Aletes humilis Coult. & Rose (Colorado aletes): A Technical Conservation Assessment

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

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COVER PHOTO CREDIT

Aletes humilis (Colorado aletes). Photograph by Rebecca Day-Skowron (used with permission).

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ALETES HUMILIS*

Status

Aletes humilis (Colorado aletes) is not currently designated a sensitive species by the USDA Forest Service Region 2. This species is a regional endemic that is found in north-central Colorado (with one historical population located on the Wyoming-Colorado border). It is globally ranked between imperiled and vulnerable (G2G3) by NatureServe. It is ranked between imperiled and vulnerable (S2S3) by the Colorado Natural Heritage Program and is ranked as known from historical records only (SH) by the Wyoming Natural Diversity Database. The concern for viability with *A. humilis* is based on its limited global distribution and abundance. It is restricted to two geographic areas in north-central Colorado separated by the Cache La Poudre River.

The Colorado Natural Heritage Program reports 39 occurrence records for *Aletes humilis* in Colorado. The Wyoming Natural Diversity Database tracks one occurrence located on the Colorado-Wyoming border. The Wyoming population has not been relocated since 1902 and is considered historical. Populations are small to moderate with the number of individuals ranging from 50 to at least 1,000. Despite a lack of abundance data for some occurrences, numbers are estimated to be 15,300 individuals in Larimer County and 12,100 individuals in Boulder County. There are no population trend data for *A. humilis* covering its entire range, and this assessment provides no inferences of population trend.

No federally protected areas have been designated that include the conservation of this species or its habitat as an explicit goal. There are 40 occurrences in Region 2 (including the one historical occurrence in Wyoming). Of these known occurrences, 33 occurrences are located on the Arapaho-Roosevelt National Forest (ARNF), five on private land (including two occurrences managed by The Nature Conservancy and the one Wyoming occurrence), and two on Colorado State lands managed by the Colorado Division of Wildlife (CDOW). All occurrences on federal lands (ARNF) are located on lands managed for multiple uses. No specific management or conservation plan is in place for protection of this species on National Forest System lands.

Primary Threats

Current and potential threats that could cause a loss of occurrences of *Aletes humilis* are management activities and natural disturbances that would affect occurrences or habitat. These appear to be limited due to the remote and inaccessible locations of many of its occurrences. The most likely management activities to influence *A. humilis* are prescribed fire, recreation, and grazing. Occurrences located in sparsely vegetated habitats would not be directly impacted by fire due to the minimal fuels available in these types of habitats. Occurrences located in forest duff could be directly impacted by prescribed fire. Recreation use in the proximity of occurrences located on the ARNF consists primarily of camping, hiking, rock climbing and off-road vehicle use. Palatability of *A. humilis* has not been documented; however, the plant's low stature, sparsely vegetated locations, and steeply sloped habitats may provide some protection from herbivory. Secondary grazing impacts from changes in plant species composition (including spread of invasives), soil compaction, and erosion may still be important. Little knowledge is available to determine the degree of threat posed by natural or prescribed fire, recreation use, or grazing; however, individuals or occurrences could be directly or indirectly impacted. A proposed water development project near Greyrock Mountain has been identified as a potential threat to known occurrences. No information is available concerning the status of the planned water development.

Other potential threats to the species that may occur naturally include extreme weather conditions, herbivory by native wildlife (e.g. elk, deer or rodents), global warming, and air pollution. Global warming and increased nitrogen may provide a long-term potential threat. There is little direct evidence to indicate whether or not specific individuals or occurrences of *Aletes humilis* in Region 2 or rangewide are at risk as a result of management activities or natural disturbance.

Primary Conservation Elements

Priorities for determining conservation elements include gathering current population census information on known occurrences; developing and implementing demographic monitoring to supplement information being gathered by The Nature Conservancy on the species; collecting data on community structure and composition to provide a baseline for future habitat monitoring; evaluating reproductive and ecological characteristics (e.g., pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting and dispersal vectors); investigating genetic issues such as outbreeding depression; surveying for new occurrences; and determining impacts to population viability from management activities and natural disturbances.

Demographic data show that germination and seedling establishment may be the most vulnerable periods of the life cycle of *Aletes humilis*. It appears that a safe site could be required, such as in the cracks of rocks; however, there are no data to support or negate this possibility.

Because it is based on potential demographic, environmental, genetic, and natural stochastic risks to *Aletes humilis*, information concerning minimum viable population size could be utilized to identify protection parameters. Protection of diverse populations across the range of habitats and elevations may also be important in the preservation of genetic diversity.

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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). *Aletes humilis* (Colorado aletes) is the focus of an assessment due to viability concerns based on its limited distribution and abundance. It is not currently listed as a sensitive species in Region 2 (USDA Forest Service 2003).

This assessment addresses the biology of *Aletes humilis* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologist, 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 focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and, when these have been implemented, the assessment examines the success of their implementation.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Aletes humilis* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. This assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. humilis* in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, the authors reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. The assessment emphasizes refereed literature because this is the accepted standard in science. Some non-refereed literature (i.e., state natural heritage program status reports) was utilized in this assessment, when information was unavailable elsewhere, but these materials were regarded with greater skepticism. Unpublished data (i.e., state natural heritage program records and The Nature Conservancy population monitoring data) were important in estimating the geographic distribution and abundance. These data required special attention because of the diversity of persons and methods used in collection. The population viability analysis should be regarded with some skepticism as The Nature Conservancy published it as an example of a population viability analysis and not as refereed literature. However, the data used in the analysis were collected using a standardized protocol for the purpose of future publication. Other data for the species assessment were obtained through herbarium specimen labels, scientific literature, and knowledgeable individuals. Status information was requested from The Nature Conservancy, but the data were not made available to the authors. Fifty-three herbaria within Region 2 and surrounding states were contacted. Seven responded with pertinent data including the Rocky Mountain Herbarium (RM), Stanley L. Welsh Herbarium (BYU), Intermountain Herbarium (UTC), University of Montana (MONTU), Kathryn Kalmbach Herbarium (KHD), University of Northern Colorado Herbarium (GREE), and University of Colorado Museum (COLO). Literature of closely related taxa was reviewed, and inferences were drawn where reasonable and when a basis could be established for application to *Aletes humilis*. The authors present no empirical data.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Publication of Assessment on the World Wide Web

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

Management Status

Aletes humilis is not currently designated as a sensitive species by the USFS Region 2 (USDA Forest Service 2003). *Aletes humilis* is globally ranked between imperiled and vulnerable (G2G3) by NatureServe. This species is a regional endemic that is found in north-central Colorado (with one unverified population located on the Wyoming-Colorado border). It is ranked between imperiled and vulnerable (S2S3) by the Colorado Natural Heritage Program (CNHP) and as known from historical records only (SH) by the Wyoming Natural Diversity Database (WYNDD).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies.

The concern for viability with *Aletes humilis* is based on its limited global distribution and abundance. The CNHP reports 39 Element Occurrence Records (EORs) for *A. humilis* in Colorado. The WYNDD tracks one EOR, which has not been relocated since it was collected and is considered historical. Thirty-three of the known occurrences are located in the Arapaho Roosevelt National Forest (ARNF), with two clusters of distribution, one in northern Larimer County and the other in northern Boulder County. *Aletes humilis* is not currently listed as a sensitive species in Region 2 (USDA Forest Service 2003). Management on the ARNF is currently accomplished according to the standards and guidelines of the 1997 Revised Land and Resource Management Plan for the Arapahoe and Roosevelt National Forests and Pawnee National Grassland (USDA Forest Service 1997). No specific management or conservation plan is in place for protection of *A. humilis* on USFS lands.

Five occurrences are located on private lands. Four of these are in Larimer County, Colorado: two on land owned by The Nature Conservancy (TNC), one at the Caprock Preserve, and the other in the Phantom Canyon Preserve. The fifth private land occurrence is in Albany County, Wyoming. Two additional occurrences are located on lands managed by the state of Colorado at the Cherokee Park State Wildlife Area in Larimer County. The remaining thirty-three occurrences are on the Arapaho-Roosevelt National Forest.

Existing laws, regulations, management, and their enforcement may not adequately protect occurrences on USFS lands because no species-specific protective mechanisms are in place. The remote location of occurrences may provide some protection. However, there is a lack of knowledge concerning reproductive and ecological characteristics, demographics, and impacts to population viability from management activities and natural disturbances.

Biology and Ecology

Systematics and general species descriptions

The Apiaceae (Umbelliferae) is an important crop-producing family of plants. This family can also claim a number of very interesting and rare species. The focus of this assessment is the umbel *Aletes humilis*. *Aletes humilis* is related to several genera of plants termed the "Rocky Mountain umbellifers" (Downie et al. 2000). This includes several diverse members of this family that are endemic to western North America. Several of these are relatively recently described, including *Shoshonea pulvinata*, *Cymopterus evertii*, *C. williamsii*, and *C. davisii* among others. *Aletes humilis* represents a unique element of the Rocky Mountain flora because of its restricted distribution, interesting microhabitat, and genetic relationships with its congeners.

G.E. Osterhout first collected *Aletes humilis* in 1899 in the Dale Creek area of Larimer County, Colorado. *Aletes humilis* was the second species of this genus to be described by Coulter and Rose in 1900; *A. acaulis* was the first. **Table 1** summarizes the current classification of *A. humilis*.

Historically, *Aletes* is included in the subfamily Apioideae, within the tribe Peucedaneae (Drude 1897-1898). Within the subfamily Apioideae, the Rocky Mountain umbellifers, (including *Aletes*) are only weakly supported as monophyletic using ITS data (Downie et al. 1998). It is interesting to note that relationships in this group are uncertain and the taxonomy unstable using morphological data; it appears that the ITS data will add very little insight into the resolution of the Rocky Mountain umbellifers. Preliminary results of cladistic analysis using both morphological and molecular data show that *Cymopterus*, *Lomatium*, *Aletes*, *Musineon*, and *Oreoxis* appear to be polyphyletic (Sun et al. 2000, Hartman personal communication 2003).

The genus *Aletes* consists of approximately seven species (plus two subspecies), located in western and central North America (Kartesz 1994). The genus is considered controversial and has been divided and lumped more than once into several genera including *Oreoxis*, *Cymopterus*, *Pseudocymopterus*, *Cynomaranthrum*, *Musineon*, *Lomatium*, and *Neoparrya* (Theobald et al. 1963, Weber 1984, Cronquist et al. 1997). The type species for *Aletes* (*A. tenuifolium*) has been placed into *Musineon* by Cronquist et al. (1997), and the rest of the genus was realigned into *Cymopterus*, *Lomatium*, and *Neoparrya*, eliminating *Aletes* in the Intermountain Flora altogether. Kartesz (1994) recognizes six species of *Aletes* in New Mexico, five in Colorado, three in Utah, and two each in Arizona and Texas.

There are no synonyms associated with *Aletes humilis*, and despite the difficulty in circumscribing the genus *Aletes*, *A. humilis* is considered a distinct species (Weber 1984). *Aletes humilis* is closely related to *A. acaulis*. Isozyme analysis of *A. humilis* and *A. acaulis* suggests that *A. humilis* evolved from a substantial portion of the *A. acaulis* original genome, because they share seven of nine polymorphic loci. It is possible that *A. humilis* represents a sizeable northern gene pool that gradually diverged from the *A. acaulis* gene pool to the south (Linhart and Premoli 1993). The ranges of these two species overlap in central Colorado. *Aletes acaulis* extends from central Colorado, to northeast and central New Mexico, across the panhandle of Texas, and into Coahuila, Mexico (Linhart and Premoli 1993). These two taxa are similar morphologically. They are both caespitose, acaulescent, and deeply rooted herbaceous perennials. The most obvious difference is that the peduncles of *A. acaulis* are longer than the leaves, exposing the inflorescence above, where as in *A. humilis* the peduncles are short, hiding the inflorescence among the leaves. In addition, *A. acaulis* is more robust, reaching heights of 15 to 30 cm, where as *A. humilis* rarely grows over 10 cm.

Aletes humilis is a stemless, taprooted, mat forming, perennial herb that grows from 2 to 10 cm in height. The leaves are thick, once or twice pinnately compound, with ovate sharp-tipped leaflets. Two forms have been reported from the field. The most common form is compact, short-leaved, and mat-forming. The other is described as a long-leaved, open cushion form (Colorado Natural Heritage Program 2003). The inflorescence is a compound umbel, with umbellets appearing to be protogynous (pistillate flowers developing first). Branches of the inflorescence are unequal, glabrous, and usually over 2 cm long. Fruits are only slightly flattened, glabrous, and have poorly defined ribs. Leaves are aromatic with a celery or soapy odor (Theobald et al. 1963, Linhart and Premoli 1993, Fertig et al. 1994, Colorado Natural Heritage Program 1996, Fertig 2001, Colorado Natural Heritage Program 2003).

Several species could be misidentified as *Aletes humilis*. In Colorado, *A. anisatus* has a strong anise or citronella odor, differing from the celery or soapy odor

Table 1. Classification of *Aletes humilis*.

Aletes humilis Coult. & Rose
Family: Apiaceae (Umbelliferae)
Genus: *Aletes*
Species: *Aletes humilis* Coult. & Rose
Synonyms: None
Vernacular Name: Colorado aletes
Type: United States, Colorado. Larimer Co.: Dale Creek, 19 July 1899, *G.E. Osterhout 6* (US 40156) (Holotype: RM; ISOTYPE COLO; TOPOTYPE COLO)

of *A. humilis*. *Aletes acaulis* forms loose clumps, has an inflorescence that extends above the leaves, and the fruits have visible, conspicuous ribs on the schizocarp. *Aletes humilis* forms tight mats and has inconspicuous ribs on the fruit. Another look-alike is *Heuchera parvifolia*. *Heuchera parvifolia* occurs in similar cliff dwelling habitats but has leaves that are more orbicular, less green, and have regular coarse teeth along the leaf margins (Colorado Natural Heritage Program 2003). In Wyoming, *A. humilis* could be confused with *Cymopterus* (*Oreoxis*) *alpinus*, which has minutely scabrous, twice pinnately compound leaves, fruits with thick ribs, and inflorescences extending above the leaves. *Musineon divaricatum* is taller, with leafy stems, scabrous fruits, and inflorescence branches. *Shoshonea pulvinata* has scabrous fruits and linear leaflets (Fertig 2001). **Figure 1** is a photograph of *A. humilis*, and **Figure 2** is a representative line drawing of this species.

Figure 1. Photograph of *Aletes humilis*, used with the permission of Rebecca Day-Skowron 1999.

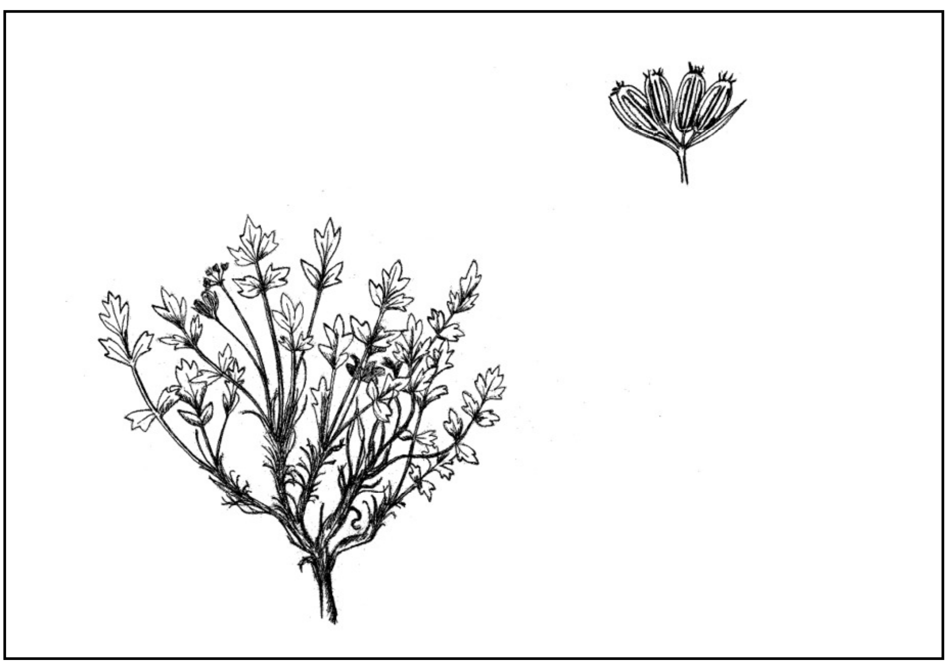

Figure 2. Line drawing of *Aletes humilis*, used with the permission of Walter Fertig (Fertig 2001).

Distribution and abundance

Historic and current global distributions of *Aletes humilis* are restricted to the floristic region defined by Takhtajan (1986) as the Rocky Mountain Province of the Holarctic Kingdom. Distribution of this species is limited to two geographic areas within Region 2. Historically, this species was first discovered in the 1890s in northern Larimer County, Colorado. Documented collections were restricted to this area, and most were made by Osterhout until 1913. After that, it was 60 years before any further collections were archived (Hartman and Crawford 1972).

The CNHP reports 39 EORs for *Aletes humilis* in Colorado, and the WYNDD tracks one EOR, a collection made by Gooding in 1902 (Fertig 2001). The Wyoming occurrence has not been relocated since it was collected and is considered historical. Dr. Ronald Hartman of the University of Wyoming has been unable to relocate the Wyoming occurrence and has questioned whether the original collection was actually made in Colorado. RM does not recognize the occurrence until it has been verified. Potential habitat is present throughout the area with the nearest verified location approximately seven miles south along the state line at Virginia Dale (Hartman personal communication 2003). The Wyoming element occurrence record is based upon interpretation by the WYNDD staff according to Dr. Robert Dorn's Flora of Wyoming (Heidel personal communication 2004). Due to the close proximity of potential habitat and the confirmed location along the state line, this assessment will follow the WYNDD conclusion and include it as an occurrence, albeit an historical location.

In Colorado, thirty-three of the known occurrences are within the ARNF, with two clusters of distribution, one in northern Larimer County and the other in northern Boulder County. Five occurrences are documented on private land, including one historical report for a location in Wyoming along the Colorado-Wyoming border (Colorado Natural Heritage Program 2003), and two occurrences are in the Cherokee Park State Wildlife Area, which is managed by the Colorado Division of Wildlife. *Aletes humilis* exhibits a discontinuous distribution, restricted to two geographic areas within Colorado. The two major groups of occurrences are separated by the Cache La Poudre River. The northern group is centered in the region southwest of Virginia Dale, and the southern group is approximately centered along tributaries of South St. Vrain Creek. *Aletes humilis* is considered a regional endemic of north-central Colorado. Within Region 2, *A. humilis* can be characterized as narrowly endemic, with an occurrence located on or near the Wyoming border. **Figure 3** shows the distribution of *A. humilis* in Region 2.

Population trend

As mentioned above, 39 EORs are reported for Colorado, and one historical location is reported near the Colorado-Wyoming border. Four of the Colorado occurrence records (all on ARNF lands; three in Boulder County and one in Larimer County) report general site information, but no abundance data were included. WYNDD reports no population estimate for the historical occurrence in southern Wyoming. Based on the available EOR data summarized in **Table 2**, it is estimated that 15,300 individuals are located in Larimer County, and approximately 12,100 reside in Boulder County (with the caveat that abundance data are missing for approximately one third of the Boulder County locations). CNHP estimates 25,000 total individuals as of the November 1998 record maintenance update. Addition of the population numbers by occurrence estimates the total population of *Aletes humilis* to include approximately 25,000 to 27,500 individuals (**Table 2**). The EOR column in **Table 2** represents the names of the current EOR occurrences. Some of the occurrences were combined in the past; therefore the EOR name (e.g., 14CO) does not reflect the quantity of occurrences.

Aletes humilis occurs in a clumped pattern, consisting of one to two or more individuals occupying crevices of rock outcrops and canyon walls or in forest duff. Individual populations range in size from fifty to several thousand. An accurate estimation of ecological density in the strict sense is not possible given the available data. Based upon the available EOR data, rough estimates of density vary from approximately 20 individuals per hectare to 10,000 per hectare. One suboccurrence in Phantom Canyon has an estimated density of 2.3 individuals per m^2 (Colorado Natural Heritage Program 2003). Revisits did occur for the majority of the EOR locations (approximately once per decade since the 1970s with most revisits occurring in the 1990s). The majority of the revisits focused on observing if the occurrence was still present, and no consistent method of determining abundance was utilized to allow any inferences concerning trends in population density (i.e., an occurrence recorded as abundant, locally common, or scarce does not provide a meaningful census). Furthermore, in those few occurrences that did report numerical data, it was often reported as a standard range such as 51 to 100 or 1,000 to 10,000 with the next revisit reporting the same count.

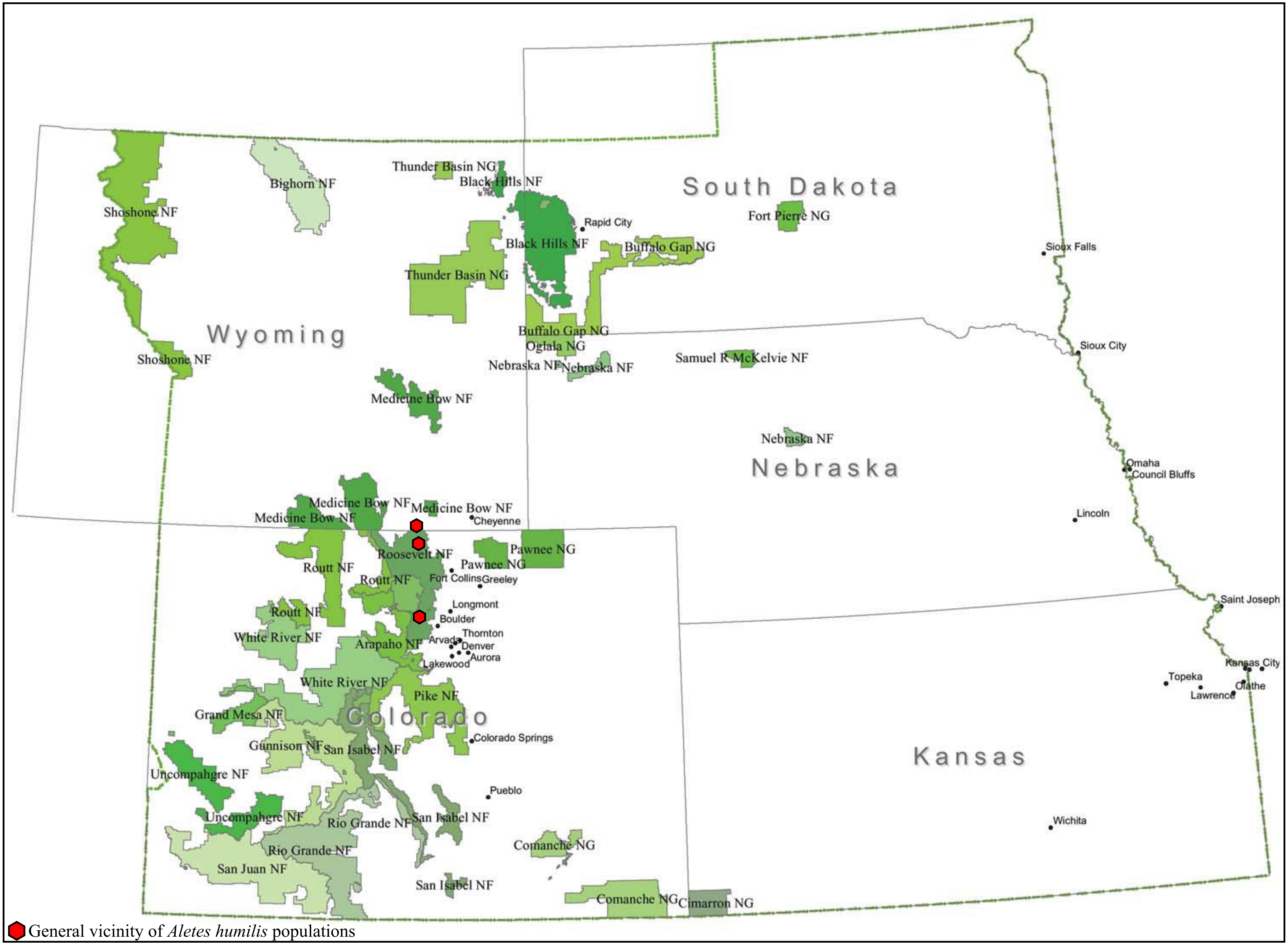

Figure 3. Distribution map for *Aletes humilis* in Region 2.

Table 2. Summary of abundance data for *Aletes humilis* taken from Colorado Natural Heritage Program and Wyoming Natural Diversity Database Element Occurrence Records (EOR). The EOR column represents the names of the current EOR occurrences, not the quantity.

EOR	County	Area (hectares)	Number of sub-occurrences	Total number plants	Land ownership
1CO	Larimer	8	4	51 to 1,000+	Arapaho Roosevelt National Forest
2CO	Larimer	Not available	1?	10,000+	Arapaho Roosevelt National Forest
3CO	Larimer	1	3	20 to 10,000	Private
4CO	Larimer	Not available	1?	350 to 450	Colorado Division of Wildlife (Cherokee Park State Wildlife Area)
5CO*	Larimer	0.5	5	50 to 1,000+	Private (The Nature Conservancy)
6CO	Boulder	Not available	1?	100+	Arapaho Roosevelt National Forest/Private
7CO	Larimer	1	1?	489	Arapaho Roosevelt National Forest/Private
9CO*	Larimer	<0.1	1?	934	Private (The Nature Conservancy)
13CO	Boulder	0.4 to 2.7	3	150 to 2,300+	Arapaho Roosevelt National Forest
14CO	Boulder	Not available	2	100+	Arapaho Roosevelt National Forest
15CO	Boulder	Not available	2	100 to 1,000+	Arapaho Roosevelt National Forest
16CO	Boulder	Not available	1?	100+	Arapaho Roosevelt National Forest **?**
17CO	Boulder	Not available	Several	100+	Arapaho Roosevelt National Forest
18CO	Boulder	2 to 5	2	Not available	Arapaho Roosevelt National Forest
19CO	Boulder	Not available	2	100 to 300+	Arapaho Roosevelt National Forest
20CO	Larimer	Not available	1?	100+	Arapaho Roosevelt National Forest **?**
21CO	Larimer	Not available	1?	100's	Arapaho Roosevelt National Forest
22CO	Boulder	Not available	1?	Not available	Arapaho Roosevelt National Forest **?**
23CO	Boulder	Not available	2?	1,000+	Arapaho Roosevelt National Forest
24CO	Boulder	Not available	1?	1,000+	Arapaho Roosevelt National Forest
25CO	Boulder	Not available	1?	1,000+	Arapaho Roosevelt National Forest
26CO	Boulder	14	5	3,000+	Arapaho Roosevelt National Forest
27CO	Boulder	Not available	1?	1,000+	Arapaho Roosevelt National Forest
28CO	Boulder	2	3	77 to 300+	Arapaho Roosevelt National Forest
29CO	Boulder	1	1?	400	Arapaho Roosevelt National Forest
30CO	Boulder	Not available	1?	16 to 73	Arapaho Roosevelt National Forest
31CO	Boulder	Not available	1?	Not available	Arapaho Roosevelt National Forest
32CO	Larimer	Not available	1?	840	Arapaho Roosevelt National Forest
33CO	Boulder	Not available	1?	73 to 100+	Arapaho Roosevelt National Forest
34CO	Larimer	4.45	2	100+	Arapaho Roosevelt National Forest Colorado Division of Wildlife (Cherokee Park State Wildlife Area)
35CO	Larimer	Not available	1?	840	Arapaho Roosevelt National Forest
36CO	Boulder	91m strip	1?	250 to 300	Arapaho Roosevelt National Forest
37CO	Larimer	1 to 10	2	100+	Arapaho Roosevelt National Forest Colorado Division of Wildlife (Cherokee Park State Wildlife Area)
38CO	Boulder	Not available	1?	100+	Arapaho Roosevelt National Forest
39CO	Larimer	Not available	1?	Not available	Arapaho Roosevelt National Forest
40CO	Boulder	Not available	1?	200+	Arapaho Roosevelt National Forest
41CO	Boulder	Not available	2	100 to 500+	Arapaho Roosevelt National Forest
42CO	Larimer	2.1	3	2,000+	Arapaho Roosevelt National Forest
43CO	Larimer	2	1?	200+	Private
01WY	Albany	Not available	Not available	Not available	Private **?**

*=occurrences with demographic monitoring sites.

Demographic monitoring has been conducted at two locations on lands owned by the Nature Conservancy (Caprock Preserve and Phantom Canyon) over a seven-year period. This demographic monitoring effort is still in progress. The population viability analysis of the Phantom Canyon occurrence resulted in prediction of a nearly 50 percent decline over a 50-year period; analysis of the Caprock Preserve occurrence resulted in a prediction of stability or a slight increase in numbers over a 50-year period. These results represent a fraction of the *Aletes humilis* population, and inferences about population trend for the species as a whole cannot be made. For a detailed discussion, refer to the demography section of this assessment. Due to the lack of data, no inferences can be made concerning the temporal pattern of abundance at any spatial extent.

Habitat

Aletes humilis is a plant of the montane forests located on slopes and foothills of the front range of the Colorado Rocky Mountains. This species shows a marked preference for a relatively distinct habitat type. It appears to occupy a certain belt of vegetation and to be confined to a predictable substrate and topography. It can be found growing primarily on north or west-facing slopes, in decomposed granite derived soils, in the crevices and cracks of rock outcrops. The rock outcrops on which *A. humilis* occurs are on moderately steep to nearly vertical cliffs within a sparsely vegetated ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) forest. Occasionally it is found in the forest duff of open ponderosa pine/Douglas-fir forests. Thirty-seven of the 40 occurrences reported habitat data. Of these, 73 percent were located on rock outcrops or rock crevices, 22 percent were located on both rock outcrops/crevices and in forest duff, and 5 percent were located in the duff of a sparsely vegetated ponderosa pine forest. **Table 3** summarizes EOR site information and presents population habitat data by occurrence, including vegetation, elevation, substrate, slope, and aspect. **Figure 4** is a photograph illustrating the generalized habitat of *A. humilis*.

Based on the CNHP EOR occurrence data and herbarium label data, the most common community for this taxon is the *Pinus ponderosa* Lawson and *Pseudotsuga menziesii* (Mirbel) Franco (ponderosa pine/Douglas-fir) habitat association. It tends to occur more or less exclusively in these communities. Infrequently, co-dominance occurs with *Pinus flexilis* James (limber pine) and *Juniperus scopulorum* Sarg. (Rocky Mountain juniper). Commonly associated trees and shrubs include *Populus tremuloides* Michaux (aspen), *Jamesia americana* Torrey & Gray (fivepetal cliffbush), *Arctostaphylos uva-ursi* (L.) Sprengel (kinnikinnick), *Juniperus communis* L. ssp. *alpina* (Smith) Celakovsky (common juniper), and *Ribes cereum* Douglas (wax currant). Several forbs and grasses consistently occur with *Aletes humilis* including *Heuchera parviflora* Nuttall (littleflower alumroot), *Potentilla fissa* (Nuttall) Rydberg (bigflower cinquefoil), *Muhlenbergia montana* (Nuttall) Hitchcock (mountain muhly), and *Stipa comata* (Trinius & Ruprecht) Barkworth (needle and thread grass). Other taxa associated with *A. humilis* documented by EORs and herbarium labels are listed in **Table 4**.

According to the EORs and herbarium label data, estimates of total vegetation range from 20 to 80 percent. The cover estimates of each strata range from 5 to 30 percent for trees, 5 percent for shrubs, 5 to 30 percent for grasses and forbs, and 35 to 60 percent for barren ground (primarily rock).

Ponderosa pine is well adapted to high frequency, low intensity, surface fires, which play a large role in shaping the form of this vegetation type (Knight 1994, Jones and Ogle 2000). Intensive grazing and fire suppression have reshaped the physiognomy of these forests from open and even-aged to more closed with a second growth of trees as understory (Knight 1994). Ponderosa pine is considered climax at lower elevations and generally gives way to Douglas-fir in mesic sites at higher elevations. In addition, Douglas-fir tends to be more abundant on north facing slopes within the ponderosa pine dominated forests. Douglas-fir can be either seral or climax depending upon the elevation and the fire regime. Douglas-fir can survive low intensity fires but is susceptible to crown fires because of the low level branches (Knight 1994, Jones and Ogle 2000). *Aletes humilis* occurs in ponderosa pine/Douglas-fir dominated forests. This species prefers areas protected from continual sunlight, such as those found on north facing slopes, where Douglas-fir tends to be more abundant. There are no data to demonstrate whether *A. humilis* is more abundant in these areas, but it might prove useful in predicting habitat if the relative abundance of Douglas-fir to ponderosa pine were documented.

Documented habitat descriptions from EOR and herbarium label data consistently note this species occurring on coarse, decomposed gravels and sands derived from Precambrian granite. Most often *Aletes humilis* is found on the Silver Plume Formation. This formation is derived from igneous rock dated at 1.45 billion years before present (Foutz 1994). The plant is occasionally found on metamorphic gneiss and schist

Table 3. Summary of habitat data for known occurrences of *Aletes humilis*. Taken from Element Occurrence Record (EOR) data forms, herbarium specimen labels, and USGS 7.5 minute topographic maps (Colorado Natural Heritage Program 2003).

EOR	Elevation (meters)	Aspect	Substrate	Slope (percent)	Vegetation cover (percent)*	Habitat characteristics and association - (1) short-leaved form and (2) long-leaved form
01CO	1,926 to 2,341	All	Silver plume granite/ gravelly soil	35	Not Available	Crevices among rock outcrops. Ponderosa pine/Douglas-fir/cushion.
02CO	2,195 to 2,317	All	Silver plume granite/ sandy and gravelly	30	Not Available	(1) Sandy crevices and cracks near vertical cliffs (2) forest duff below ponderosa pine. Ponderosa pine/Douglas-fir/cushion.
03CO	2,103 to 2,170	N, SSW	Granite outcrops/ gravel soils and sandy pockets	20	Not Available	Compact cushions in cliff crevices, xeric. Ponderosa pine/Douglas-fir/ cushion.
04CO	2,317 to 2,362	Not Available	Granite gravels	0 to 35	Not Available	Exposed rocky knoll on outcrops. Ponderosa pine/Rocky Mountain juniper.
05CO**	1,878 to 2,024	All	Granite outcrops and tors/ shallow gravels and sands	5+	Not Available	Cracks in rocks in shallow soils on steep cliffs, slopes, and rim. Ponderosa pine/Douglas-fir/mountain mahogany.
06CO	2,310	All	Precambrian granites/ sandy soil	Not Available	Not Available	Cracks and crevices of rock outcrops above river.
07CO	2,219 to 2,256	N, W, NW	Decomposed granite gravels	Not Available	0 to 40	Bare promontories and in duff on rocks. Ponderosa pine/Douglas-fir.
09CO**	2,292 to 2,304	N	Precambrian granite /<1.5 cm gravel soils	15 to 35	Not Available	On duff under trees in open ponderosa pine/Douglas-fir/kinickinick.
13CO	2,370 to 2,536	N, W, NNW	Silver plume granite/ gravelly coarse loam/ stony colluvial granite and gneiss	40 to 70	T=15 to 25 S=5 to 25 G=5 to 30 B=35 to 50	Partially shaded, unglaciated ridge top and crest. Colluvial canyon slopes. Moist to dry montane forest. Ponderosa pine/Douglas-fir.
14CO	2,408 to 2,439	S, W, NW	Silver plume granite/ decomposed granite gravels	Not Available	Not Available	Sparse ground cover on gentle slopes. Ponderosa pine/Douglas-fir.
15CO	2,317 to 2,451	N, NW	Silver plume granite/ coarse sand and decomposed gravel	Not Available	Not Available	Shaded, steep slopes, in crevices of rocks and along base of cliffs. Forested boulder talus slopes. Pine/ Douglas-fir.
16CO	2,317 to 2,451	Not Available	Not Available	Not Available	Not Available	Not Available
17CO	2,408 to 2,530	SW, NW	Silver plume granite/ coarse sandy soils	Not Available	Not Available	Steep forest slopes occasioNot Availablelly in duff. Ponderosa pine/ Douglas-fir.
18CO	2,286 to 2,682	N, NNW	Granite and metamorphic rocks/ well drained gravelly, loamy, coarse sandy soil	50	T=20 to 30 S=5 G=10 B=50	Partially shaded straight and convex slopes. Ponderosa pine/limber pine/ Douglas-fir.
19CO	2,225 to 2,317	NW	Silver plume granite	Not Available	Not Available	Both (1) and (2) occur on gentle to steep slopes. Ponderosa pine/Douglas-fir.
20CO	2,134 to 2,225	N	Silver plume granite	Not Available	Not Available	Steep cliffs in canyon.
21CO	2,210 to 2,378	N, W	Granite	Not Available	Not Available	Moderate slopes and cliffs.

Table 3 (cont.).

EOR	Elevation (meters)	Aspect	Substrate	Slope (percent)	Vegetation cover (percent)*	Habitat characteristics and association - (1) short-leaved form and (2) long-leaved form
22CO	2,134 to 2,225	N	Silver plume granite	Not Available	Not Available	Steep cliffs.
23CO	2,134 to 2,225	N	Silver plume granite	Not Available	Not Available	Steep cliffs.
24CO	2,621 to 2,682	N, SW, W, NW	Silver plume granite and gneiss bedrock/ coarse sand and decomposed granite	Not Available	Not Available	Both (1) and (2) occur on gentle slopes and cliffs occasioNot Availablelly in duff. Ponderosa pine/limber pine/ Douglas-fir.
25CO	2,621 to 2,682	Not Available	Not Available	Not Available	Not Available	Not Available
26CO	2,469 to 2,606	All	Silver plume granite/ fine gravels	0 to 20	T=5 S=5 G=15 B=60	Open to partially shaded, barren habitat on crests of foothill ridges. Ponderosa pine/Douglas-fir.
27CO	2,469 to 2560	W	Silver plume granite	Not Available	Not Available	Both (1) and (2) occur on gentle to steep slopes and crest. Some aspen and Rocky Mountain juniper. Ponderosa pine/Douglas-fir.
28CO	2,469	All	Silver plume granite/well drained gravels	0 to 5	T=10 S=5 G=5 B=60	Dry, open to partially shaded, exposed, windy foothills ridge tops, and in rock crevices. Woodland/shrub mix. Ponderosa pine/Douglas-fir.
29CO	Not Available	NW	Igneous gravels	0 to 15	T=20 S=5 G=20 B=60	Dry, foothills ridge woodland. Ponderosa pine/limber pine.
30CO	2,225 to 2,378	N, W	Silver plume granite	Not Available	Not Available	Cliff sides and rugged outcrops in ponderosa pine/Douglas-fir.
31CO	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available
32CO	2,256 to 2,317	W, NW	Granite rocks	Not Available	Not Available	Steep rock outcrops Ponderosa pine/Douglas-fir.
33CO	2,118 to 2,225	N, W, NW	Silver plume granite	Not Available	Not Available	Steeply sloping cliffs above creek. Ponderosa pine/Douglas-fir/Rocky Mountain juniper.
34CO	2,530 to 2,637	S, SW, W, NW	Gneiss, schist, and granite	Not Available	Not Available	Gentle to steep slopes. Ponderosa pine/Douglas-fir.
35CO	2,317 to 2,461	W	Silver plume granite	Not Available	Not Available	Cliffs and mountain crest. Ponderosa pine/Douglas-fir/Rocky Mountain juniper.
36CO	2,451 to 2,463	W	Metamorphic Gneiss	Not Available	Not Available	Cliff spur. Ponderosa pine/limber pine.
37CO	2,286 to 2,347	N, W	Granite outcrops/gravelly loamy sand	5 to 50	Not Available	Dry partially shaded montane woodland, in rock crevices. Ponderosa pine/Douglas-fir.
38CO	2,378 to 2,408	NW	Not Available	Not Available	Not Available	Top and sides of cliff.
39CO	2,317 to 2,524	N, S, W	Silver plume granite	Not Available	Not Available	Cliffs and slopes on mountaintop. Ponderosa pine/limber pine/Douglas-fir.
40CO	2,256 to 2,353	N, W	Silver plume granite	Not Available	Not Available	Vertical cliffs along creek in ponderosa pine/Douglas-fir.

Table 3 (concluded).

EOR	Elevation (meters)	Aspect	Substrate	Slope (percent)	Vegetation cover (percent)*	Habitat characteristics and association - (1) short-leaved form and (2) long-leaved form
41CO	2,012 to 2,576	All	Silver plume quartz monzonite/ gravels	Not Available	Not Available	Rugged forested foothills, steep cliffs, and rolling ridge top. Old growth ponderosa pine/Douglas-fir.
42CO	2,347 to 2,378	N	Granite outcrops	Not Available	Not Available	Rock outcrops. Ponderosa pine/Douglas-fir.
43CO	2,073 to 2,085	N, NW	Broken pinkish granite	0 to 60	Total cover=40	Flat rocks or benches, in pine duff next to granite boulders. Ponderosa pine.
01WY	Not Available	Not Available	Not Available	Not Available	Not Available	Stoney cliffs.

*T=trees; S=shrubs; G=grass/forb; B=bare ground

**= occurrences with demographic monitoring sites.

Figure 4. General habitat for *Aletes humilis*, used with the permission of C. Refsdal-Delmatier, Wyoming Natural Diversity Database.

Table 4. Taxa documented to co-occur with *Aletes humilis*. Taken from Element Occurrence Record data forms and herbarium specimen labels (Colorado Natural Heritage Program 2003).

Associated Species	Common name
Achillea millefolium L.	common yarrow
Aletes acaulis (Torrey) Coulter & Rose	stemless Indian parsley
Antennaria spp. Gaertn.	pussytoes
Artemisia frigida Willd.	prairie sagewort
Artemisia spp. L.	sagebrush
Calamagrostis stricta (Timm) Koeler.	slimstem reedgrass
Carex rostrata Boott	beaked sedge
Cercocarpus montanus Raf.	alderleaf mountain mahogany
Cystopteris fragilis (L.) Bernhardi	brittle bladderfern
Erigeron compositus Pursh	cutleaf daisy
Erigeron vetensis Rydberg	early bluetop fleabane
Eriogonum umbellatum Torr	sulphur-flower buckwheat
Geranium spp. L	geranium
Harbouria trachypleura (Gray) Coult. & Rose	whiskbroom parsley
Heterotheca villosa (Pursh) Shiners	hairy false goldenaster
Heuchera bracteata (Torrey) Seringe	bracted alumroot
Leucopoa kingii (Watson) Weber	spike fescue
Lupinus spp. L.	Lupine
Penstemon virens Penn.	Front Range beardtongue
Potentilla effusa Douglas	cinquefoil
Potentilla rupincola Osterhout	branched cinquefoil
Pulsatilla patens (L.) Miller ssp. multifida (Pritz.) Zamels	cutleaf anemone
Purshia tridentata (Pursh.) DC.	antelope bitterbrush
Ranunculus spp. L.	buttercup
Rosa spp. L.	Rose
Rubus spp. L.	blackberry
Saxifraga bronchialis L. ssp. austromontana (Wiegand) Piper	matted saxifrage
Schizachyrium scoparium (Michaux) Nash	little bluestem
Sedum lanceolatum Torr.	spearleaf stonecrop
Selaginella densa Rydberg	spikemoss
Selaginella mutica D.C. Eaton	bluntleaf spikemoss
Senecio spp. L.	ragwort
Shepherdia canadensis (L.) Nutt.	russet buffaloberry
Solidago spp. L.	golden rod
Townsendia hookeri Nutt..	Hooker's Townsend daisy

(Green 1992). It appears to be restricted to these well-drained substrates, both in the rock crevice habitat and in the overlying forest duff.

Aletes humilis prefers the microsites found in the cracks and crevices formed in granite rock outcrops on steep slopes and cliffs. In nearly all accounts, this species is found in microhabitats offering protection from direct sun exposure and good drainage. A potential microhabitat preference of the short-leaved form versus the long-leaved form may exist. **Figure 5** and **Figure 6** are photographs illustrating the different forms and the habitats in which they occur. The short-leaved form (**Figure 5**) occurs almost exclusively as compact mats in the cracks and crevices of rock outcrops, where as the long-leaved form (**Figure 6**) is found in the forest duff, occasionally along side boulders. EOR occurrence records consistently report finding the long-leaved form in the duff below patches of the compact form growing in the cracks of cliffs and promontories above the forest floor. The shaded forest floor, below the rocky cliffs, provides suitable habitat through protection from sun exposure and wind plus the potential of increased moisture (EOR 09CO). The forest floors under the cliff populations are also derived from the same granite substrate, with an additional organic layer on the surface.

Figure 5. Short-leaved cushion habit of *Aletes humilis*, used with the permission of Rebecca Day-Skowron 1999.

Figure 6. Long-leaved forest floor habit of *Aletes humilis*, used with the permission of Rebecca Day-Skowron 1999.

Herbarium label data and EORs describe this species as occurring on gentle to steeply sloping hillsides (0 to 70 percent slope). It also has been found on near vertical cliffs and on the crests of ridges. Occasional occurrences can be found on nearly level forest floors, growing against boulders. Individuals have been documented in patches of forest duff located below colonies occupying crack and crevices (EOR 02CO and 15CO). *Aletes humilis* can occur on all aspects, but frequently occupies north and west-facing slopes. Eighty percent of the known occurrences are located on north to northwest-facing slopes. The WYNDD (Fertig 2001) state species abstract states that plants are usually found on north-facing sites, which do not receive continual direct sunlight. CNHP data concur with the WYNDD description of landscape preferences. The elevation range of *A. humilis* varies between 1,878 to 2,682 meters, with the majority of occurrences located between 2,200 and 2,500 meters.

Aletes humilis is distributed across the eastern slopes of the Laramie Mountains in northern Larimer County, Colorado and southern Albany County, Wyoming. Habitat can be found in the Precambrian granite canyons formed by the tributaries of the Cache La Poudre River and along the crests of hills and ridge tops above the tributaries. Additional known habitat for this species is located along the eastern flanks of the Continental Divide in Boulder County Colorado, east of Rocky Mountain National Park and the Indian Peaks Wilderness Area.

Intensive surveys for *Aletes humilis* have been an integral part of the CNHP tracking program, and new occurrences are discovered periodically. Documentation of locations is time and resource intensive; on eleven of the known occurrences only presence data are recorded. In nearly all cases, the new occurrences are found on Precambrian granite within the ponderosa pine/Douglas-fir vegetation belt. Occasional occurrences are found on Precambrian metamorphic gneiss and schist; these areas may harbor additional occurrences. Three of the EORs estimate potential habitat surrounding the known occurrences as follows: 01CO estimates 1.05 ha, 03CO estimates 0.3 ha, and 18CO reports 7.3 ha. Furthermore, it is noted in several of the EORs that the surrounding terrain is inaccessible. Therefore, it is difficult to estimate potential habitat surrounding some of the known occurrences (Colorado Natural Heritage Program 2003). Due to the rough topography of the sites, estimating potential habitat for *A. humilis* requires taking into consideration the possibility of occurrences remaining undiscovered. These inaccessible areas most likely possess some habitat for this species. The ponderosa pine/Douglas-fir vegetation types occurring on hillsides and canyons of this geologic formation could harbor unknown occurrences of this species.

Reproductive biology and autecology

An extensive literature search resulted in no empirical data describing the ecological strategies for *Aletes humilis*. Grime (1979) developed a system of classifying plant strategies based on three basic stress responses. He termed these responses competitor, stress tolerant, and ruderal. Grime proposed four guidelines to aid in classifying plant stress responses: morphology, life-history, physiology, and miscellaneous (litter and palatability).

Aletes humilis is a hemicryptophyte, with small, leathery, pinnately compound leaves. This morphology is often associated with species that are well-adapted to surviving stressful environments, as the perennating bud is protected during a harsh winter or dry summer (Grime 1979, Barbour et al. 1987). In addition, *A. humilis* can form extensive circular or elliptic mats, indicating an ability to protect itself from further extreme environmental conditions (Grime 1979). The small leathery leaves and low stature of the plant provide a strategy of surviving the episodic droughts and periodic heavy rainfall characteristic of the Rocky Mountain region (Theobald et al. 1963, Grime 1979, Fertig 2001).

Aletes humilis is suggested to be a very long-lived plant. It was calculated that the average half-life of this species is 60 years (Schulz and Carpenter 1995). This species accumulates persistent leaf bases, suggesting a long life. This adds to the dimension of the mats as well as contributes to the litter. Palatability of this species has not been documented. EORs document one report of browsing on the outer portions of some leaves. However, no observations were recorded as to which herbivore did the browsing.

Nothing is known about the physiology of this species other than the location of its photosynthate storage system in the root crown (Theobald et al. 1963). It was observed that a late spring snowstorm or an unusually wet and cold spring reduced the number of individuals flowering and/or setting seed (Schulz and Carpenter 1995). This morphogenetic response to stress indicates a reduction in reproductive fitness. In reality, species can take on any combination of characteristics of ruderal, competitor, and stress tolerant responses. Taken in combination with the other criteria discussed above, this taxon is more likely stress tolerant than either a competitor or a ruderal. Grime's (1979) system is not a foolproof method of classifying autecological strategies for individual species. However, it can tell us where an individual species may be placed in the broader picture.

There is no morphological evidence to suggest that *Aletes humilis* reproduces vegetatively or exhibits clonal growth (Theobald et al. 1963). *Aletes humilis* is monecious, reproducing sexually by seed. The inflorescence is a compound umbel; the umbellets are comprised of small protogynous (pistillate flowers developing first) flowers. *Aletes humilis* flowers from May through July, with undispersed fruits present from July through October (Theobald et al. 1963, Linhart and Premoli 1993). There have been no empirical studies to show that *A. humilis* is either self-compatible or an obligate outcosser. However, protogynous flowers increase the likelihood of outcrossing, and most members of the Apiaceae studied to date are self-compatible (Hartman personal communication 2003). If *A. humilis* is self-fertilizing, then a mechanism to overcome a lack of pollinators would exist, giving this species a reproductive advantage in the short term (in the event pollination vectors are absent). On the other hand, in the long term, selfing may promote homozygosity and possibly reduce fitness and the species' ability to adapt to changing environmental conditions (inbreeding depression) (Menges 1991, Weller 1994). *Aletes humilis* shows a high degree of genetic variability within and among populations (Linhart and Premoli 1993); therefore inbreeding depression is not likely. If *A. humilis* is an outcrosser, then it would also have a long-term reproductive advantage by maintaining higher heterozygosity. In the short-term, any loss of pollination vectors could theoretically reduce seed set (Weller 1994).

There are currently no known examples of hybridization in the genus *Aletes*. There is little evidence of hybridization between any species of western North American umbels, therefore it is highly unlikely that *A. humilis* undergoes hybridization (Hartman personal communication 2003).

The flowers of *Aletes humilis* are diminutive. A honeybee was reported alighting on flowers at one of the EOR locations (Colorado Natural Heritage Program 2003). Herbarium label data from 1996 note numerous visits by Anthomyiid flies (*Paregle* spp. unverified). Occasional visits from the honey bee (*Apis mellifera* Linn.) and the sweat bee (*Dialictus* spp.) were also noted (*Richard Scully, May 1996, s.n.*). No formal investigations have been developed to characterize the pollination mechanisms for this species. No other reproductive mutualisms for this species have been identified.

No information is available about the physiology of germination or establishment of seedlings for *Aletes humilis*. Moreover, no experimental data exist concerning the fertility or viability of the seeds. The amount of annual reproduction allocation devoted to seeds is not known. In two occurrences, this species flowered consistently year after year, producing an estimated 10 to 35 seeds per tagged individual. After flowering, the leaves grow up around the fruits; thus, most of the seeds fall within the parent plant (Schulz and Carpenter 1995). According to Grime (1979), a persistent seed bank is one in which at least some of the seeds are at least one year old. No investigations into seed dispersal have been accomplished for this species. The relatively large and weakly-ribbed fruits of *A. humilis* tend to fall within the parent plant, where they apparently reside until the mature plant dies or gravity carries the seeds downslope. Indeed, two occurrences (EOR 02CO and 15CO) document individuals occurring in the duff below a colony located in cracks and crevices. Demographic monitoring of two occurrences in the Phantom Canyon Preserve (owned by The Nature Conservancy), documented seedling establishment and presence of fruits within the thick leaves of the individual plant, indicating that a persistent seed bank of some level is maintained (Schulz and Carpenter 1995). However, the results of the study showed that fewer than 10 seedlings were observed in any given year, and only 0.5 percent germinated over the course of the seven-year study (Schulz and Carpenter 1995). It was documented that 20,000 seeds were produced over a seven-year period, of which only 100 germinated in situ. Schulz and Carpenter (1995) noted that of those few seedlings that were observed, germination occurred where a mature *A. humilis* individual had died. They speculated that the lack of seedling recruitment is due to a lack of safe sites and an inability to disperse across slopes to other open safe sites. It is not known whether seed viability is a factor.

Linhart and Premoli (1993) identified a relationship between geographic distance and genetic identity. They suggested that five of the occurrences included in their study were closely related. However, two other occurrences, which occur geographically close to one another, were not genetically similar, suggesting an inability to disperse. *Aletes humilis* seedlings may be unable to compete with mature individuals for microsites successfully occupied by the mature plants for decades. The biology behind this phenomenon is not known. Gopher burrows on the forest floor at one of the demographic monitoring sites apparently opened up the duff and created a germination site for *A. humilis*. Schulz speculates that while this burrowing activity may benefit seedling establishment, it may also harm mature plants (Schulz personal communication 2003). No observations have been made concerning seed predation of *A. humilis* fruits. No other known cryptic phases in the *A. humilis* life history have been identified.

Phenotypic plasticity is defined as marked variation in the phenotype as a result of environmental influences on the genotype during development (Lincoln et al. 1982). This species produces two forms: the short-leaved, mat-forming form and the long-leaved, open cushion form. The EORs indicate that the short-leaved form is found more often on the rocky outcrop habitat type, while the long-leaved form typically occurs in the less rocky, north-facing forest duff communities. There is no empirical evidence to support the hypothesis that the presence of these two forms is a result of phenotypic plasticity. There is a possibility that it is another taxonomic variety. An investigation into this observation (through transplant experiments and morphological studies) would perhaps answer the question of whether this variation in form is an ecotype or a taxonomic variety of *Aletes humilis*.

Current literature indicates that relationships commonly exist between most higher plants and mycorrhizal fungi (Barbour et al. 1987). These relationships are poorly known, and in fact, this is a growing area of scientific study. It is not surprising then, that there are no documented or observed mycorrhizal associations for *Aletes humilis*, but it is possible that such relationships exist.

Genetic characteristics play an important part in the reproductive fitness of plants. As stated in the above discussion, there is little evidence of hybridization in western North American umbels (including *Aletes*). However, other genetic factors such as inbreeding depression and outbreeding depression should be considered in analyzing the genetic fitness of a species. The relationship between rarity and genetic variation is a subject of increasing interest, and the past notion that rare species have a low level of genetic variation has been questioned (Stebbins 1980, Gitzendanner and Soltis 2000). There is no doubt that low genetic diversity does affect some rare plants' ability to reproduce and survive (Fenster and Dudash 1994, Weller 1994). However, low genetic diversity does not appear to be the case for *A. humilis*. Isozyme analysis of *A. humilis* and *A. acaulis* determined that *A. humilis* is not genetically depauperate when compared to its widespread relative. Levels of genetic variability and patterns of organization are comparable in both species (Linhart and Premoli 1993).

Based upon an assumption that *Aletes humilis* has a mixed mating system (Hartman personal communication 2003), it is likely that *A. humilis* is not affected by inbreeding depression. Furthermore, population analysis of the alleles considered in the isozyme investigation cited above shows a marked genetic differentiation among the six sampled populations of *A. humilis* (Linhart and Premoli 1993). On the surface, this genetic differentiation indicates that outbreeding depression might be a factor affecting the reproductive fitness of *A. humilis*. However, because it is unlikely that this species undergoes hybridization, loss of fertility or viability following a hybrid event is doubtful.

Demography

The Nature Conservancy (TNC) established two demographic monitoring sites on TNC-owned land; one is located within the Caprock Preserve and the other in the Phantom Canyon Preserve. The Caprock Preserve location supports the long-leaved form found in the forest duff under ponderosa pine/Douglas-fir forest, and the Phantom Canyon site exhibits the more typical short-leaved form found on granite rock outcrops. Demographic data are discussed below for the Phantom Canyon site, but they are not available for the Caprock Preserve monitoring site. The Phantom Canyon monitoring site consists of five plots established in 1989. Difficulties arise in measuring demographic parameters because *Aletes humilis* is a long-lived perennial (Elzinga et al. 1998). TNC chose reproductive output (seed count) and size (measured by two perpendicular diameters) as the most informative demographic parameters. These parameters were then designated into size classes, chosen to allow the most even distribution of data and most common transition in size. After seven years of annual monitoring, Schulz and Carpenter (1995) were able to determine several vital rates. The data showed that mortality is low (1 percent), and life span is thought to be in the decades (the average half-life was calculated to be 60 years). Recruitment was very low (0.5 percent), with fewer than 100 seedlings observed over the seven-year study, despite the fact that 20,000 fruits were counted. Anywhere from 46 to 80 percent of the population was reproducing, measured by numbers of individuals setting fruit (Schulz and Carpenter 1995).

A population viability analysis (PVA) is a rigorous quantitative analysis used to predict the future status of a given species. It is important to note that the PVA and projection data matrix for *Aletes humilis* were done as an example for the PVA handbook published by TNC and were not peer reviewed (Morris et al. 1999). For the purpose of an assessment such as this, the minimum viable population (MVP), or the minimum population size necessary to have an acceptably low extinction probability, can provide useful information for management purposes. It has been suggested that demography is of more immediate importance then genetics in determining the MVP of a plant population. If a plant population is able to buffer environmental stochasticity, then the population will be sufficient to protect the genetic integrity of plant populations (Landes 1988, Menges 1991). No determinations have been made concerning MVP size for *A. humilis*. Data were acquired through the efforts of volunteers for TNC and continues to be collected annually. Ten years of demographic monitoring for *A. humilis* will be presented in a manuscript to be published some time in the future (Schulz personal communication 2003).

The Phantom Canyon demographic monitoring site yielded six size class matrices (**Table 5**). The size classes chosen were seedling, 2 to 4 cm^2, >4 to 50 cm^2, >50 to 100 cm^2, and >100 cm^2. A life cycle diagram was constructed using the Year 3 matrix (**Figure 7**). The authors selected this matrix because it contained most of the elements represented by all six size class matrices. Demographic matrices are presented as the probability of one stage attaining the next stage. Limitations associated with the presentation of this information include duration of study and lack of formal review process. However, the data collected during the study provide good general information concerning demographic processes.

Table 5. Phantom Canyon projection matrices for *Aletes humilis*. Stage/size classes are as follows: seedlings, 2 to 4 cm^2, >4 to 50 cm^2, >50 to 100 cm^2, >100 cm^2 (Unpublished data, M. Groom University of Washington, Bothell; T. Schulz, The Nature Conservancy).

Year	Size Class	Seedlings	2 to 4 cm^2	>4 to 50 cm^2	>50 to 100 cm^2	>100 cm^2
Year 1	2 to 4 cm^2	0.143	0.000	0.000	0.000	0.000
	>4 to 50 cm^2	0.857	1.000	0.750	0.086	0.012
	>50 to 100 cm^2	0.000	0.000	0.227	0.707	0.054
	> 100 cm^2	0.000	0.000	0.023	0.207	0.934
Year 2	Seedlings	0.000	0.000	0.000	0.000	0.000
	2 to 4 cm^2	0.000	0.000	0.042	0.000	0.000
	>4 to 50 cm^2	0.000	0.000	0.625	0.015	0.006
	>50 to 100 cm^2	0.000	1.000	0.271	0.708	0.036
	>100 cm^2	0.000	0.000	0.063	0.277	0.959
Year 3	Seedlings	0.000	0.000	0.000	0.000	0.000
	2 to 4 cm^2	0.000	0.500	0.000	0.000	0.005
	>4 to 50 cm^2	0.000	0.500	0.793	0.132	0.005
	>50 to 100 cm^2	0.000	0.000	0.207	0.794	0.027
	>100 cm^2	0.000	0.000	0.000	0.074	0.962
Year 4	Seedlings	0.000	0.000	0.000	0.000	0.000
	2 to 4 cm^2	0.000	1.000	0.000	0.033	0.016
	>4 to 50 cm^2	0.000	0.000	0.706	0.115	0.033
	>50 to 100 cm^2	0.000	0.000	0.294	0.705	0.033
	100 cm^2	0.000	0.000	0.000	0.148	0.918
Year 5	Seedlings	0.000	0.000	0.000	0.000	0.000
	2 to 4 cm^2	0.000	0.000	0.024	0.000	0.000
	>4 to 50 cm^2	0.000	0.571	0.561	0.276	0.012
	>50 to 100 cm^2	0.000	0.000	0.195	0.638	0.095
	>100 cm^2	0.000	0.143	0.073	0.069	0.888
Year 6	Seedlings	0.000	0.000	0.600	0.046	0.044
	2 to 4 cm^2	0.000	0.000	0.000	0.000	0.006
	>4 to 50 cm^2	0.000	0.000	0.690	0.246	0.006
	>50 to 100 cm^2	0.000	0.000	0.214	0.554	0.127
	>100 cm^2	0.000	0.000	0.048	0.123	0.809

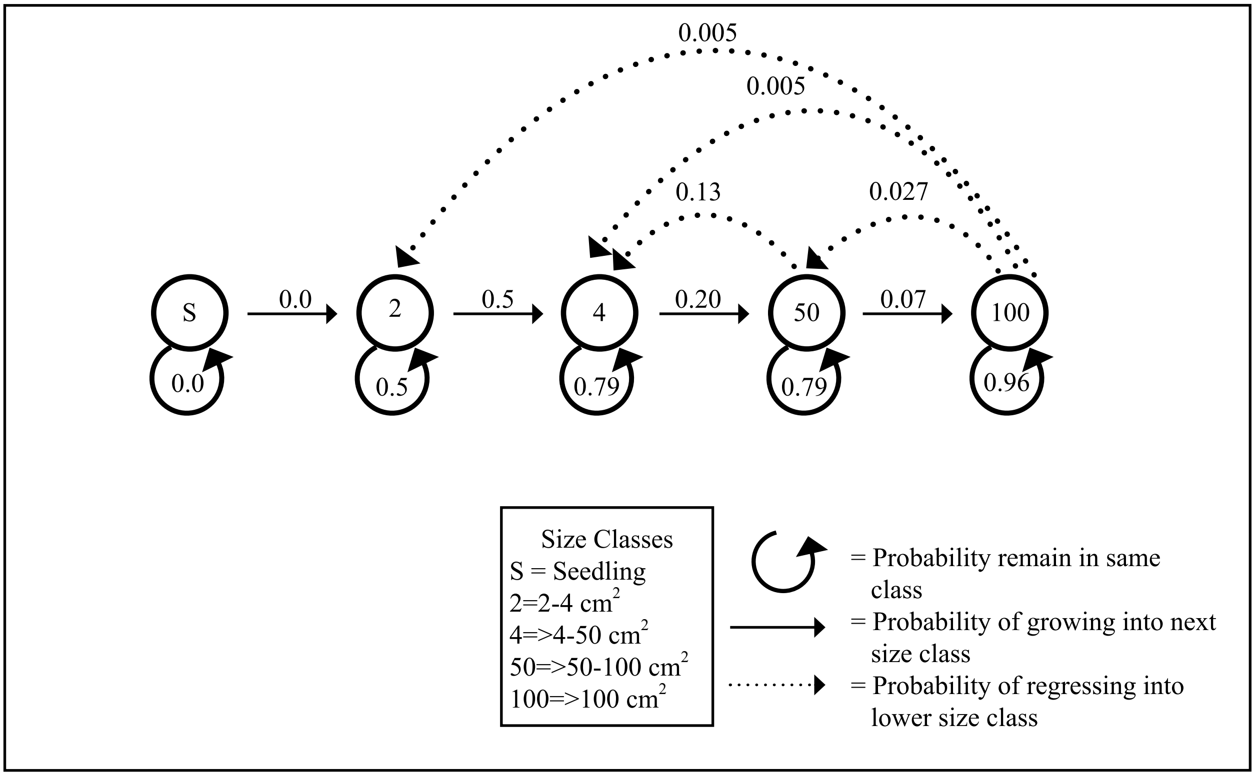

Figure 7. Generalized life cycle diagram for *Aletes humilis* based on the Year 3 population projection matrix presented in **Table 5**.

Table 5 presents data showing a 0.0 percent probability of seedlings attaining the next stage for five of the six years. This species appears to have a low seed germination rate; therefore it is not surprising that TNC volunteers did not observe seedlings during those five years. Increasing the length of the study could identify the actual probability of seedlings growing into the next stage. The life cycle diagram in **Figure 7** illustrates several important factors. As stated above, there was insufficient data to determine the probability of a seedling growing into the >2 to 4 cm^2 size class. Approximately 50 percent of individuals in the >2 to 4 cm^2 size class are likely to grow into the >4 to 50 cm^2 class. However, in about half of the matrices the probability of the >2 to 4 cm^2 class reaching the >4 to 50 cm^2 was zero, indicating that in some years the small individuals of *Aletes humilis* did not grow rapidly. Incidentally, about 50 percent remained in the same size class. It is also shown that approximately 20 percent of the >4 to 50 cm^2 class is likely to attain the >50 to 100 cm^2 class, the probability for this growth interval was consistent in all six matrices. The probability of individuals remaining in the >4 to 50 cm^2 class is 79 percent; this number was generally consistent throughout all six matrices. A less consistent finding is the probability of individuals in the >50 to 100 cm^2 size class reaching the >100 cm^2 class. The representative diagram shows 7 percent; however, the probability varied among the six matrices between 6 and 27 percent. Seventy-nine percent of the >50 to 100 cm^2 individuals remained in that size class. A consistent finding showed that between 80 and 99 percent of the >100 cm^2 sized individuals remained in that class, indicating the long lifespan of *A. humilis*. The very low probability of the transition between the seedling class to the >2 to 4 cm^2 class indicates there may be a problem with seedling mortality, possibly caused by pathogens, desiccation, or lack of safe sites for establishment. The data also showed that some individuals made the jump from the >4 to 50 cm^2 class to the >100 cm^2 class (data vary from 4 to 7 percent). An inconsistent result was the less than 1 percent probability of individuals regressing into a smaller size class. This may be due to mortality followed by germination within the same year, reduction of size through herbivory, dieback due to climatic conditions (drought), some unidentified parasite or disease, or sampling error.

The PVA handbook (Morris et al. 1999) presented several interesting results. **Figure 8** shows a projected trend in population size over the next 50 years for the Caprock Preserve monitoring site (model based on stochastic projection matrix). This model indicates that the Caprock population will approximately double in 50 years. In contrast, **Figure 9** indicates that the Phantom Canyon populations show a 50 percent decline over the next 50 years (model based on field data). Morris et al. (1999) concluded that this might be due to the lack of safe seed germination sites in the granitic rock outcrops at the Phantom Canyon site.

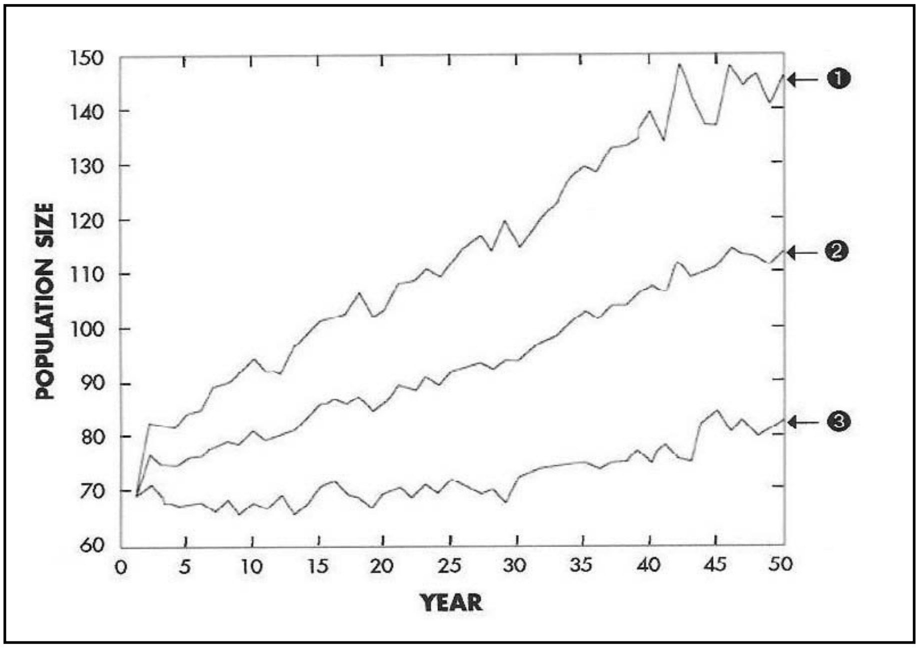

Figure 8. Population trends in the Caprock Preserve population of *Aletes humilis* projected over 50 years using a stochastic projection matrix model. Line 2 is the average of 100 independent runs of the simulation, and lines 1 and 3 are the 95 percent confidence limits on the population size over a 50-year interval (Morris et al. 1999).

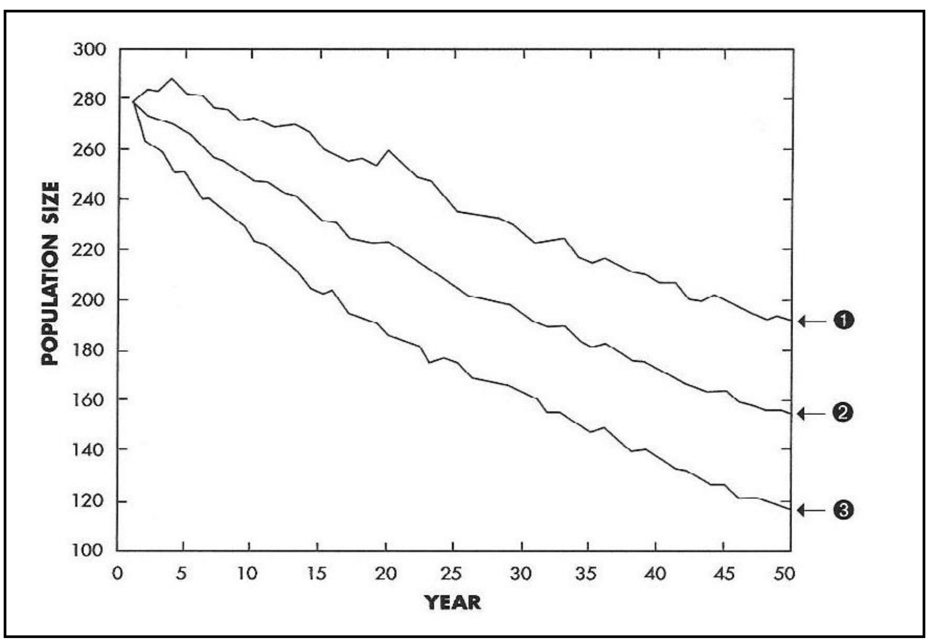

Figure 9. Population trajectory for Phantom Canyon population of *Aletes humilis*. Field data based projection matrix showing a nearly 50 percent decline over 50 years. Line 2 is the average trajectory taken over 100 simulations, and lines 1 and 3 are the 95 percent confidence limits (Morris et al. 1999).

An extinction risk profile for the Phantom Canyon location was constructed (**Figure 10**). The results show that there is a 50 percent and 100 percent probability that the population will drop below 45 or 200 individuals respectively over the next 100 years (Morris et al. 1999). The authors of the PVA handbook presented a projection model experiment of doubling seedling recruitment by planting seeds in empty crevices. The average trajectory showed an increase in population over a 50-year interval. The results shown in **Figure 11** indicate that this may not guarantee an increase in population size, and it may actually still decline.

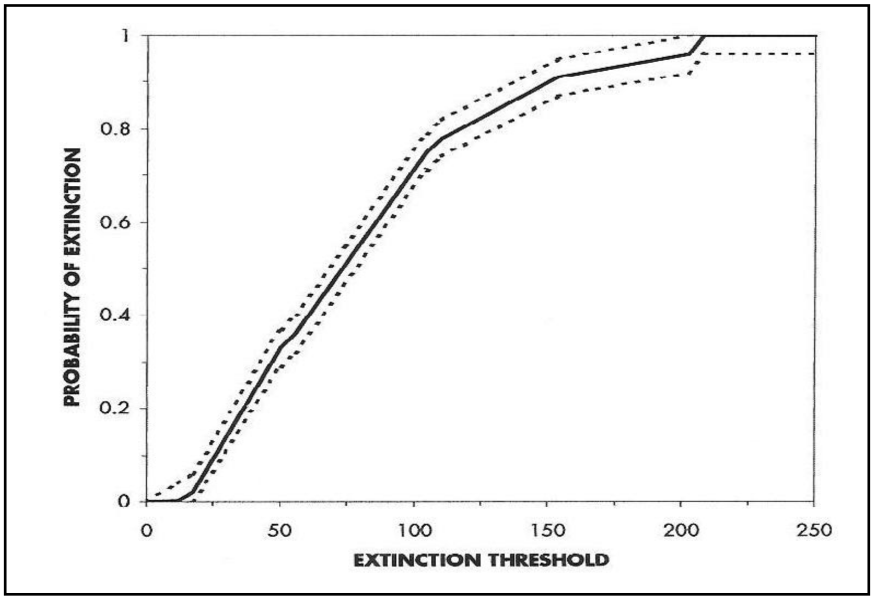

Figure 10. Extinction risk profile for the Phantom Canyon population of *Aletes humilis*. The probability of dropping below a threshold population size by 100 years is shown in the bold line, and the 95 percent confidence limits are indicated by the dotted lines (Morris et al. 1999).

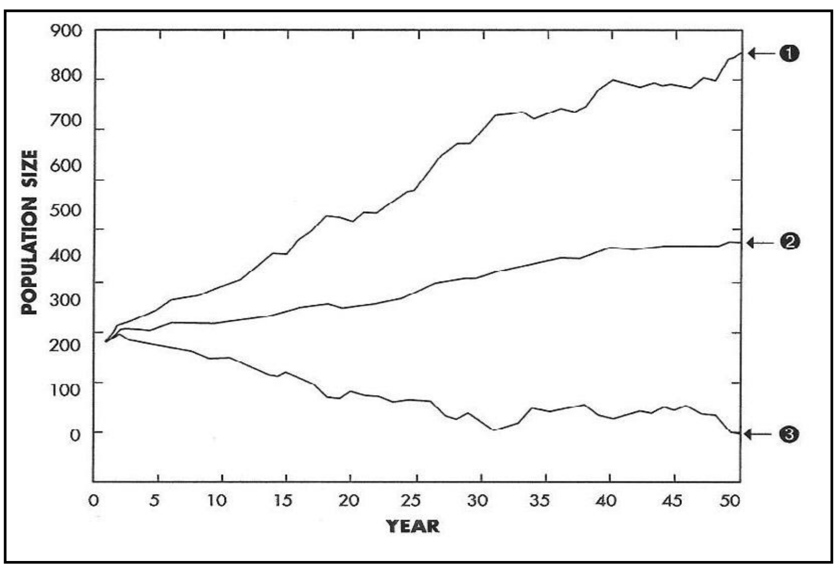

Figure 11. A projection model experiment of the Phantom Canyon population of *Aletes humilis*. Model is based on planting seeds in open crevices thereby doubling recruitment. Results show the average population increases over a 50-year interval (although some replicates still decline). Line 2 is the average trajectory taken over 100 simulations, and lines 1 and 3 are the 95 percent confidence limits (Morris et al. 1999).

Based on the above discussion it is evident that the seedling stage appears to be the critical period in the life cycle of *Aletes humilis*. The two forms of this species occupy different parts of the species' preferred habitat. The compact form is found in rock outcrops and crevices. A possible limiting factor for the species could be an inability to disperse across distances to occupy open safe sites (Schulz and Carpenter 1995). The long-leaved form appears to be limited by the closed and sealed nature of the substrate on the forest floor. Gopher burrows at the Caprock site apparently opened up the duff and created a germination site for *A. humilis*. Schulz (personal communication 2003) speculates that while this burrowing activity may benefit seedling establishment, it may also harm mature plants. Once individuals of *A. humilis* survive the seedling stage, they tend to live a long time. The population growth appears to be limited to those years between seedling establishment and reaching the 2 to 4 cm^2 size, at which point the plants appear to stabilize and continue to grow to maturity, albeit very slowly. Regional weather patterns may affect rate of growth and germination for this species. Favorable conditions may cause a periodic rapid growth spurt while unfavorable conditions may prevent the individuals from attaining the next size class (Schulz and Carpenter 1995).

Information concerning the demographic spatial characteristics for this species is limited. Based on genetic data analysis, it appears that the Phantom Canyon populations of *Aletes humilis* are distinct even though some are less then a kilometer apart (Linhart and Premoli 1993). Without comparable genetic data and accurate abundance information from all 40 occurrences, it is not possible to predict population sources and sinks. A rough estimate of population centers was constructed to provide a basis for relating geographic areas to population size. Data from EOR sites were classified into two categories: locations with greater than 1,000 individuals and locations with less than 1,000 individuals. **Figure 12** and **Figure 13** show the distribution of populations categorized by size in Region 2. Refer to **Table 2** and **Table 3** for detailed population and habitat data. Unfortunately, five of the 40 EOR sites discussed in this assessment lack any quantifiable abundance data. Ten of the 35 occurrences with abundance data have populations above 1,000 individuals, and the remaining 25 sites had populations under 1,000 individuals. Both TNC monitoring sites are from populations with less than 1,000 individuals. The 10 largest occurrences occur on the crests of rocky ridge tops in the cracks and crevices of rock outcrops and in the forest duff below. Four of these are located in Larimer County, and the other six are in Boulder County. No data are available to determine whether the forest floor occurrences are more abundant in terms of numbers of individuals than the rock outcrop occurrences. It is conceivable that sources and sinks could be identified if all of the EORs reported accurate quantifiable data, if a dispersal mechanism was identified, and if the genetic identity of each population was known. Currently, there are not enough quantifiable abundance and demographic data to identify sources and sinks of *A. humilis* populations. The previous section of this assessment summarizes what is known about the geographic distribution and abundance of *A. humilis*.

Possible factors limiting the population growth of *Aletes humilis* include low germination and/or establishment, low seedling survivorship, and an inability to disperse. Neither insect predation nor grazing evidence (domesticated livestock or native mammals) has been observed at any of the known occurrences. CNHP biologists at the Caprock Preserve occurrence observed dead branches falling from the trees above, covering individuals of *A. humilis* and probably causing them to die. Currently, no empirical data exist examining other factors such as seed predation, competition, habitat destruction or fragmentation, or any other factor limiting population growth.

Community ecology

Aletes humilis is generally located in inaccessible areas. Thirty-seven of the 40 occurrences documented habitat data. Of these, 73 percent were located on rock outcrops or rock crevices, 22 percent were located on both rock outcrops/crevices and in forest duff, and 5 percent were located in the duff of a sparsely vegetated ponderosa pine forest. Topographic location has provided a degree of isolation from interactions with invasive species. EORs from the CNHP document a consistent presence of cheatgrass (*Bromus tectorum* L.) at some of the locations. One occurrence is located adjacent to private land that is grazed by cattle, and several invasive plant species were documented by CNHP biologists in the area surrounding the occurrence. The invasive species include nodding plumeless thistle (*Carduus nutans* L.), common mullein (*Verbascum thapsus* L.), white clover (*Trifolium repens* L.), common plantain (*Plantago major* L.), timothy (*Phleum pratense* L.), toadflax (*Linaria* spp. P. Mill.), and redtop (*Agrostis gigantea* Roth). None of these species occurred in significant density, so it was unlikely that there is a current impact to *Aletes humilis*. High numbers of invasive species may compete with *A. humilis* for possible germination sites. It is unknown if

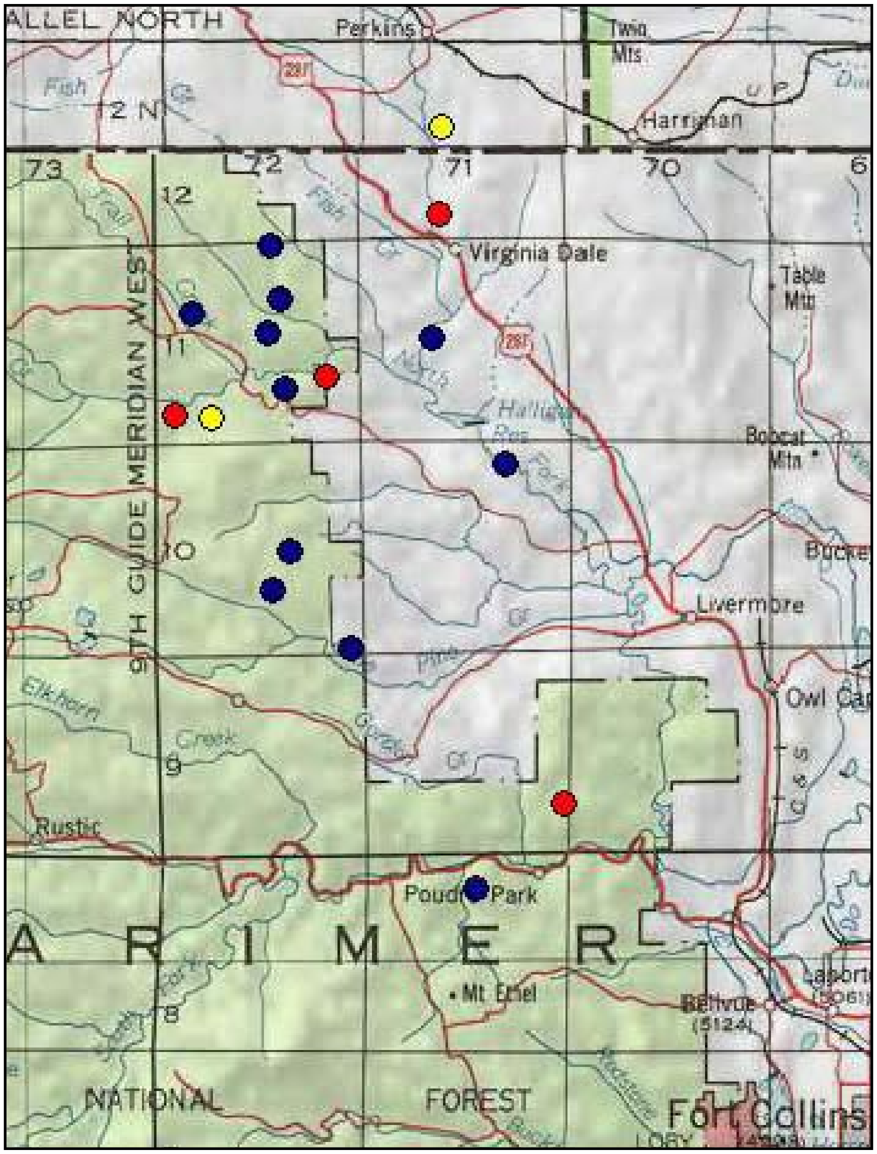

Figure 12. Distribution of *Aletes humilis* occurrences categorized by size in Larimer County, Colorado. Red dot = populations estimated above 1,000 individuals, and blue dot = populations estimated below 1,000. Element Occurrence Records without abundance data are represented by a yellow dot.

interactions with native species has any effect on the distribution or abundance of *A. humilis*. Possible effects of competition with native species include change in species composition and shading that could affect the ability of *A. humilis* to compete.

There have been no recorded observations of interactions between *Aletes humilis* and herbivores. CNHP biologists noted browsing of the leaves at one of the EOR locations, but it is not known which herbivore did the browsing. Bighorn sheep and bear sign have also been noted at other locations. No damage from herbivory has been recorded.

Observations of habitat preferences and the autecology of *Aletes humilis* lead us to conclude that this species is stress tolerant. It tends to colonize a specific habitat where there is less competition to overcome (see above discussion on habitat and autecology). The forest duff occurrences were noted to be sparsely vegetated, further supporting the hypothesis that this species is a poor competitor. Based upon the principles set forth by Grime (1979), the authors of this assessment speculate that this species is adapted to a non-competitive, stress tolerant strategy, and it would have difficulty establishing itself in microhabitats with greater species diversity.

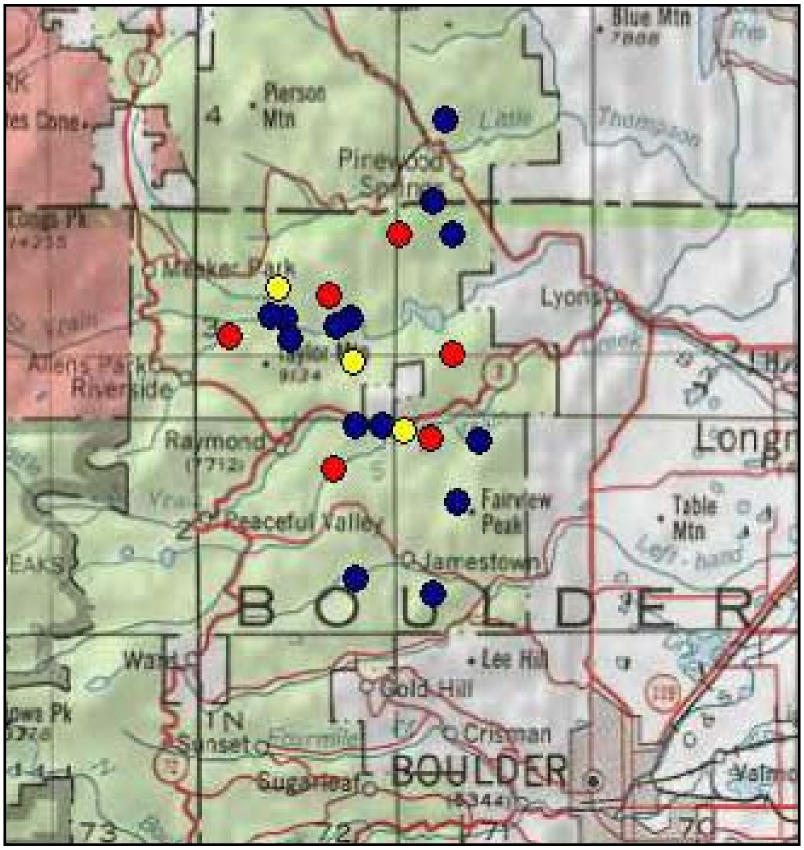

Figure 13. Distribution of *Aletes humilis* occurrences categorized by size in Boulder County, Colorado. Red dot = populations estimated above 1,000 individuals, and blue dot = populations estimated below 1,000. Element Occurrence Records without abundance data are represented by a yellow dot.

There are no studies investigating parasites or diseases that may affect *Aletes humilis*, nor have there been any investigations of symbiotic or mutualistic interactions.

An envirogram is a useful tool for evaluating the relationship between the environment and a single species. It traces the environmental factors that affect a species from the most indirect (distal) interactions to factors that have a direct (proximal) effect (Andrewartha and Birch 1984). Traditionally, it is most often applied to animal/environment interactions. An example of an envirogram constructed for the sugar pine (*Pinus lambertiana* Douglas) showed that the same principles used to construct an envirogram for animals could be equally applied to plants (Schlesinger and Holst 2000). The envirogram is a series of webs that converge upon a centrum. The centrum consists of the basic components of environment that cause an increase, decrease, or no change in the expectation of fecundity and survivorship of a species. It is the most proximal level of the envirogram and directly affects the target species (Andrewartha and Birch 1984). For plants, the centrum consists of resources (light, soil moisture, and nutrients), reproduction (flowering/fruiting, growth and development, and seedling establishment), and malentities (fire, extreme weather, and herbivory).

The envirogram is constructed as a modified dendrogram, with the centrum placed at the most proximal level to the species. A web is constructed distally from each of the centrum components, illustrating factors that affect the centrum component, termed Web 1. Web 2 consists of factors that affect Web 1; Web 3 consists of factors that affect Web 2; and so on. Two of the primary functions of an envirogram are to identify areas of research and to propose hypotheses (Andrewartha and Birch 1984). As with all analytical tools, the best envirogram is based upon a complete data set. A preliminary envirogram was constructed for *Aletes humilis*, despite the lack of ecological and environmental data (**Figure 14**, **Figure 15**, and **Figure 16**). Entries with a question mark denote areas in need of further research, such as pollination mechanisms,

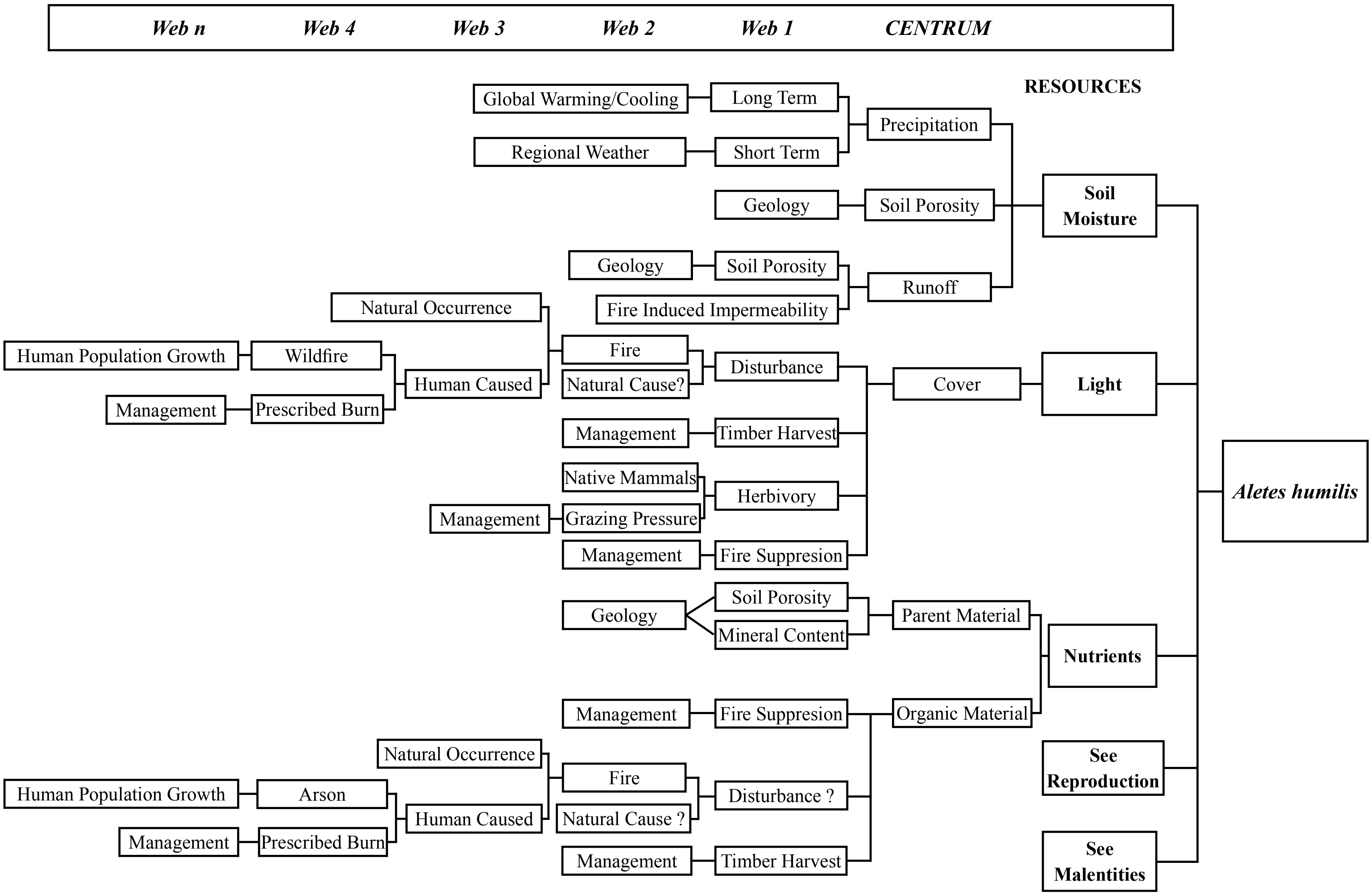

Figure 14. Resources centrum for *Aletes humilis* envirogram.

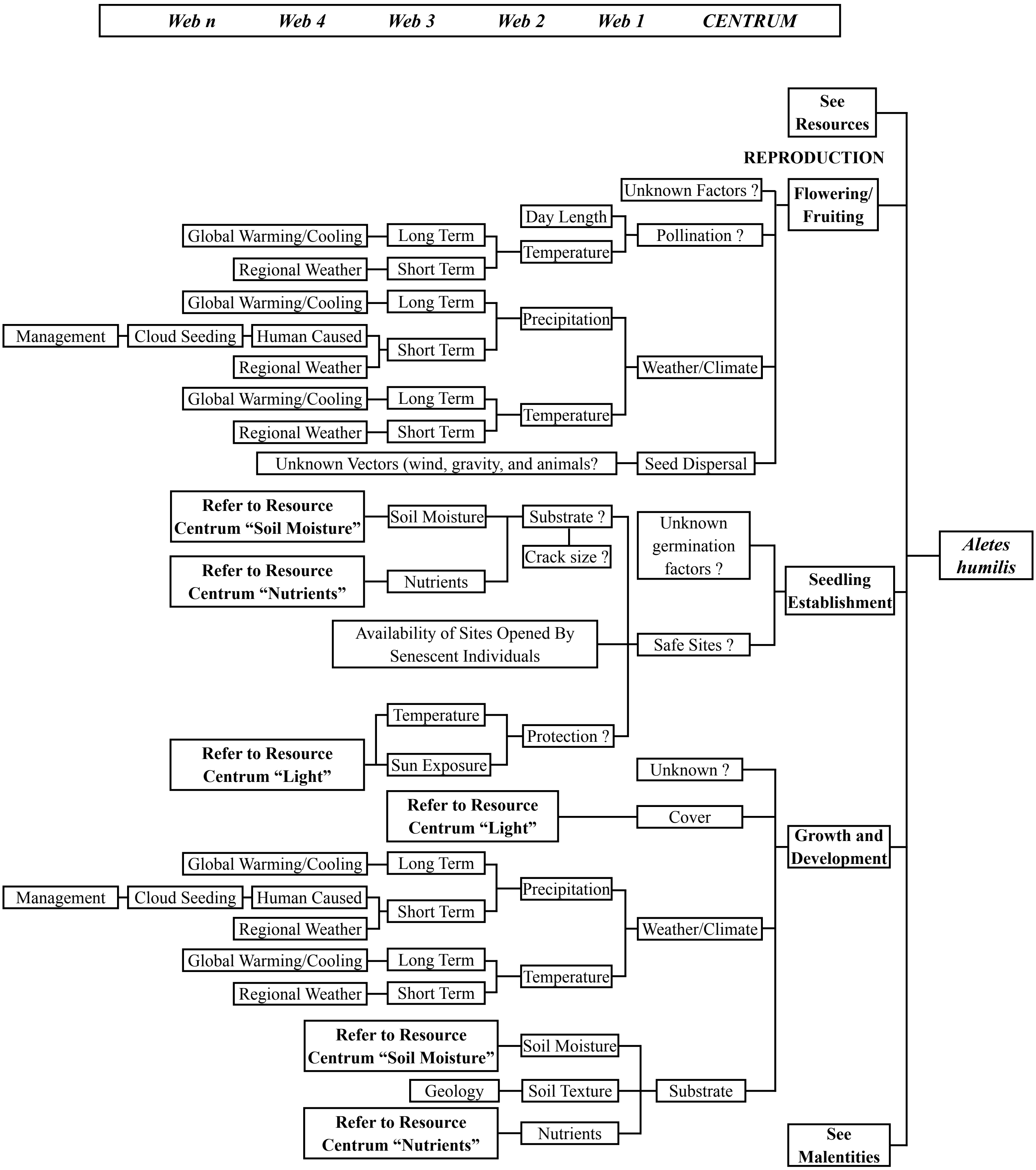

Figure 15. Reproduction centrum for *Aletes humilis* envirogram.

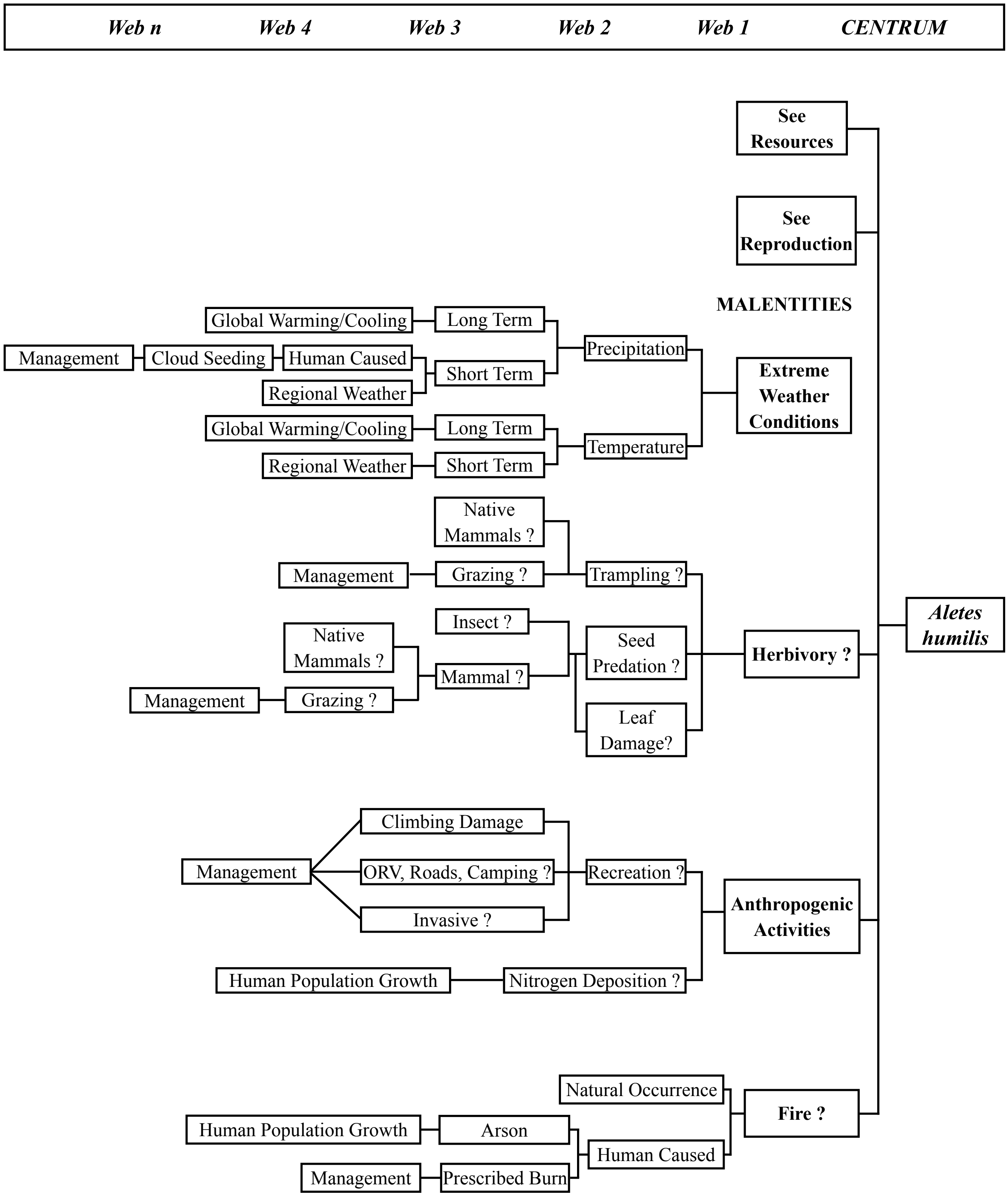

Figure 16. Malentities centrum for *Aletes humilis* envirogram.

herbivory, flowering/fruiting, the effect of disturbance, and dispersal vectors. To conserve space, occasionally second- and third-level webs are referred to a more complete web rooted in Web 1. Web 4 levels and above (Web *n*) generally identify areas beyond the ecological and biological scope of the species assessment.

The resources centrum for *Aletes humilis* is made up of three proximal factors: soil moisture, light, and nutrients. Soil moisture is affected by precipitation, soil porosity (permeability), soil water retention, and runoff. Moisture is generally modified through natural processes; however, cloud seeding activities may increase the soil moisture of an area. Light can be affected by vegetation cover (including invasive species), which in turn can be modified by disturbance, timber harvest, range utilization, and fire suppression. The nutrient centrum is affected by such things as substrate parent material and the addition or subtraction of organic materials such as decomposition of coarse woody debris, manure, or removal of decomposing materials through timber harvest or fire. The reproduction centrum consists of factors affecting flowering and fruiting (pollination, weather, dispersal), seedling establishment (availability of safe sites, substrate, protection from desiccation), and growth and development (weather, light, substrate). The malentities centrum identifies factors that may negatively affect *A. humilis*. These include such things as extreme weather conditions, for example drought or unusually cold weather during the flowering and fruiting season. Herbivory may cause damage through trampling, seed predation, or leaf damage. This may result from either domesticated livestock or native fauna including mammals and insects. Recreational use such as climbing may adversely affect this species through trampling and removal of soil from cracks. Other anthropogenic effects include global warming and nitrogen deposition. Air pollution, including acid rain, silver residue from cloud seeding, and the development of greenhouse gases, may also have a negative effect on some communities. However, these effects are more likely to occur at high elevations. High-intensity fires, from either natural or anthropogenic sources, pose a threat for individuals of *A. humilis* occurring in forest duff.

CONSERVATION

Threats

The concern for viability with *Aletes humilis* is based on its limited global distribution and abundance. These factors make it vulnerable to both management activities and natural disturbances, even though occurrences are isolated and difficult to access (Carpenter 1989). Thirty-seven of the 40 occurrences documented habitat data. Of these, 73 percent were located on rock outcrops or rock crevices, 22 percent were located on both rock outcrops/crevices and in forest duff, and 5 percent were located in the duff of a sparsely vegetated ponderosa pine forest. Occurrences located in rock outcrops or rock crevices may be afforded protection from some management activities due to the nature of their habitat.

Of the management activities that typically occur or are planned for the ARNF, prescribed fire, grazing, and recreation may potentially impact *Aletes humilis* occurrences. Due to the steep, remote locations of the occurrences, no commercial timber harvest or mechanical fuels treatment are currently planned in areas with *A. humilis*. Potential natural threats to the species include extreme weather conditions, herbivory by native wildlife (e.g. elk, deer, or rodents), competition from invasives, global warming, and air pollution. No research has been conducted evaluating whether the species has been over-utilized for commercial, recreational, scientific, or educational purposes; or threatened by disease or predation or other natural or manmade factors that affect its continued existence.

Prescribed fire

The effects of fire on vegetation are difficult to quantify as intensity, timing, and duration all produce variable responses (Brown 2000). Little knowledge is available to determine the degree of threat posed by prescribed fire. Occurrences of *Aletes humilis* located in the cracks and crevices of rocky cliffs would not be affected by prescribed fire (Petterson personal communication 2003). However, there is potential for impact to occurrences located in forest duff. No information was identified to suggest that a recurring fire regime is necessary to maintain *A. humilis* populations.

A bibliography of fire effects on threatened and endangered species can be found in Hessl and Spackman (1995) and a discussion of the effects of fire on plant species in general can be found in the publication concerning wildland fire in ecosystems and its effects on flora (Brown 2000). No references were identified in these publications specifically concerning *Aletes humilis*. Occurrences located in sparsely vegetated habitats would not directly be impacted by fire; however, fire line construction and access could impact individuals or occurrences located in forest duff habitats through trampling that destroys individual plants, or causes habitat fragmentation. The extent of these impacts would depend on the fire's timing, duration, and intensity, and potential changes in plant community composition of the surrounding community. Invasion and competition from exotic species post-fire can be considered a threat to rare plants (Brown 2000).

Grazing

Palatability of this species has not been documented; however, the plant's low stature, and its sparsely vegetated, steeply sloped habitats may provide some protection from herbivory. No specific information concerning the palatability of *Aletes humilis* is available. Secondary impacts of grazing, such as changes in plant species composition (including spread of invasives), soil compaction, and erosion, may still be important. Information contained in three EORs (EORs 03CO, 29CO, 39CO, 41CO, and 42CO) indicated that horse or cattle grazing may occur in the vicinity of those occurrences, but at the time of observation no direct impacts were recorded. *Aletes humilis* does not occur in any active grazing allotments Boulder District of the ARNF (Baker personal communication). Although *A. humilis* does occur within active grazing allotments on the Canyon Lakes District, cattle do not prefer the rocky habitats in which it occurs (LaFontaine personal communication).

Grazing can induce an alteration of plant species composition with a resulting loss of diversity, net primary production, and groundcover (Archer and Smeins 1991). Plant species composition can be altered when a specific intensity, frequency, and/or seasonality of grazing changes the competitive advantage of one group of plants over another (Briske 1991). Grazing can potentially contribute to an increase in the distribution of invasive species as a result of the transportation of weed seeds into uninfested sites; preferential grazing of native species over weed species; creation of patches of disturbed soils that act as seedbeds for weeds; potential alteration of soil surface and horizons; reduction of soil mycorrhizae; and accelerated soil erosion (Briske 1991). Observations recorded by observers at three EOR locations (EORs 03CO, 41CO, 43CO) indicated that *Bromus tectorum* could be a potential problem. It is unknown whether interactions with native species have any effect on the distribution or abundance of *Aletes humilis*. In summary, grazing may threaten individuals or occurrences of *A. humilis*, the most significant aspect of which is increased potential for invasives.

Recreation

Recreation use in the proximity of *Aletes humilis* occurrences located on the ARNF consists primarily of camping, hiking, rock climbing, and off-road vehicle (ORV) use. Recreation conflicts with rare plant species areas may include trampling within populations, collecting flowers or seeds, and a general degrading of habitat (Hamilton and Lassoie 1986). Occurrences located on moderately steep to nearly vertical cliffs within a sparsely vegetated ponderosa pine/Douglas-fir forest would not be favored by ORV traffic or camping, so impacts to a majority of the populations (73 percent of known occurrences) located in these habitats would be limited. An undeveloped hiking trail providing access to Greyrock Mountain could impact some individuals (EOR 01CO; Carpenter 1989), but to what extent is unknown. Two other occurrences (EORs 24CO and 25CO) had an undeveloped campsite and 4-wheel drive road that impacted a portion of the population (unconfirmed report). It is unknown what the extent of impacts to *A. humilis* are as a result of this undeveloped hiking trail, dispersed camping, or 4-wheel drive use. Several EORs mention ORV trails in the area of the occurrence, but the extent of impact has not been determined. Perhaps the greatest recreation threat is inadvertent destruction by hikers and rock-climbers (NatureServe 2002). The ARNF has 14 million visitors per year (6.2 million site visitors and 7.8 million highway visitors), so the potential risk of impact increases each year as visitation increases. No information was available to determine the extent of the potential threat from recreation use to the species.

Other threats

A proposed water development project near Greyrock Mountain could threaten one occurrence (EOR 01CO; Carpenter 1989). No information is available concerning the status of the planned water development. Other potential threats to the species include extreme weather conditions, herbivory from native wildlife, global warming, and air pollution. Extreme drought may impact late snowmelt habitats. Unusually cold springs may delay reproduction and subsequently seed set. Herbivory may occur from native fauna including mammals (such as pikas or marmots) and insects, and this could result in seed predation or leaf damage.

Global warming has been identified as a potential threat to forested communities. In Colorado, both lower elevation and alpine snow covers are very sensitive to changes in climate. Theoretically, Colorado's snow cover could be reduced in extent, duration, and depth. Global warming could cause severe drought or other modification of climate regimes affecting the survivorship or reproductive ability of *Aletes humilis*.

Nitrogen emissions from fixed, mobile, and agricultural sources have increased dramatically along the Front Range of the Rocky Mountains (Baron et al. 2000). Possible effects of nitrogen deposition on a terrestrial ecosystem include premature abscission of pine needles, alteration of mycorrhizal fungi, loss of lichen communities, enhancement of non-native species invasions, and alteration of fire cycles by increasing fuel loads (Fenn et al. 2003). A study of nutrient availability, plant abundance, and species diversity in alpine tundra communities determined that the addition of nitrogen resulted in an increase in species diversity in a dry meadow (Theodose and Bowman 1997). Global warming and increased nitrogen may provide a long-term potential threat or benefit.

The effectiveness of cloud seeding is still in debate. It may be harmful to flora, fauna, and water through introduction of silver iodide or alteration of precipitation regimes in ecosystems (Irwin et al. 1998). It has been speculated that cloud seeding a west to east-moving storm in one area may decrease the precipitation a given storm produces in areas east of the seeded region. The nearest occurrences to cloud seeding operations are the Boulder County locations. These occurrences are located more then 50 miles from ski areas known to experience cloud seeding such as Winter Park, Loveland Pass, and Vail. It is highly unlikely that cloud seeding will have any measurable affect upon *Aletes humilis*. The dynamics of cloud seeding are poorly understood, but the effects of silver on biological systems have been well documented (Irwin et al. 1998).

Conservation Status of the Species in Region 2

TNC has provided baseline work concerning an extinction threshold for the Phantom Canyon populations and determined population trends. This information suggested that the probability of extinction within the next 100 years is high (**Figure 10**) for the Phantom Canyon population because the rate of seedling establishment is low (possibly due to lack of germination sites). Modeling of the Caprock Preserve population showed an increase over 50 years. However, it is important to note that the Caprock projection matrix is based upon a stochastic model and the Phantom projection matrix is based upon field data. This population trend prediction is based on only two populations sampled out of 40 known locations. There is no evidence that the decline would be the result of management activities. These projections should be approached with skepticism. Terri Schultz of TNC is working on a manuscript that analyzes data gathered over a ten-year period. When the analysis is published, it will provide conclusions that have a greater degree of accuracy than the results of the TNC PVA handbook reported here (Schultz personal communication 2003).

There are no data that can be used to draw conclusions concerning the trend for the remaining populations of *Aletes humilis*. No inferences can be made about population trend for the species at the scale of individual populations or rangewide. The nominal amount of data available concerning population and abundance does not allow inferences as to whether populations are increasing, decreasing, or remaining stable. Population revisits taking place approximately once per decade (with some occurrences visited more often) did occur for the majority of the EOR occurrences, recording primarily presence/absence of populations. The only inference that can be made is that *A. humilis* is persistent in those locations that have been revisited over the past 20 years.

Populations of *Aletes humilis* may also be at risk from environmental stochasticity or natural catastrophes based on the size of occurrences. As mentioned in the demography section, 30 percent of occurrences with abundance data would have some degree of protection against environmental stochasticity and natural catastrophe based on a population size of 1,000+ (Menges 1991). Menges (1991) provides a *general* reference to population size and stability. No actual determinations have been made concerning a minimum viable population size for *A. humilis*. Based on Menges' population size of 1,000 individuals, there is a possibility that both demographic and genetic stochastic risk exists. Sessile growth habitat, generally small neighborhood size, edaphic specialization, and population isolation could potentially increase the vulnerability of *A. humilis* to stochastic risk. *Aletes humilis* may be self-fertilizing; however, it shows a high degree of genetic variability within and among populations (Linhart and Premoli 1993). Therefore, inbreeding depression is most likely not a factor in increasing vulnerability to stochastic risk (Menges 1991, Weller 1994). If *A. humilis* is an outcrosser, then it would have a long-term reproductive advantage by maintaining higher heterozygosity (Weller 1994). Indeterminate growth, possible phenotypic plasticity, seed dormancy, and the long-lived character of the species may also provide a buffer against risk. *Aletes humilis* appears to be a long-lived plant. There are no other data or observations indicating that the species is adaptable to disturbance or any other factors decreasing risk. There are no identified specific mutualisms including mycorrhizal partners, pollinators, or dispersers. However, no investigations have been conducted concerning these possible mutualisms.

There is little direct evidence to indicate whether or not specific individuals or occurrences of *Aletes humilis* in Region 2 or rangewide are at risk as a result of management activities or natural disturbance. Thirty-three of the 40 occurrences are located on National Forest System lands. Management decisions made by the USFS could impact a majority of the known occurrences of *A. humilis*. As mentioned above, the remote locations where the plant occurs may provide some level of protection for the species.

Potential Management of the Species in Region 2

Implications and potential conservation elements

The section above on threats details the potential impacts to *Aletes humilis* from management activities and natural disturbance. There are 40 occurrences in Region 2 (including the one historical occurrence in Wyoming). Of these known occurrences, thirty-three occurrences are located on the ARNF. Of the management activities that typically occur or are planned for the ARNF, prescribed fire, grazing, and recreation may impact *A. humilis* occurrences. Other potential threats to the species include extreme weather conditions, herbivory by native wildlife, competition from invasives, global warming, and air pollution.

High intensity prescribed fire may impact individuals of *Aletes humilis* located in forest duff habitats through mortality, destruction of habitat, erosion, or change in plant community structure. Grazing could potentially impact *A. humilis* individuals or habitat through herbivory, travel routes (fences, waterlines, stock pond/tank placement), changes in plant species composition (including spread of invasives), soil compaction, or erosion. Consequences of these actions could include loss of individuals or populations, habitat fragmentation, disruption of the reproductive cycle, or changes in plant community structure.

Trail building, maintenance, reconstruction, or use, as well as camping, hiking, and recreation site development, could potentially impact individuals or occurrences of *Aletes humilis*. Trail design and placement can result in erosion, soil compaction, trampling, and habitat fragmentation as well as increasing disturbance and traffic in the vicinity of occurrences, which could in turn increase the potential of plant collection issues. Soil disturbance during trail construction, maintenance, or use could impact individuals or occurrences from changes in hydrology, soil compaction, trampling, or changes in plant community structure (e.g., introduction of invasives or reseeding).

Natural disturbances (e.g., high winds, unfavorable temperatures, drought) that occur during reproductive periods (including flowering, seed set, germination, and seedling establishment) ***may*** have the potential to augment impacts from management activities to *Aletes humilis*. Other potential disturbances include grazing from native wildlife populations, disturbance caused by gophers, and interactions with other native plants. Consequences of these natural disturbances could include loss of individuals, changes in plant community composition, alteration of mycorrhizal fungi or lichen communities, enhancement of non-native species invasions, or alteration of fire cycles by increasing fuel loads.

Conservation elements

Additional information will be required to formulate a conservation strategy for *Aletes humilis*. These elements include investigation of biological parameters of the species including reproduction (e.g. pollinator activity, timing and duration of flowering/seed set, germination requirements), habitat (disruption of necessary community components), autecology (weed invasion or change in plant community composition), and response to management activities or natural disturbance.

Demographic data show that germination and seedling establishment may be the most vulnerable periods of the life cycle of *Aletes humilis*. It appears that a possible safe site could be required. However, there are no data to support or negate this possibility. Safe sites have not been defined for this species. Studies focused on safe sites and variables controlling germination and seedling establishment could broaden our knowledge of factors that limit growth and establishment.

Based on potential demographic, environmental, genetic, and natural stochastic risk to *Aletes humilis*, information concerning minimum viable population size can be utilized to identify protection parameters. Protection parameters may include maintaining existing occurrences and providing adequate habitat protection from alteration or fragmentation; maintaining diverse occurrences across the range of habitats and elevations may also be important in the preservation of genetic diversity (Karron 1987).

Tools and practices

Continued efforts in the location of other occurrences by use of presence/absence surveys may provide additional information concerning distribution and abundance of the species. *Aletes humilis* appears to be restricted to Precambrian granite; approximately 443,398 ha of this geologic substrate exists within a 300 km radius of the center of the range of this species (Green 1992). Additional areas of Precambrian granite occur south along the eastern foothills of the Front Range and may provide suitable habitat for *A. humilis*. Species-specific surveys for *A. humilis* would likely identify new occurrences, although discovering vast numbers of new colonies is not likely. A complete inventory of the flora of the Rocky Mountains is in progress (Hartman 1992); the known regional distribution of *A. humilis* may expand upon completion of this survey work. However, floristic surveys are not species-specific, and intensive floristic work often does identify new occurrences of rare plants (Lyon 1996, Chumley 1998, Moore 1998, 2000). *Aletes humilis* flowers from May through July, with seeds present from July to October. Species or habitat surveys should be conducted during this timeframe.

Population monitoring should be designed to ascertain parameters of the species' life history including generation time, net reproductive rate, age distribution, and potential reproductive output lost to abortion and predation. Additional quantitative data that document the condition of the community where *Aletes humilis* occurs, including the plant composition, structure, and function, would make information available to infer existing conditions should an increase/decrease in *A. humilis* occurrences take place. This information may also provide "clues" as to possible limiting factors controlling the distribution of the species. Common variables to be measured include cover or density of plant species, demographic parameters of important species, soil surface conditions, fuel loads, and animal signs. Measurement and scheduled remeasurement would provide a long-term ecological study to document rates and types of change that can occur in response to natural processes such as succession and disturbance (Elzinga et al. 1998).

Habitat monitoring describes how well an activity meets the objectives or management standards for the habitat (Elzinga et al. 1998). Establishing a minimum total vegetative plant cover and type of forage species in a grazing allotment would be an example of such objectives. Habitat monitoring is most effective when research has shown a clear link between a habitat parameter and the condition of a species (Elzinga et al. 1998). Without additional knowledge of factors controlling the growth and distribution of *Aletes humilis*, it would be difficult to utilize this type of sampling program. Collection of quantitative data relevant to community structure and composition, as mentioned above, would provide a baseline for use of this methodology.

The mission of the Center for Plant Conservation is to conserve and restore the rare native plants of the United States. Plant material for *Aletes humilis* has been stored with the Center for Plant Conservation.

Information Needs

No monitoring data have been collected to determine the response of this species to management actions. Additional research to determine the impact on species viability from both man-made and natural causes, surveys to determine geographical extent, and evaluation of future planned activities with respect to their impact on *Aletes humilis* occurrences would assist in providing protection and management direction to ensure long term species viability. Additional recommendations for further study include:

- Establishment of demographic monitoring sites on USFS occurrences to answer basic demographic questions (vital rates, recruitment, survival, reproductive age, lifespan or proportion of populations reproducing, seed viability, seed bank dynamics, longevity). Coordination of study design and results with TNC would provide additional understanding of the critical phases such as seed viability and seedling establishment.

- ❖ Evaluation of the reproductive and ecological characteristics of the species (i.e., pollination mechanisms, seed germination, herbivory, and dispersal vectors) to provide a basis to further assess the factors controlling the growth of *A. humilis*.

- ❖ Periodic revisiting and monitoring of known occurrences to provide information concerning vulnerability, implications of management practices, and population dynamics.

- ❖ Identification of any threats to known occurrences including invasive species and impacts related to camping, hiking, grazing, and ORV traffic.

DEFINITIONS

Deterministic model: A mathematical model in which all the relationships are fixed and the concept of probability is not involved, so that a given input produces one exact prediction as an output (Lincoln et al. 1982).

Ecotype: A locally adapted population; a race or infraspecific group having distinctive characters that result from selective pressures of the local environment (Lincoln et al. 1982).

Generation time: The mean period of time between reproduction of the parent generation and reproduction of the first filial generation (Lincoln et al. 1982).

Hemicryptophyte: A perennial plant with renewal buds at ground level or within the surface layer of the soil; typically exhibiting degeneration of vegetative shoots to ground level at the onset of the unfavorable season (Lincoln et al. 1982).

Homozygosity: Having identical alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Inbreeding: Mating or crossing of individuals more closely related than average pairs in the population (Lincoln et al. 1982).

Inbreeding depression: Reduction of fitness and vigor by increased homozygosity as a result of inbreeding in a normally outbreeding population (Lincoln et al. 1982).

Longevity: The average life span of the individuals of a population under a given set of conditions (Lincoln et al. 1982).

Metapopulation: A group of different but interlinked populations, with each different population located in its own, discrete patch of habitat.

Monoecious: Used of a plant species having separate male and female organs born on the same individual (Lincoln et al. 1982, Allaby 1992).

Monophyletic: Derived from the same ancestral taxon; used of a group sharing the same common ancestor (Lincoln et al. 1982).

Outbreeding depression: Reduction of fitness and vigor in the progeny when individuals mate from distant source populations (Lincoln et al. 1982).

Outcrossing: Mating or crossing of individuals that are either less closely related than average pairs in the population, or from different populations (Lincoln et al. 1982).

Polyphyletic: Derived from two or more distinct ancestral lineages; used of a group comprising taxa derived from two or more different ancestors (Lincoln et al. 1982).

Self-compatible: Used of a plant that can self-fertilize (Lincoln et al. 1982).

Selfing: Self-fertilizing or self pollinating (Lincoln et al. 1982).

Sink: A population patch, in a metapopulation, that does not have a high degree of emigration outside its boundaries but, instead, requires net immigration in order to sustain itself.

Source: A population patch, in a metapopulation, from which individuals disperse to other population patches or create new ones.

Stochastic model: A mathematical model founded on the properties of probability so that a given input produces a range of possible outcomes due to chance alone (Lincoln et al. 1982).

Vestiture: General descriptive term of degree and type of pubescence on a plant (Harris and Harris 1994).

Vital rates: The class-specific annual rates of survival, growth, and fecundity (Morris et al. 1999).

References

Allaby, M. 1992. The concise Oxford dictionary of botany. Oxford University Press, Oxford.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web. The University of Chicago Press, Chicago, IL.

Archer, S. and F.E. Smeins. 1991. Ecosystem-level processes. Pages 109-140 *in* R.K. Heitchmidt and J.W. Stuth, editors. Grazing management: an ecological perspective. Timber Press, Portland, OR.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial plant ecology, 2nd edition. Benjamin/Cummings Publishing Company, Inc., Menlo Park, NJ.

Baron, J.S., H.M. Rueth, A.M. Wolfe, K.R. Nydick, E.J. Allstott, J.T. Minear, and B. Moraska. 2000. Ecosystem responses to nitrogen deposition in the Colorado Front Range. Ecosystems 3:352-368.

Briske, D.D. 1991. Developmental morphology and physiology of grasses. Pages 85-108 *in* R.K. Heitchmidt and J.W. Stuth, editors. Grazing management: an ecological perspective. Timber Press, Portland, OR.

Brown, J.K. and J.K. Smith. 2000. Wildland fire in ecosystems: effects of fire on flora. USDA Forest Service, Ogden, UT.

Carpenter, A.T. 1989. Element stewardship abstract for *Aletes humilis* (Larimer Aletes. Unpublished report prepared for the Colorado Field Office, Nature Conservancy, Boulder, CO.

Chumley, T. 1998. Floristic Survey of Central Colorado, East Slope: from the Mosquito Range to the Plains. University of Wyoming, Laramie, WY.

Colorado Natural Heritage Program. 1996. Colorado's Natural Heritage: Rare and Imperiled Animals, Plants, and Natural Communities. Colorado Natural Heritage Program, Fort Collins, CO.

Colorado Natural Heritage Program. 2003. Element occurrence records for *Aletes humilis*. Colorado Natural Heritage Program, Fort Collins, CO.

Cronquist, A., N.H. Holmgren, and P.K. Holmgren. 1997. Intermountain flora, vascular plants of the intermountain west, U.S.A. Pages 1-446 *in* New York Botanical Garden, Bronx, NY.

Downie, S.R., D.S. Katz-Downie, and M.F. Watson. 2000. A phylogeny of the flowering plant family Apiaceae based on chloroplast DNA *RPL16* and *RPOC1* intron sequences: towards a suprageneric classification of subfamily Apioideae. American Journal of Botany 87:273-292.

Downie, S.R., S. Ramanath, D.S. Katz-Downie, and E. Llanas. 1998. Molecular systematics of Apiaceae subfamily Apioideae: phylogenetic analyses of nuclear ribosomal DNA internal transcribed spacer and plastid *RPOC1* intron sequences. American Journal of Botany 85:563-591.

Drude, C.G.O. 1897-1898. Umbelliferae. Pages 63-250 *in* A. Engler and K. Prantl, editors. Die naturlichen Planzenfamilian.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. *In*: U. S. Department of Interior, Bureau of Land Management, Denver, CO.

Fenn, M.E., J.S. Baron, E.B. Allen, H.M. Rueth, K.R. Nydick, L. Geiser, W.D. Bowman, J.O. Sickman, T. Meixner, D.W. Johnson, and P. Neitlich. 2003. Ecological effects of nitrogen deposition in the western United States. Bioscience 53:404-420.

Fenster, C.B. and M.R. Dudash. 1994. Genetic considerations for plant population restoration and conservation. Pages 34-62 *in* M.L. Bowles and C.J. Whelan, editors. Restoration of Endangered Species; Conceptual Issues, Planning, and Implementation. Cambridge University Press, Cambridge, MA.

Fertig, W. 2001. State Species Abstract: *Aletes humilis*. Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W.F., C.F. Refsdal, and J. Whipple. 1994. Wyoming rare plant field guide. Wyoming Rare Plant Technical Committee, Cheyenne, WY.

Foutz, D.R. 1994. Geology of Colorado Illustrated. Your Geologist, Grand Junction, CO.

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of Genetic Variation in Rare and Widespread Plant Congeners. American Journal of Botany 87:783-792.

Green, G.N. 1992. The digital geologic map of Colorado in ARC/INFO format. U.S. Geologic Survey Open-File Report 92-507 U.S. Geologic Survey, Denver, CO.

Grime, J.P. 1979. Plant strategies and vegetation processes. John Wiley & Sons Ltd., Bath.

Hamilton, M.P. and J.P. Lassoie. 1986. Rare plant management in wilderness: theory, design and implementation. Gen. Tech. Report INT 212 USDA Forest Service.

Harris, J.G. and M.W. Harris. 1994. Plant identification terminology an illustrated glossary. Spring Lake Publishing, Spring Lake.

Hartman, R.L. 1992. The Rocky Mountain Herbarium, associated floristic inventory, and the flora of the Rocky Mountains project. Journal of the Idaho Academy of Science 28:22-43.

Hartman, R.L. 2003. Personal communication.

Hartman, R.L. and D.J. Crawford. 1972. Chromosome Numbers and Taxonomic Notes for Rocky Mountain Umbelliferae. American Journal of Botany 59:386-392.

Heidel, B. 2004. Personal Communication.

Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese, and W. Basham. 1998. Environmental contaminants encyclopedia. *In*: National Park Service, Water Resources Division, Fort Collins, CO.

Jones, G.P. and S.M. Ogle. 2000. Characterization abstracts for vegetation types on the Bighorn, Medicine Bow, and Shoshone National Forests. Prepared for USDA Forest Service, Region 2 Wyoming Natural Diversity Database.

Karron, J.D. 1987. A comparison of the pollination biology, breeding systems and population genetic structure of geographically restricted and widespread species in the genus Astragalus (Fabaceae). Biological Conservation 39:179-193.

Kartesz, J.T. 1994. A synonymized checklist of the vascular flora of the United States. *In*: Canada and Greenland.

Knight, D.H. 1994. Mountains and plains. Yale Univ. Press, New Haven, CT.

Landes, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Lincoln, R.J., G.A. Boxshall, and P.F. Clark. 1982. A dictionary of ecology, evolution, and systematics. Cambridge University Press, Cambridge.

Linhart, Y.B. and A.C. Premoli. 1993. Genetic variation in *Aletes acaulis* and its relative, the narrow endemic *A. humilis* (Apiaceae). American Journal of Botany 80:598-605.

Lyon, M.J. 1996. A Floristic Survey of the San Miguel and Lower Dolores River Drainages, Colorado and Utah. M. S. Thesis. University of Wyoming, Laramie, WY.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Pages 45-61 *in* K.E. Holsinger, editor. Genetics and conservation of rare plants. Oxford University Press, NY.

Moore, L.M. 1998. Floristics of the Upper Dolores River Drainage and Adjacent Areas, Southwestern Colorado. M. S. Thesis. University of Wyoming, Laramie, WY.

Moore, L.M. 2000. A floristic survey of the Weminuche Wilderness area, upper Pine River, Hinsdale County, Colorado. Report submitted to the Colorado Natural Areas Program, Durango, CO.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Schlesinger, M.D. and E.M. Holst. 2000. Appendix O Species accounts for select focal species. *In*: D.D. Murphy and C.M. Knopp, editors. Lake Tahoe watershed assessment: Volume I. Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

Schulz, T.T. and A.T. Carpenter. 1995. Monitoring Survival, Growth, and Reproduction of *Aletes humilis*. Pages 281-285 *in* Southwestern Rare and Endangered Plants: Proceedings of the Second Conference. USDA Forest Service, Flagstaff, AR.

Stebbins, G.L. 1980. Rarity of plant species: a synthetic viewpoint. Rhodora 82:77-86.

Sun, F.-J., S.R. Downie, and R.L. Hartman. 2000. A phylogenetic study of *Cymopterus* and related genera. American Journal of Botany 87:161-162.

Takhtajan, A.L. 1986. Floristic regions of the world. University of California Press, Berkeley and Los Angeles, CA.

Theobald, W.L., C.C. Tseng, and M.E. Mathias. 1963. A Revision of *Aletes* and *Neoparrya* (Umbelliferae). Brittonia 16:296-315.

Theodose, T.A. and W.D. Bowman. 1997. Nutrient availability, plant abundance and species diversity in two alpine tundra communities. Ecology 78:1861-1872.

USDA Forest Service. 1997. Revised land and resource management plant for the Arapahoe and Roosevelt National Forests and Pawnee National Grassland, Fort Collins, CO.

USDA Forest Service. 2003. Forest Service Manual, Rocky Mountain Region, Title 2600 - Wildlife, Fish and Sensitive Plant Habitat Management. R2 Supplement No. 2600-2003-1. Document Name 2670.

Weber, W.A. 1984. New names and combinations, principally in the Rocky Mountain flora, IV. Phytologia 55.

Weller, S.G. 1994. The relationship of rarity to plant reproductive biology. Pages 90-117 *in* M.L. Bowles and C.J. Whelan, editors. Restoration of Endangered Species; Conceptual Issues, Planning, and Implementation. Cambridge University Press, Cambridge.