiency could potentially reduce reproductive success. Pollinator populations do not appear to be threatened at New Mexico sites with this species (R. Sivinski personal communication 2003). *Delphinium robustum* is known from approximately 15 scattered occurrences within its restricted range; the amount of gene flow, genetic variability, and inbreeding is unknown for this species.

Based on current knowledge, the exact locations of *Delphinium robustum* occurrences on USFS Region 2 lands are unknown. Threats to the long-term persistence of *D. robustum* occurrences or habitats likely differ for each of the nine occurrences in USFS Region 2. Possible threats to the seven occurrences of *D. robustum* on USFS Region 2 lands may include motorized and non-motorized recreation, non-native plant invasion, livestock trampling, succession, and global environmental changes. Occurrences near roads, trails, or campgrounds are likely at higher risk for the detrimental effects of road or trail associated activities and non-native plant invasion.

Conservation Status of the Species in USFS Region 2

Delphinium robustum is a species of special concern because of its endemic distribution, small number of documented occurrences, and possible human-related and environmental threats to its persistence. The viability of this species within USFS Region 2 is difficult to ascertain because its full distribution and abundance are unknown and demographic parameters

have not been studied. In 1998, one of the authors of this assessment (W. Jennings) revisited most of the reported locations of this species in Colorado and was unable to find a single individual. At several of these sites, though, he found individuals of *D. ramosum*. Thus, environmental conditions in 1998 were not suitable for the growth of *D. robustum*, this species had been mostly extirpated in Colorado, or these individuals had been previously misidentified as *D. robustum*.

Up to seven *Delphinium robustum* occurrences may be on USFS Region 2 lands, but this species is not specifically protected as a sensitive species. Grazing, road activities (e.g., road maintenance, erosion/sedimentation), motorized and non-motorized recreation, land management activities (e.g., fire suppression), exotic species invasion, landscape fragmentation, and environmental fluctuations potentially threaten this species. Much information is lacking on the abundance, distribution, and biology of *D. robustum*. It is difficult to predict the ability of this species to tolerate environmental stochasticity and any future environmental or management changes.

Population declines

We are unable to conclude that the distribution or abundance of *Delphinium robustum* is declining, expanding, or remaining stable throughout its range. Herbarium and occurrence records for this species do not include abundance estimates. In addition, as discussed earlier, this species was not found during a 1998 survey of known sites by one of the authors of this assessment (W. Jennings; Jennings 1998a, Jennings 1998b). Thus, environmental conditions in 1998 were not suitable for the growth of *D. robustum*, this species had been extirpated in Colorado, or these individuals had been previously misidentified as *D. robustum*. There have been no detailed status reports or intensive surveys for additional occurrences of this species. The rate at which this species disperses and colonizes new locations is unknown because we know little of its dispersal and establishment capabilities.

Habitat variation and risk

The habitat requirements for *Delphinium robustum* are largely undefined, and the variation and risks within this environment, or over space and time, have not been assessed. 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., drought, sedimentation, trampling), or other fluctuations in disturbance processes that could affect existing occurrences or creation of habitat. Specific occurrences could be at a greater risk than other occurrences, depending on the landscape context, such as proximity to roads and microhabitat characteristics. Some occurrences of this species are found in areas susceptible to trampling and direct damage from OHV use and hiking. It is difficult to predict the spread of non-native invasive plants and the potential risk of alteration to plant communities. Riparian habitats in the Rocky Mountain region are often fragmented and highly vulnerable to human activities and disturbances. As a result of human influences on the environment and the unpredictable effects of environmental fluctuations, significant habitat variation and risk may exist for *D. robustum* within USFS Region 2.

Potential Management of the Species in USFS Region 2

Quantitative demographic monitoring and detailed biological and ecological studies of *Delphinium robustum* occurrences 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

Delphinium robustum occurrences and habitat may be at risk as a result of management activities within the range. Possible human-related threats to existing occurrences of this species include off-road (or off-trail) motorized and non-motorized activities, landscape fragmentation (e.g., possibly caused by livestock grazing activities, trail activities), and introduction of non-native species. Currently, there is some protection of this species through travel management plans and NEPA regulations requiring surveys before construction on USFS and BLM lands. The exposure and response of *D. robustum* to livestock grazing, prescribed fires, thinning, or timber harvest are unknown. It is possible that these activities could beneficially reduce litter and interspecific competition and encourage germination and growth. Alternatively, these activities could change competition dynamics or environmental conditions and create unsuitable habitat for *D. robustum*. The long-term persistence of this species will rely on monitoring the effects of current USFS Region 2 land-use practices and reducing human-related threats to existing occurrences.

Potential conservation elements

Delphinium robustum is a regional endemic with a small number of recorded occurrences and potentially high vulnerability to human-related activities and environmental changes. The taxonomic status of this species and its relationship with closely-related species such as *D. ramosum* are not fully understood. The distribution, abundance, and ecological range 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 asexual reproductive potential, or genetic variability of this species makes it difficult to predict its long-term vulnerability. Determining the taxonomic status of this species, assessing its current distribution and abundance, protecting any existing occurrences from direct damage, documenting and monitoring the effects of current management activities, surveying high probability habitat for new occurrences, and preventing non-native plant invasions are key conservation elements for this species on USFS Region 2 lands.

Tools and practices

There are no existing population monitoring protocols for *Delphinium robustum*, and very little is known about its biology, ecology, taxonomy, and spatial distribution. Thus, 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

The distribution and total abundance of *Delphinium robustum* are not sufficiently known to formulate conservation strategies on USFS Region 2 lands. Inventories and a status report on the distribution and abundance of *D. robustum* over its range are necessities. Researchers could visit all reported sites to ascertain both current distribution and occurrence status. These sites could be regularly re-visited for update reports. Ascertaining the current abundance of this species would help to estimate its vulnerability to environmental fluctuations and to monitor the effects of human activities.

Additional surveys of habitat are needed to document the full spatial extent of *Delphinium robustum* and to identify its ecological range. The distribution of *D. robustum* is scattered, with small occurrences or groups of occurrences spread over a range of elevations in a variety of habitat types. The current distribution map for *D. robustum* (**Figure 1**) shows that there are "holes" (areas surrounded by or adjacent to areas with the presence of this species) within the range of this species that could have undocumented occurrences. For example, *D. robustum* is known from one occurrence on the western side of the Continental Divide in the Gunnison National Forest, and additional occurrences may exist between that site and other occurrences located further east.

Once survey areas have been identified, researchers could further identify areas of potential habitat using topographic maps, geologic maps, land status maps, and aerial or satellite images. In addition, surveys could use existing occurrences as starting points because similar habitats may extend along topographic lines or topographical formations. Locations downslope or downwind (e.g., down a drainage) from existing occurrences could be surveyed because *Delphinium robustum* seeds are possibly wind, water, and gravity dispersed.

The size and extent of existing *Delphinium robustum* occurrences could be mapped and recorded using global positioning system (GPS) and geographic information system (GIS) technology. Mapping each known occurrence of *D. robustum* will maintain consistency for future observations and help in making estimates of density and abundance over time. Mapping occurrences of *D. robustum* will also elucidate the spatial distribution of occurrences at the regional level and provide a framework for creating a metapopulation study. 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, reproductive biology, demography, and population trends of *Delphinium robustum*. Information is lacking on longevity, germination requirements, seed survival, extent of asexual reproduction, factors affecting flower development, pollination ecology, role of the seed bank, relationship with herbivores, 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, seed bank studies could assess the abundance of seeds to reveal dispersal patterns. Studies of germination needs in the field might elucidate potential limiting factors for the

establishment of new individuals. Basic studies on the reproductive biology of *D. robustum* are necessary to begin to understand its demography and any genetic considerations important to the conservation of this species. There is a body of research on the reproductive biology and conservation genetics of other *Delphinium* species that could provide useful information and tools for designing future studies of *D. robustum*, as discussed in previous sections (e.g., Waser and Price 1979, Waser and Price 1985, Waser 1988, Inouye 1991, Graham and Jones 1996, Bosch et al. 1998, Bosch and Waser 1999, Williams 1999, Williams and Waser 1999, Bosch et al. 2001, Bosch and Waser 2001, Johnson 2001, Koontz et al. 2001, Schulke and Waser 2001, Simon et al. 2001, Williams et al. 2001, Dodd and Helenurm 2002).

No long-term demographic monitoring has been initiated for *Delphinium robustum*. Long-term monitoring studies could yield helpful information, such as temporal and spatial patterns of abundance and dormancy; environmental factors that influence abundance (e.g., drought); whether occurrences are increasing, decreasing, or remaining stable; and the minimum number of plants necessary to perpetuate the species. In addition, assessing the genetic differences between and among populations will help to understand metapopulation dynamics and possible taxonomic distinctions between populations and species.

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

- What is the current abundance?
- What are the rates of survival, longevity, and recruitment?
- What are the occurrence 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 sexual and vegetative reproduction?
- What is the gene flow between populations?

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

Occurrence records for *Delphinium robustum* do not identify associated plant species, substrate types, microhabitat characteristics, or the landscape context for each occurrence. The habitat characteristics of this species have not been adequately described to understand what factors are critical in maintaining or restoring its habitat. For example, 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. Land management techniques, such as livestock grazing, thinning, prescribed burns, and fire suppression, are used throughout these habitats and presumably may influence the persistence of this species. The cumulative beneficial or detrimental effects of these activities on *D. robustum* and its habitats have not been studied or monitored. Documenting land management and monitoring habitat could occur in conjunction with occurrence monitoring efforts in order to associate population trends with environmental conditions.

Some examples of management practices that would protect *Delphinium robustum* habitat and minimize possible plant destruction include regulating cattle activities, restricting off-road vehicle traffic, encouraging hikers to use trails, prohibiting the collection of native plants, and preventing the spread and establishment of non-native invasive species. Habitat management could also consider issues related to the surrounding landscape, such as barriers to dispersal, landscape fragmentation, pollinator habitat needs, and trail proximity and position in relation to occurrence 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 collected for *Delphinium robustum*. The ecological needs of *D. robustum* are not known in sufficient detail to evaluate its response to habitat changes. Research studies to evaluate the effects of livestock activities, landscape fragmentation, drought, succession, and fire at several scales (local and regional) 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 maintain an occurrence, what disturbance intensity and frequency may be most appropriate, and what factors would result in local extirpation of a population.

Availability of reliable restoration methods

There has been no research to date involving the production of *Delphinium robustum* in greenhouse environments or the harvest or storage of seed for use in restoration projects. Honda et al. (2002) performed viability tests on the stored pollen of perennial, ornamental *Delphinium* species. The researchers found the highest pollen viability for those pollen grains stored up to 180 days at –30 ºC. Williams and Cronin (1968) found that native *Delphinium* species are difficult to grow from seed in greenhouse environments. M. Price and N. Waser (personal communication 2004) also noted that *D. nuttallianum* was difficult to germinate in the lab, but germinated well when pots with seeds were dug into the ground in the field. Conducting germination and transplantation studies of *D. robustum* in natural environments and performing genetic analyses of existing plant material would be helpful as occurrences in USFS Region 2 are potentially at risk of extirpation, and managers may want to consider restoration of this species.

Information Needs and Research Priorities

Based on our current understanding of *Delphinium robustum*, we can identify research priorities where additional information will help to develop management objectives, initiate monitoring and research programs, and 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 a large number of research projects could be implemented.

Verifying the taxonomic status of this species, re-visiting all occurrences, estimating current abundance, assessing imminent threats, studying genetic variability, and determining ecological needs and limitations are of primary importance to furthering our understanding of *Delphinium robustum* in USFS Region 2. The following types of studies are priorities to supplement basic knowledge regarding this species:

- Taxonomic analyses of this and closely related species (e.g., *Delphinium ramosum*, *D. sapellonis*)
- Re-visitation and detailed mapping of existing occurrences
- Addressing imminent threats to known occurrences
- Surveys for new occurrences
- Genetic analyses to assess gene flow and variability throughout range
- Microhabitat characterizations and measurements
- Documenting and monitoring the impacts of current land management practices on the species

- Studies related to reproductive biology, including breeding system, germination trials, dispersal capabilities, pollinator surveys, mycorrhizal associations, seedbank analyses, and relationship with herbivores.

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. Databases also facilitate the sharing of information to all interested parties. The Colorado NHP and NatureServe have developed databases and GIS components to assist in information storage and habitat modeling (D. Anderson personal communication 2003). Such a database should be integrated with GIS and allow activities such as the following:

- Efficient incorporation of data in the field
- Documentation and cataloging of herbarium specimens
- Generation of location and habitat maps
- Characterization of associated habitats, including geologic substrates
- Identification of population trends over time
- Identification of data gaps that require further information gathering
- Easy modification as additional information becomes available.

DEFINITIONS

Achene – Small, dry fruit with a close-fitting wall surrounding a single seed.

Acuminate – Gradually tapering to a sharp tip.

Alkaloids – Organic compounds present in some vascular plants and fungi.

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

Anthesis – Stage in floral development when the flower is open and sheds pollen.

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

Bract – Reduced, modified leaf associated with flowers.

Calyx – The collective name for sepals.

Caudex – Short, swollen, often woody portion of a plant stem that is at or beneath ground level on top of a taproot. This structure functions in new stem production, serves as a storage organ, and/or produces short rhizomes.

Cauline leaves – Leaves that are attached on the stem above the ground; compared to basal leaves present at ground level.

Corolla – Portion of flower comprised of petals.

Decurved – Curved downwards.

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

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 of its range or extirpated in 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.

Entire – Having a margin that lacks any toothing or division, as the leaves of some plants.

Fertility – Reproductive capacity of an organism.

Fitness – Success in producing viable and fertile offspring.

Follicle – Fruit that dehisces along seed-bearing suture at maturity.

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 2003).

G2 ranking – Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe 2003).

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 2003).

G4 ranking – Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe 2003).

G5 ranking – Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe 2003).

Glabrous – Smooth, without hairs, trichomes, or glands.

Glandular – Having glands, protuberances or depressions on the surface of an organ, which produces a sticky, greasy, or viscous substance.

Glaucous – Covered with a fine, waxy powder that imparts a whitish cast to the surface.

Habitat fragmentation – The breakup of a continuous landscape containing large patches into smaller, usually more numerous, and less connected patches. Can result in genetic isolation.

Habitat isolation – When two or more habitats are separated (i.e., geographically) to an extent to prevent cross breeding, thereby genetically isolating two parts of a once continuous population.

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

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

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

Intraspecific competition – Competition for resources among individuals of one species.

Mesic – Characteristic of an environment that is neither extremely wet, nor extremely dry.

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

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

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

Ovate – Egg-shaped, with the larger end toward the base (i.e. ovate leaves).

Palmate – With three or more lobes or branches or veins arising from a common point.

Palmatisect – Divided deeply in a palmate fashion.

Panicle – A branching inflorescence usually broadest near the base and tapering upwards.

Paniculate – Arranged in a panicle.

Pedicel – Stalk of a single flower in an inflorescence.

Perennial – A plant that lives for 3 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.

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

Petaloid – Petal-like in color and texture.

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.

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

Pollen – The male spores in an anther.

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.

Puberulent – Minutely pubescent, with soft, curled hairs.

Pubescent – Bearing hairs.

Raceme – An elongate inflorescence with pedicellate flowers arising from a central, unbranched 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.

Ruderal habitat – Temporary or frequently disturbed habitats.

Ruderal species – Species that can exploit low stress, high disturbance environments.

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 2003).

S2 ranking – Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe 2003).

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 2003).

S4 ranking – Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe 2003).

S5 ranking – Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe 2003).

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.

Sexual reproduction – Reproduction involving the union of gametes.

Spur – Hollow appendage of corolla or calyx.

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.

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

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

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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LIST OF ERRATA

09/22/05 Changed peer review organization from Society for Conservation Biology to Center for Plant Conservation on the cover and under "Peer Review" heading.