Shoshonea pulvinata Evert & Constance (Shoshone carrot): A Technical Conservation Assessment

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

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Many people helped with the preparation of this technical conservation assessment. Kent Houston, Shoshone National Forest, provided historical information about species surveys and about individuals who contributed to our knowledge of *Shoshonea pulvinata*. Tessa Dutcher and Bonnie Heidel of the Wyoming Natural Diversity Database both helped to make files and reports available. Erwin Evert and Robert Dorn also discussed their considerable field and herbarium studies, as well as their ideas about future conservation needs. Laura Bell of The Nature Conservancy's Heart Mountain Reserve also shared her knowledge about *S. pulvinata* at that site, and discussed future conservation needs there.

AUTHOR'S BIOGRAPHY

Jennifer C. Lyman received her Ph.D. in Plant Ecology and Genetics from the University of California, Riverside. Her thesis focused on an ecological and genetic comparison of the endemic plant *Oxytheca emarginata* (Polygonaceae), restricted to the San Jacinto Mountains of California, with a few of its widespread congeners. After completion of her doctorate, she became a biology professor at Rocky Mountain College in Billings, MT in 1989. In 1991, Dr. Lyman left teaching to work for BioSystems Analysis, Inc., an environmental consulting firm based in California but with a branch office in Billings, MT. After managing the Billings office for four years, Dr. Lyman returned to teaching at Rocky Mountain College in order to develop an Environmental Sciences program. Dr. Lyman is currently Chair of the Science and Mathematics division at the college. Her research interests include the study of floristics and ecology of plants of the Djungarsky and Altai mountain ranges in Russia and Kazakhstan. She is co-author with Drs. Juri Kotokov and Anna Ivashenko of the book, The Flora of the Vascular Plants of the West Altai Reserve, Kazakhstan, published in 2002 as well as a number of articles about new rare plant findings in Kazakhstan.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SHOSHONEA PULVINATA*

Status

Shoshonea pulvinata Evert and Constance (Shoshone carrot) is a narrow endemic with a global distribution limited to 12 occurrences. Eight occurrences are located in Wyoming, in the eastern Absaroka Mountains and the Owl Creek Mountains in Fremont, Hot Springs, and Park counties; three of these occurrences are found on the Shoshone National Forest. Four occurrences are located in the Beartooth and Pryor mountains in south-central Montana. Occurrences are composed of mats that are comprised of hundreds or even thousands of individual plants. The total number of plants is estimated to be 210,000 in Wyoming and 12,000 in Montana. Due to uncertainty about its exact status, *S. pulvinata* is ranked between globally imperiled and vulnerable (G2G3) by NatureServe; imperiled (S2) by the Wyoming Natural Diversity Database; and critically imperiled (S1) by the Montana Natural Heritage Program. *Shoshonea pulvinata* is designated a sensitive species in Regions 1 and 2 of the USDA Forest Service and is included on the Wyoming Bureau of Land Management State Sensitive Species List. It was once listed as a Category 2 species on the Federal Endangered Species List, but the U.S. Fish and Wildlife Service has discontinued the use of this designation.

Primary Threats

Observations show that there are potential threats to the persistence of *Shoshonea pulvinata*. In order of decreasing priority these threats include regional natural disturbances, such as fire or extreme drought; trampling from recreationists; off-road vehicle use; commercial activities, such as mineral development; invasion by exotic plants; and global climate change. The three occurrences on the Shoshone National Forest occupy rugged sites at mid- to high elevations and are largely undisturbed.

Primary Conservation Elements, Management Implications and Considerations

On public lands the opportunity exists to create areas that are designated for research: Research Natural Areas (RNAs) on USDA Forest Service lands and Areas of Critical Environmental Concern (ACECs) on Bureau of Land Management lands. Pat O'Hara Mountain and Bald Peak are two areas on the Shoshone National Forest that have been proposed as RNAs, and both support *Shoshonea pulvinata* colonies. This species, along with other rare calcifers, was identified as one of the management targets for Bald Peak and Pat O'Hara Mountain. Its inclusion in an RNA or an ACEC would bring attention to *S. pulvinata*'s unusual taxonomic placement in a monotypic genus, and to its status as a rare plant species known from only 12 occurrences. The RNA or ACEC could provide a place to conduct long-term population studies to expand our understanding of the demography and population trends of this long-lived perennial. Occurrences on private land are afforded protection only if the landowners recognize the importance of conservation as one of their personal management goals.

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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). *Shoshonea pulvinata* (Shoshone carrot) is the focus of an assessment because it is designated a sensitive species in Region 2 (USDA Forest Service 2003). In the USFS, a sensitive species is a plant or animal species whose population viability is identified as a concern by a Regional Forester due to significant current or predicted downward trends in abundance or in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *S. pulvinata* throughout its range in Region 2 and in adjacent areas. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species, based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. 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, the assessment cites management recommendations proposed elsewhere, and when management recommendations have been implemented, the assessment examines the results of the implementation.

Scope

The *Shoshonea pulvinata* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature on the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *S. pulvinata* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

In producing the assessment, the author 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. The 1986 publication by E.F. Evert "The Yellowstone region: endemics and other interesting plants" published in *Rocky Mountain Alpines* by the American Rock Garden Society and Denver Botanical Gardens was not used to prepare this document because it is not available in libraries. Some non-refereed literature was used in the assessment when information was unavailable elsewhere. However, these references were regarded with greater skepticism. Unpublished data (e.g., state natural heritage program records) were important in estimating the geographic distribution of this species. These data required special attention because of the diversity of persons and methods used in their collection.

Treatment of Uncertainty

Science is a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964).

However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist, T. C. Chamberlain (1897) suggested an alternative approach to science, where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, or logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide our understanding of the world (Hillborn and Mangel 1997).

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

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the USFS Region 2 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 Center for Plant Conservation, employing at least two recognized experts on this or closely 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

NatureServe ranks *Shoshonea pulvinata* as G2G3; while its exact status is uncertain, it is between globally imperiled (G2) and globally vulnerable (G3) (NatureServe 2003). For an explanation of NatureServe's ranking system, see the Definitions section of this document. The Wyoming Natural Diversity Database ranks this taxon as imperiled in the state (S2) and considers it to be a regional endemic that has medium conservation priority based on the number and condition of occurrences (**Figure 1**). *Shoshonea pulvinata* also occurs in south-central Montana (USFS Region 1), where the Montana Natural Heritage Program (MNHP) considers it critically imperiled (S1) because there are only four known occurrences (**Figure 2**).

Shoshonea pulvinata was formerly a Category 2 species under the Federal Endangered Species Act (Heidel 2001). Category 2 candidates were "taxa for which information in the possession of the Service indicated that proposing to list as endangered or threatened was possibly appropriate, but for which sufficient data on biological vulnerability and threat were not currently available to support proposed rules" (U.S. Fish and Wildlife Service 1996). In 1996, the U.S. Fish and Wildlife Service discontinued the use of designating species as Category 2 (U.S. Fish and Wildlife Service 1996). As a result, *S. pulvinata* currently has no federal status under the Endangered Species Act. *Shoshonea pulvinata* is designated a sensitive species in Region 2 of the USDA Forest Service (USDA Forest Service 2003) and in Region 1 (USDA Forest Service 2004). It is also listed on the Wyoming Bureau of Land Management State Sensitive Species List (Bureau of Land Management 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Six of the eight known Wyoming occurrences occur on public lands in the eastern Absaroka Mountains (Park County) and the Owl Creek Mountains (Fremont and Hot Springs counties). These lands are managed by the USFS (Shoshone National Forest) and the Bureau of Land Management (BLM). The remaining two known Wyoming occurrences of *Shoshonea pulvinata* are located on lands managed by the Wind River Indian Reservation, The Nature Conservancy (TNC) Heart Mountain Reserve, and on lands owned by private individuals.

Both the USFS and the BLM have designated *Shoshonea pulvinata* as a sensitive species, a status that conveys special management considerations aimed at preventing its listing as a threatened or endangered species by the U.S. Fish and Wildlife under the Endangered Species Act of 1973 (U.S.C. 1531-1536, 1538-1540) (FSM 2600, BLM Manual Supplement H-6840).

In USFS Region 2 no management plans specifically address the conservation of *Shoshonea pulvinata*. The only restrictions that apply to the areas where *S. pulvinata* occurs are general travel restrictions (Houston personal communication 2003). Grazing is allowed on the Shoshone National Forest (Fertig 1995). Periodically, the Shoshone National Forest surveys and evaluates the occurrences of *S. pulvinata* on its lands (Marriott 1988, Fertig 1997, Heidel et al. 2002).

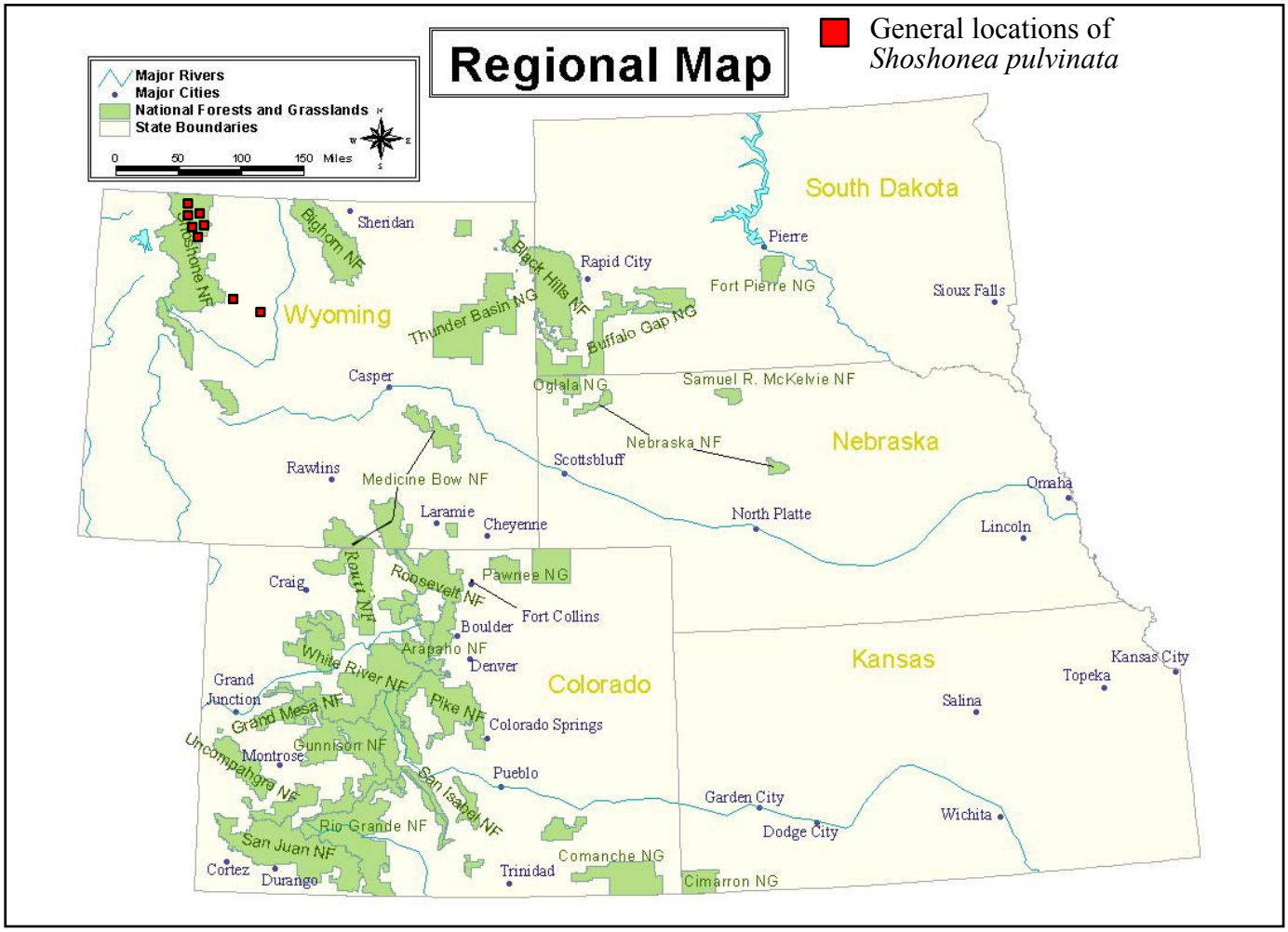

Figure 1. Occurrences of *Shoshonea pulvinata* relative to USDA Forest Service Region 2 boundaries.

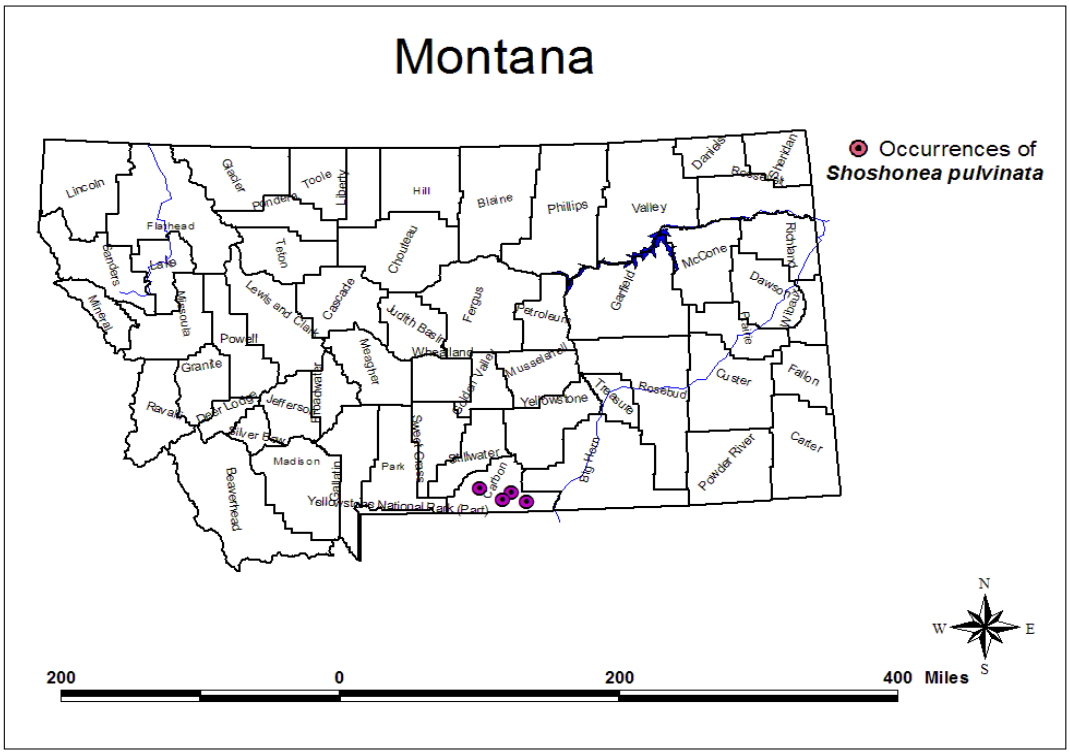

Figure 2. Locations of *Shoshonea pulvinata* in Montana (Montana Natural Heritage Program 2002).

In 2002, Heidel et al. (2002) reported that population trends appeared to be stable and that there were no direct threats to *S. pulvinata* habitat.

A 1991 report prepared for the Shoshone National Forest proposed *Shoshonea pulvinata* and a suite of calceophilic plant species for protection in the Bald Ridge Special Botanical Area (SBA) under the Special Interest Areas policy of the USFS (Jones 1991). Jones recommended that, if the SBA designation was approved, the designation should be changed in the future to a Research Natural Area (RNA) if or when the Bureau of Land Management created an Area of Critical Environmental Concern (ACEC) on adjacent lands. The two agencies could then coordinate management activities. To date, a proposal to create the SBA or an ACEC on Bald Ridge has not been submitted to the Cody Field Office (Blymer personal communication 2003). A second biological report, prepared by Fertig and Bynum (1994) for the Shoshone National Forest, addressed the objectives of establishing an RNA on Bald Ridge. Along with *Pinus flexilis* (limber pine) woodlands, *Pseudotsuga menziesii* (Douglas-fir) and *Picea engelmannii* (Engelmann spruce) forests, and *Agropyron spicata* (bluebunch wheatgrass) community types, the report specifically identified the presence of *S. pulvinata* and other calcifers as part of the justification for the proposed RNA (Fertig and Bynum 1994). An RNA has also been proposed for Pat O'Hara Mountain to include extensive subalpine *P. engelmannii* forests, other herbaceous vegetation types, and occurrences of rare plants, including *S. pulvinata*. Shoshone National Forest personnel will evaluate these proposed RNAs when they revise their forest plan (Houston personal communication 2003).

The Cody and Worland field offices of the Wyoming BLM have developed no formal management plans for any *Shoshonea pulvinata* occurrences on their lands. However, policies for sensitive species protection require that, prior to initiating any activities in areas where there are known rare plants or suitable habitat, the BLM botanist conduct pre-project surveys for rare plant species. Subsequently, a report with conservation recommendations is forwarded to the field office director (Carroll personal communication 2003). The *S. pulvinata* occurrence that is within lands managed by the Worland Field Office is located in the Grass Creek Planning Area. This occurrence is located on lands open to oil and gas leasing, but there are currently no active leases there. Travel is limited to designated roads and trails and is limited seasonally (Hepp personal communication 2003). Grazing of livestock is allowed from June 15 to November 15. Although grazing is allowed in the Grass Creek Planning Area, occurrences of *S. pulvinata* are believed to be adequately protected by the rugged habitat in which they occur, as well as the low palatability of the species to livestock (Elliott personal communication 2005). *Shoshonea pulvinata* habitat is restricted to limestone outcrops, shallow calcareous soils, ridgetops, and talus slopes, and as a result, sites inhabited by *S. pulvinata* typically receive little livestock use due to limited available forage and water (Fertig 1995, Welp et al 2000).

Occurrences known from private lands and from lands of The Nature Conservancy and the Wind River Indian Reservation have no management plans in place at this time. Outside Region 2 in Montana, the Lost Water Canyon RNA was created in the Custer National Forest in 1994. The objectives for this RNA specify that it provide a protected site for long-term monitoring of *Shoshonea pulvinata* (USDA Forest Service 1994). The Montana State office of the BLM created an ACEC on lands adjacent to the RNA.

Biology and Ecology

Classification and description

Systematics and synonymy

Shoshonea pulvinata is a member of the Apiaceae (Umbelliferae; parsley or carrot) family (**Figure 3**). It is a species in a monotypic genus (a genus containing only one species). The name *Shoshonea* refers to the Shoshone River of northwestern Wyoming (Evert and Constance 1982). The specific epithet, *pulvinata*, refers to its cushion-plant habit. *Shoshonea pulvinata* was first described by Erwin F. Evert and Lincoln Constance (Evert and Constance 1982). The species' unique suite of characters, including its pulvinate habit, lignified pericarp, dimorphic flowers (perfect and staminate), vestigial carpophores, and unwinged fruit ribs, separate it from its nearest allies in the Apioideae, including members of the genera *Oreoxis*, *Musineon*, *Neoparrya*, and *Aletes*. The following key excerpt from Evert and Constance (1982) demonstrates the taxonomic separation of *Shoshonea* from other related genera:

Essentially, the plant key distinguishes *Shoshonea* from the other genera based on flower type and the presence of lignin in the tissue that forms the outer layer of the fruit. In *Shoshonea*, two flower types, perfect and staminate, are found within the umbellets, which are single umbellate clusters that form the compound umbel inflorescence. The perfect flowers of *S. pulvinata* include both male and female reproductive parts

Umbellets with sharply distinct sessile perfect flowers and pedicellate staminate flowers; fruit pericarp with a continuous lignified tissue layer. . . . . *Shoshonea*

Umbellets with all perfect flowers, or with some poorly distinguished staminate flowers also; fruit pericarp unlignified or only the ribs with lignified tissue.

Caudex clothed with conspicuous persistent leaf bases; fruits broadest at commissure.

Rays spreading to ascending, none reflexed; vittae confined to intervals and commissure.

Fruit pericarp conspicuously thick and corky, the ribs obtuse and usually +/- winged; carpophore lacking or, if present, vittae several in intervals and on commissure…….. *Oreoxis*

Fruit pericarp thin, the ribs acute and sometimes subequally thin-winged, or undeveloped; carpophore present; vittae solitary in intervals, or if more than one, an accessory vittae in the apex of each rib. . . . .. *Aletes*

Rays spreading and reflexed; vittae scattered throughout pericarp… *Neoparrya*

Caudex without conspicuous persistent leaf bases; fruits constricted at commissure ……. . . *Musineon*

Figure 3. Line drawing of *Shoshonea pulvinata* showing important diagnostic characters (Wyoming Rare Plant Field Guide 2002). The illustration in the Wyoming Rare Plant Field Guide is reprinted from Evert and Constance (1982).

and lack pedicels. The staminate flowers have only male reproductive parts, and these flowers are borne on pedicels. The other genera have either all perfect flowers, or if staminate flowers are present, they are extremely inconspicuous. The fruit pericarp tissue in *Shoshonea* contains a continuous layer of lignin, a complex compound containing phenol rings. The other genera have no lignin, or the lignin is restricted to the ribs of the fruit.

Dorn (1988), in the taxonomic notes of *Vascular Plants of Wyoming*, wrote that *Shoshonea pulvinata* was "probably better treated in a slightly expanded concept of *Musineon* but such a change should await experimental studies." At the time of this writing, no experimental studies that would affect taxonomy have been conducted.

History of species

Evert discovered the undescribed (at that time) species during floristic studies in 1979 in the North Fork Shoshone River drainage in northwestern Wyoming (Park County) (Evert and Constance 1982). *Shoshonea pulvinata* was found on the west slope of Rattlesnake Mountain, from the south side of Pat O'Hara Mountain south along the Palisades to the south end of Rattlesnake Mountain. The Rocky Mountain Herbarium (2003) at the University of Wyoming has the holotype for *S. pulvinata* (E.F. Evert 3424). Isotypes reside in collections at the Missouri Botanical Garden, St. Louis (MO), the New York Botanical Garden, New York City (NY), and the University of California, Berkeley (UC) (Evert and Constance 1982). Evert and Constance published the species description in Systematic Botany (1982). Subsequent botanical surveys by Evert, Ronald Hartman, Robert Lichvar, and Keith Deuholm located additional occurrences in Park County, Wyoming (Shelly 1988).

WYNDD records provide a history of the subsequent discoveries of Wyoming occurrences. Evert, in May 1980, observed individuals in flower on the north and east rims of Sheep Mountain (Castle Rock Creek USGS Quad). Also in May 1980, an occurrence was located in the Absaroka Range on the summit, north rim, and southwest slopes of Logan Mountain (Castle Rock Creek and Logan Mountain USGS Quads), about 13 miles west of Cody. Another occurrence was discovered near the top of Cedar Mountain, in the Absaroka Range, about 5.5 miles west-southwest of Cody. In July 1981, an occurrence was discovered on the summit and slopes on the west and southwest side of the west cone of Heart Mountain, about 20 miles north of Cody, and another occurrence was located on the south and southwest side of Heart Mountain. Robert Lichvar located *Shoshonea pulvinata* in 1982 on Stagner Mountain in the Owl Creek Mountains (Morrison Canyon USGS Quad) on the Wind River Indian Reservation. In May 1988, an occurrence was located on Bald Ridge, from Bald Peak south to the headwater draws of Newmeyer Creek, about 23 miles northwest of Cody (Bald Peak USGS Quad). In June 1991, *S. pulvinata* was found on the rim crest north of the South Fork of Owl Creek in the Owl Creek Mountains (Eagles Nest Ranch USGS Quad).

According to Shelly (1988), John Pierce found the first Montana location of *Shoshonea pulvinata* in 1984 in Lost Water Canyon in the Pryor Mountains (Carbon County). Shelly reported that Peter Lesica located *S. pulvinata* in the Beartooth Mountains of Carbon County in 1985. In 1986, Shelly and Lesica searched for *S. pulvinata* in other areas of the Pryors and Beartooths while working for the MNHP (Shelly 1988). During 1983 Lichvar and others also conducted a floristic survey of the Big Horn Canyon National Recreation Area, including the eastern portion of the Pryor Mountains, but found no occurrences (Shelly 1988).

In July 1987, the MNHP conducted a status survey for *Shoshonea pulvinata* in Montana under contract with the U.S. Fish and Wildlife Service. This status survey included additional surveys on potential habitat in the Beartooth and Pryor mountains (Dorn 1989). A third occurrence in the Pryor Mountains (Mystery Cave) was discovered. The Crow Tribal Council refused access to their lands, where there may be additional sites of *S. pulvinata* (Shelly 1988).

Non-technical description

Shoshonea pulvinata is a low, cushion-like perennial herb that forms dense green mats (**Figure 3** and **Figure 4**). According to the element occurrence records of the WYNDD, the individual plants are 2 to 8 cm tall and up to 45 cm across (Wyoming Natural Diversity Database 2003a). The leaves are rough to the touch, "scaberulous to subscaberulous" (Evert and Constance 1982), and pleasantly aromatic. The leaves are 2 to 25 mm long and divided into two to five pairs of leaflets (once-pinnately compound). They are somewhat leathery and thick and bright green. The leaf bases are swollen and papery (Wyoming Natural Diversity Database 2003a). The flowers are either bisexual (perfect) or male (staminate), yellow, and arranged in flat, umbrella-shaped heads of one to five stalkless (sessile) perfect (male and female parts) flowers and

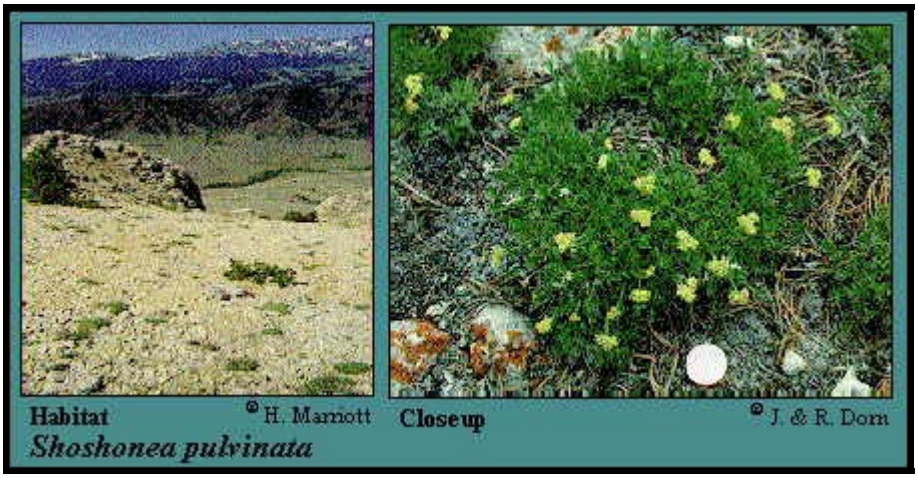

Figure 4. Habitat and close-up of *Shoshonea pulvinata* (Wyoming Rare Plant Guide 2002).

two to six pedicellate (stalked) staminate flowers, the pedicels up to 4 mm long (Evert and Constance 1982). There are five sepals that are prominent, ovate-lanceolate, and about 1 to 1.5 mm long. The stamens are about 2 mm long; the styles are spreading and slender (1 to 1.5 mm long). Fruits are 2 to 4 mm long and 1.5 to 3 mm wide, slightly rough to the touch, ribbed but without wings, and sessile (without a stalk). The woody taproot has underground branches that carry leaf bases from previous years (Evert and Constance 1982).

Local field characters: *Shoshonea pulvinata* grows in open habitats and its dense mat-forming nature, shiny green scaberulous foliage, and woody taproot and caudices distinguish it from other species of Apiaceae in the area. In open spaces, Shelly (1988) suggests that it might be confused with *Astragalus kentrophyta* (spiny milkvetch; Fabaceae), which is often in similar habitats and does co-occur with *S. pulvinata*. *Shoshonea pulvinata* also could be confused with species of *Cymopterus* with which it co-occurs (e.g. *C. hendersonii* [Henderson's wavewing] or *C. terebinthinus* [turpentine wavewing]). However, *Cymopterus* species are generally more erect and have leaves that are either bipinnate (twice divided) or tripinnate (three times divided) rather than simply pinnate (Shelly 1988).

Refer to **Figure 3** for an excellent line drawing of *Shoshonea pulvinata* reproduced in the Wyoming Rare Plant Guide from Evert and Constance (1982). Photographs of both habitat and habit can be found on the WYNDD and the MNHP Web sites and are provided in **Figure 4**.

Distribution and abundance

The range of *Shoshonea pulvinata* extends from Carbon County, Montana to the Absarokas in Park County, Wyoming. There is a gap in the distribution as far as the Owl Creek Mountains in Fremont and Hot Springs counties to the south. **Table 1** presents occurrence data on estimated size and number of individuals, elevation, and ownership. Dorn (1989) estimated the total number of plants in Wyoming at about 210,000. Shelly (1988) estimated that about 12,000 plants were reported in Montana in the late 1980s and noted that it is one of the dominant species where it grows.

Population trend

The population trend of *Shoshonea pulvinata* throughout its range is generally thought to be one of stability (Fertig and Mills 2000) although there are no population trend data for Wyoming. Occurrences of *S. pulvinata* in Wyoming and Montana have been surveyed and evaluated periodically (Heidel et al. 2002, Montana Natural Heritage Program 2003, Wyoming Natural Diversity Database). Formal long-term monitoring studies have not been initiated for Wyoming occurrences, but a monitoring study in Montana provides some insight into population trends. Lesica and Achuff (1991) developed a monitoring program that has continued with Heidel (2001) for the Grove Creek and Mystery Cave (divided into Mystery Cave Ridge and Mystery Cave Road colonies) occurrences in the Pryor Mountains. Data were collected every year

Table 1. Summary of *Shoshones pulvinata* occurrences, abundance, and habitat information.

Arbitrary occurrence number	USGS quadrangle; county, state	Land owner/ management	Habitat/elevation (ft.)	Abundance or estimated number of individuals	First / last date observed	Source	Herbarium reference information[1]
1	Castle Rock Creek quad; Park County, WY	Bureau of Land Management	Limestone outcrops on rims with widely scattered small limber pines. 6,600 to 7,200	None given (6 subgroups)	May 21, 1980/ June 9, 1996	Dorn 1989, Evert and Constance 1982, Shelly 1988, Rosenthal 1998, WYNDD 2003b	Evert, E.F. (1772, 2113) 1980 (paratypes); (3118) 1981 (paratype). Hartman, R.L. (54451, 54477) 1996.
2	Morrison Canyon quad; Wind River Indian Reservation, Fremont County, WY	Wind River Indian Reservation	Limestone chip rock with *Pinus flexilis* and *Erigeron* spp. 7,500	Not available (NA)	July 26, 1982	Dorn 1989, Shelly 1988, WYNDD 2003b	Lichvar, R.W. (5382) 1982 (RM, CWC).
3	Dead Indian Meadows, Jim Mountain, Logan Mountain, Shoshone Canyon quads; Park County, WY	Shoshone National Forest and Bureau of Land Management	Crevices and exposures of limestone bedrock and open talus slopes and rocky knolls with small pockets of exposed limestone gravel surrounded by dense stands of *Festuca idahoensis* and *F. hallii*. 6,800 to 9,200	Locally dominant	August 5, 1979/ June 16, 1996	Marriott 1988, Dorn 1989, Shelly 1988, Rosenthal 1998, Jones & Fertig 1999, Fertig 1998, WYNDD 2003b	Martin, D.L. (1432) 1980. Evert, E.F. (1577) 1979, (1918) 1980 (RM, UTC); (2778) 1981; (3424) 1981; (16793, 17151) 1989. Hartman, R.L. (13924) 1981; (24399) 1989; (54910) 1996. Lavin, M. (4422) 1983. Fertig, W. (15364) 1994. Bayer, R.G. Bilodeau, and Lebedyk, D. (WY-846) 1998.
4	Bald Peak quad; Park County, WY	Shoshone National Forest and Bureau of Land Management	Cushion plant communities on scattered limestone outcrops and reddish clay-limestone gravels in *Festuca idahoensis-Elymus spicatus-Potentilla fruticosa* grasslands and on coarse limestone soils with scattered *Pinus flexilis* on west-facing slopes and rims. 7,400 to 8,633	>10,000	May 30, 1988/ July 15, 1996	Marriott 1988, Jones 1991, Dorn 1989, Fertig 1997, Shelly 1988, WYNDD 2003b	Nelson, B.E. (12506) 1985 (RM, CWC). Dorn, R.D. (5007, 5009) 1989. Bynum, M. (567) 1994 (SNF). Fertig, W. (16856) 1996.
5	Castle Rock Creek, Logan Mountain quads; Park County, WY	Shoshone National Forest and Bureau of Land Management	Cushion plant communities on limestone bedrock outcrops, cliffs, and talus slopes with scattered *Pseudotsuga menziesii*, *Pinus flexilis*, and *Juniperus scopulorum*. Vegetative cover very low. 5,800 to 8,000	Locally dominant, ~5,000	May 20, 1980/ August 11, 1995	Evert and Constance 1982, Dorn 1989, Fertig 1994, Shelly 1988, WYNDD 2003b	Evert, E.F. (1761, 1946, 2067) 1980 (RM, UC); (3279) 1981(RM, UC); (10623). Fertig, W. (15321, 15327) 1994.

Table 1 (cont.).

Arbitrary occurrence number	USGS quadrangle; county, state	Land owner/ management	Habitat/elevation (ft.)	Abundance or estimated number of individuals	First / last date observed	Source	Herbarium reference information[1]
6	Eaglenest Basin, Goff Lake quads; Park County, WY	The Nature Conservancy and private	The stabilized talus slopes have a cushion plant/bunchgrass community of *Shoshonea pulvinata*, *Leucopoa kingii*, and *Poa secunda* amid scattered *Pinus flexilis*. Rock cover may be as high as 60 to 70 percent. Stabilized talus slopes of yellowish, white, or reddish limey-sandstone with dolomite boulders and gravel. 7,300 to 8,000	5,000 to 8,000 mats (mats 6-10 inches across)	July 1, 1981/ June 30, 1997	Fertig 1997, Dorn 1989, Evert and Constance 1982, Shelly 1988, WYNDD 2003b	Evert, E.F. (3334) 1981. Hartman, R.L. (13500) 1981. Fertig, W. and K. Lenard (17638) 1997.
7	Irma Flats quad; Park County, WY	Bureau of Land Management	*Pinus flexilis* and *Pseudotsuga menziesii* dominate the ledges, crevices, and outcrops with cushion community of *Shoshonea pulvinata* and other plants including *Koeleria macrantha*, *Astragalus kentrophyta*, and *Telesonix heucheriformis*. Limestone ledges and crevices and dolomite outcrops. 6,800 to 7,600	NA; 3 subpopulations mapped	May 29, 1980/ Summer 1989	Dorn 1989, Evert and Constance 1982, Shelly 1988, WYNDD 2003b	Evert, E.F. (3394) 1981 (RM, COLO). Hartman, R.L. and Dueholm, K. (11418, 11431) 1980 (RM, COLO, CS, UC).
8	Eagle Nest Ranch quad; Hot Springs County, WY	Bureau of Land Management	Sparsely vegetated low cushion plant community on open ridge crest and gentle slopes on rocky limestone soil. Rocky limestone soil. 9,200 to 9,300	500 to 1,000	June 21, 1991/ July 8, 1992	Marriott 1992, Fertig 1992, WYNDD 2003b	Marriott, H. (11350) 1991. Fertig, W. (12939) 1992.
9	Tolman Flat quad; Carbon County, MT	Private	Windblown ridgetops with scattered *Pinus flexilis* and *Pseudotsuga menziesii*. Gravelly limestone. 7,140	6,000 to 8,000; dominant ground cover	July 24, 1991	MNHP 2002	Lesica, P. (3417) 1985 (MONTU).
10	Lost Water Canyon quad; Carbon County, MT	Custer National Forest and Bureau of Land Management	On edges or in openings of *Pinus flexilis-Pseudotsuga menziesii* forests; west-facing rims above canyons. Stony, limestone soils. 7,677 to 7,800	2,900	July 10, 1987	MNHP 2002	Lesica, P. (4386, 4388, 4389) 1987 (MONTU). Pierce, J. 1984 (MONTU).

Table 1 (concluded).

Arbitrary occurrence number	USGS quadrangle; county, state	Land owner/ management	Habitat/elevation (ft.)	Abundance or estimated number of individuals	First / last date observed	Source	Herbarium reference information[1]
11	Mystery Cave quad; Carbon County, MT	Bureau of Land Management	On edges of *Pinus flexilis-Pseudotsuga menziesii* forests; gentle northwest-facing slopes. Gravelly limestone-derived soils. 7,480	1,000	1987/ August 14, 1995	MNHP 2002	Lesica, P. (4391, 4394) 1987 (MONTU).
12	Inferno Canyon quad; Carbon County, MT	Custer National Forest	Dry, partially shaded residual mountain ridge. Shallow stony soil from limestone parent material. 6,440 to 6,760	NA	June 11, 1995	MNHP 2002	Lesica, P. (6726) 1995 (MONTU).

[1] [1]Herbarium specimens are housed at the Rocky Mountain Herbarium, located in Laramie, Wyoming, unless otherwise noted.

COLO = University of Colorado Herbarium , Boulder, CO.

CS = Colorado State University Herbarium, Ft. Collins, CO.

CWC = Central Wyoming College Herbarium, Riverton, WY.

UC = University of California Herbarium, Berkeley, CA.

UTC = Utah State Intermountain Herbarium, Logan, UT.

from 1991 to 1993, and again in 1999. Occurrences appeared to be stable in the 1991 to 1993 surveys (Lesica 1993), and Heidel concluded after the 1999 monitoring season that the occurrences did not fluctuate significantly between any of the monitoring periods (Heidel 2001). She noted that one occurrence, Mystery Cave Ridge, declined from 1991 to 1992, but remained stable after that time. She also noted that although the occurrences remained stable, environmental conditions had fluctuated greatly from 1991 to 1999. Because *S. pulvinata* is a slow growing, long-lived perennial, it is not possible to determine long-term trends from short-term monitoring.

Habitat

Evert and Constance (1982) refer to *Shoshonea pulvinata* as a "calciphilous umbellifer", a plant in the parsley family that loves limestone soils. They describe the location of the type specimen as "exposed limestone-derived soil, talus, and crevices." *Shoshonea pulvinata* is apparently restricted to Madison limestone bedrock, outcrops, and limestone-derived gravels and soils. Not all exposures of limestone in south-central Montana and northwestern Wyoming that have been surveyed support occurrences of *S. pulvinata*, and not all limestone areas have been surveyed (e.g., the Crow Indian Reservation).

Wyoming occurrences of *Shoshonea pulvinata* are restricted to shallow, stony, calcareous soils associated with exposed limestone bedrock outcrops on ridge tops and talus slopes. Sites are open, exposed, and windswept with sparse vegetation, at elevations between 5,800 and 9,200 feet. The dominant associated tree species are *Pinus flexilis* and *Pseudotsuga menziesii*. The element occurrence records from the WYNDD (2003b) show that other species often associated with *S. pulvinata* include *Eritrichium howardii*, (Howard's alpine forget-me-not), *Arenaria hookeri* (Hooker's sandwort), *Astragalus kentrophyta* (spiny milkvetch), *Castilleja nivea* (snow Indian paintbrush), *Oxytropis viscida* (viscid locoweed), and *Senecio canus* (woolly groundsel). **Table 1** provides habitat summary data for occurrences of *Shoshonea pulvinata* across its range.

The four Montana occurrences of *Shoshonea pulvinata* vary in elevation from 6,440 to 7,800 feet. The low elevation occurrence is described as a "dry, partially shaded, residual mountain ridge" (Montana Natural Heritage Program 2002). *Pinus flexilis* shades the site somewhat. The other three sites occur on the edges or openings in *Pinus flexilis-Pseudotsuga menziesii* forests. Two of these sites are on west to northwest-facing rim slopes that are wind-exposed. The fourth occurrence, composed of three large subgroups (3,000 to 4,000 plants in the southern subgroup), is suffering pine mortality of about 10 percent, so that shading is reduced (Montana Natural Heritage Program 2002). Shelly (1988) reports the following associated species in Montana occurrences: *Potentilla fruticosa* (shrubby cinquefoil), *Petrophyton caespitosum* (mat rockspirea), *Erigeron ochroleucus* (buff fleabane), *Astragalus aretioides* (cushion milkvetch), *A. miser* (timber milkvetch), *Haplopappus acaulis* (stemless mock goldenweed), *Carex rupestris* (curly sedge), *Leucopoa kingii* (spike fescue), *Draba oligosperma* (fewseed draba), *E. compositus* (cutleaf daisy), *Potentilla diversifolia* (varileaf cinquefoil), *Phlox hoodii* (spiny phlox), *Antennaria aromatica* (scented pussytoes), and *Pulsatilla patens* (cutleaf anemone).

Reproductive biology and autecology

Shoshonea pulvinata is a long-lived, slow-growing perennial that appears to be stress-tolerant since it grows in shallow, stony calcareous soils of exposed, windswept limestone outcrops. Dorn (1989) considers it a pioneer species of these exposed talus slopes and ridgetops where the vegetation is sparse and is dominated mostly by other cushion plant species. Because the sites are blasted by winds that are strong enough to move soil during summer and snow during winter, these sites stay in an early successional phase.

Gadgil and Solbrig (1972) adapted the concepts regarding r- and K-selected animal species of MacArthur and Wilson (1967) to plants. They described r-strategy plant species as those adapted to rapid colonization of pioneer habitats in contrast to K-strategy plants that are adapted to maintaining stable population densities in stable subclimax or climax plant communities. Typically an r-selected plant is an annual plant that grows rapidly, flowers once a few weeks after germination, and then dies. It produces large numbers of small, easily dispersed seeds and does not reproduce vegetatively. In contrast, K-strategy plants grow slowly from seed and only flower after a few years. A seed may grow into a large individual plant and flower annually for many years. The adult may produce large numbers of sprouts or ramets from the roots (Richards 1986). *Shoshonea pulvinata* appears to have the profile of a K-selected plant for many of its traits, yet it also appears to be one of a few pioneers of the exposed limestone outcrop habitats where it grows in Montana and Wyoming.

Houston (personal communication 2003) and Heidel (personal communication 2003) noted that construction of a fire line on the Shoshone National Forest for the Bald Ridge fire in 1991 that scraped away six inches of topsoil bisected *Shoshonea pulvinata* habitat, removing aboveground portions of individual plants. The fire itself impacted both the crown and understory of the *Pinus flexilis* habitat. Houston (personal communication 2003) suggested that recovery of *S. pulvinata* occurred through sprouting from existing roots deep in the soil. Heidel (personal communication 2003) noted that the fire may have had effects that stimulated germination of seeds in the seedbank. Fire ecology studies for other plant species have demonstrated that some species recover through a variety of mechanisms such as germination of seeds that have accumulated in the seed bank if their numbers are sufficient (Odion and Tyler 2002) or sprouting from lignotubers (Keeley 1977). More research is needed to determine whether or not *S. pulvinata* can withstand and possibly benefit from fire. This information has important implications for future conservation strategies and plans.

Flowering occurs from the end of May through early July, depending upon location (**Table 2**) and weather conditions (Wyoming Natural Diversity Database 2003b). Fruiting begins in late June and continues through August. As the lifecycle diagram in **Figure 5** suggests, there is no known information about seed soil bank longevity, germination requirements, or percentage of seed viability after dispersal. The processes or vectors of seed dispersal are also unknown.

Shoshonea pulvinata produces both bisexual and staminate flowers on the same individual, a breeding system that is called andromonoecy. An individual *S. pulvinata* plant produces one to five perfect flowers and two to six staminate flowers per umbellet (Evert and Constance 1982).

Breeding systems are important for determining the genetic structure of populations and the patterns of gene flow between populations. Andromonoecy may influence how much within-flower selfing, outcrossing, and geitonomy occurs (Primack and Lloyd 1980, Richards 1986). Schlessman (1982) studied the life history and morphological traits of tuberous lomatiums, a group of closely related species in the Apiaceae family, and found that andromonoecy allowed for both outcrossing and selfing. He suggested that this strategy allows for seed production in isolated populations if there is no opportunity for out-crossing. It is not known whether or not *Shoshonea pulvinata* is self-compatible.

Very little is known about how the andromonoecious breeding system affects reproductive success in wild populations. Research studies on plant species that express andromonoecy have resulted in a number of unexpected findings. Miller (2003) observed that "the relative production of hermaphroditic and staminate flowers is phenotypically plastic and changes depending upon the environment, whereas in other species the sexual phenotype is apparently fixed." Diggle (1993, 1994) showed that the developmental history of a plant, which reflects both the internal and external environments to which it is exposed, and the position of a flower on a plant affect the phenotypic

Table 2. Phenology and fruiting times for *Shoshonea pulvinata* occurrences in Wyoming.

Arbitrary occurrence number and location	Flowering	Date	Fruiting	Time period
1. Absaroka Range, North Fork Shoshone River	No	Not applicable (NA)	Yes	July
2. Wind River Indian Reservation	No	NA	Yes	July 26
3. Absaroka Range, Rattlesnake Mountain; Shoshone National Forest/BLM	Yes	June	Yes	Late June to August
4. East Absaroka Range, Bald Ridge; Shoshone National Forest/BLM	Yes	Late June to early July	No	NA
5. Absaroka Range, Logan Mountains; Shoshone National Forest/BLM	No	NA	Yes	Late June to August
6. Absaroka Range, Heart Mountain; TNC and private	Yes	Late June	Yes	Late June to July
7. Absaroka Range, Cedar Mountain; BLM	Yes	Late May	Yes	August
8. Owl Creek Mountains; BLM	Yes	June	No	NA

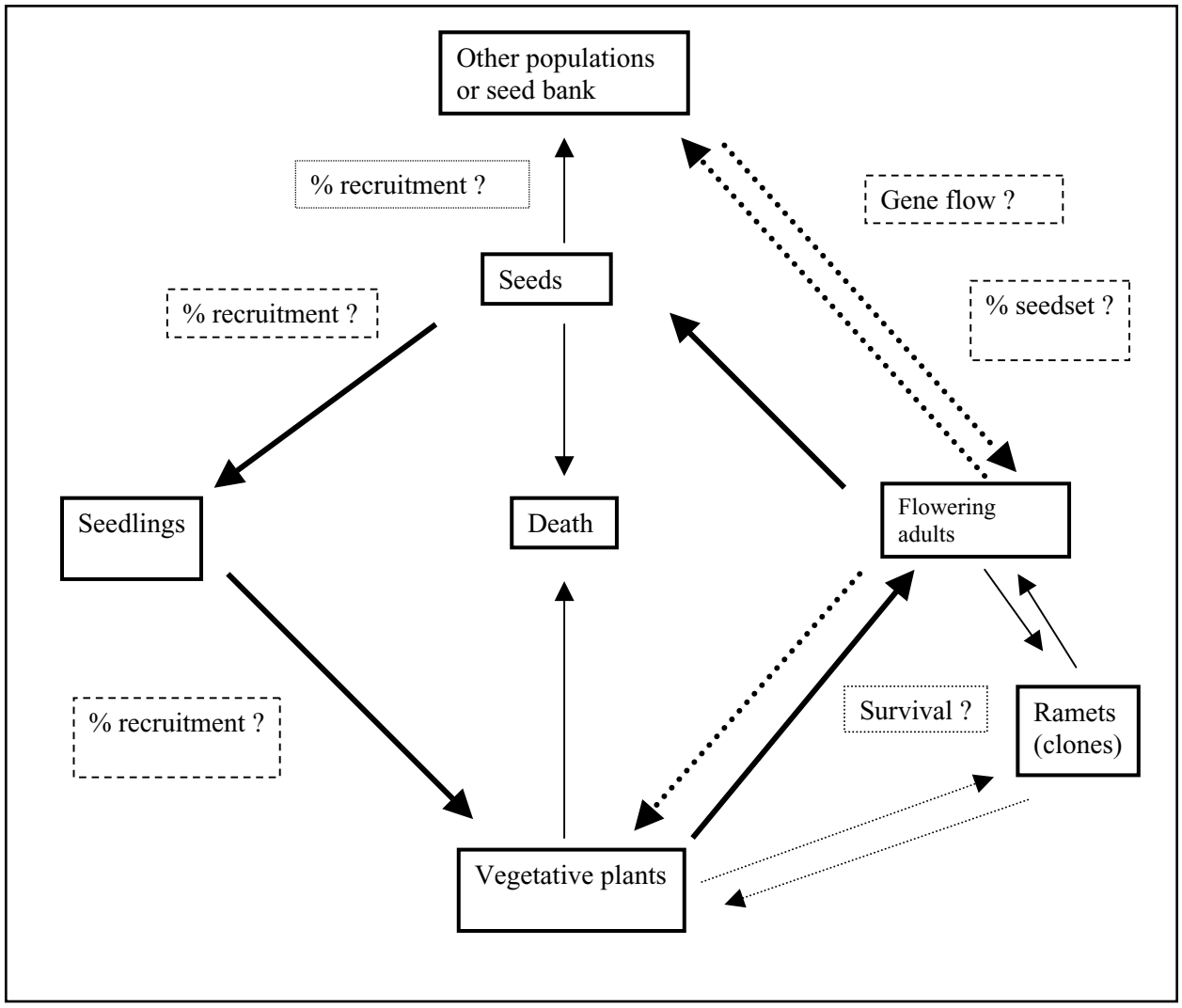

Figure 5. Lifecycle diagram for *Shoshonea pulvinata*.

expression of a flower. In *Solanum hirtum*, plants responded to environmental factors by initiating floral bud primordia (male or hermaphroditic) three years before they would flower (Diggle 1994). It is not known if *Shoshonea pulvinata*'s production of a current year's proportion of hermaphrodite and male flowers is a product of the environment that occurred as much as three years before, but that is possible.

Environmental impacts may affect the breeding system in other ways as well. Chamberlain and Hubert (2001) studied the andromonoecious tree species, *Calliandra calothyrsis*, in various environmental conditions in the tropics. The trees produced both staminate flowers with fully functional pollen and healthy bisexual, although self-incompatible, flowers. As soon as bisexual flowers began to develop pods along the lower part of an inflorescence, there was an increase in the proportion of staminate flowers toward the apex. The researchers concluded that the plant might be responding to limited resources by producing additional pollen that would ensure production of outcrossed seed (Chamberlain and Hubert 2001). The implications of these experiments for *Shoshonea pulvinata* are that resources such as nutrients, light, and water available to individual plants may limit the production of hermaphroditic flowers, and therefore limit the number of fruits and seeds; however, no studies have examined these influences for *S. pulvinata*.

The chromosome number in *Shoshonea pulvinata* is n = 22 (Evert and Constance 1982). There have been no studies on the genetic diversity within and among the 12 known occurrences. While the number of occurrences is extremely small, the number of individuals within occurrences can be quite large (e.g.,

5,000 to 8,000 mats, each mat about 6 inches across) on the west slope of Heart Mountain (Wyoming Natural Diversity Database 2003b). With such large numbers of individual plants, within-population genetic variability could be relatively high. Conversely, gene flow among populations may be quite low. Genetic studies are needed to develop useful conservation plans that will conserve the genetic health of the species.

Demography

The lifecycle diagram (**Figure 5**) for *Shoshonea pulvinata* illustrates the significant processes that influence the demography of the occurrences. The diagram represents typical assumptions for a perennial species, with bold lines indicating the basic life cycle and dashed lines illustrating places of uncertainty. The lack of investigation and information about life history traits is striking. For example, gene flow between and among occurrences, longevity of seeds in the seed bank, percentage seed set, and percent survival are all unknown factors. Vegetative or clonal reproduction is suspected, but no detailed information is available. Vegetative reproduction could be a major contributor to the number of individuals in a population. Digging up plants and looking for underground connections could determine whether vegetative reproduction occurs in *S. pulvinata*, but this would be destructive to individuals.

What we know about reproductive biology and demography comes mainly from the monitoring studies initiated by Lesica and Achuff (1991) and continued by Lesica (1992, 1993) and Heidel (2001). Refer to **Table 3** for descriptions of the monitoring sites. The monitoring strategy was set up to detect changes in the numbers of individuals in an occurrence (Lesica and Achuff 1991). Individuals were tracked between years to determine growth rates, fecundity, recruitment, and mortality (Heidel 2001). One hundred and sixty-one individuals in three sites (three transects) were tracked from 1991 to 1993, and then monitored again in 1999.

The results in **Table 4** show that plants at the three locations differ greatly in the total number of inflorescences and the mean number of inflorescences per plant. There were no seedlings detected at the Mystery Cave Ridge site during any of the monitoring years despite the high number of inflorescences per plant. Low seed set, predation, high rates of fruit abortion, or production of mostly staminate flowers are factors that might account for the lack of seedlings (Heidel 2001). The transects were read for just three years, so samples are small, especially for a long-lived plant species. It may be that conditions were not suitable for seedling survival during the years when these occurrences were tracked. Successful seed germination and seedling survival in *Shoshonea pulvinata* may require a precise combination of environmental conditions that occur infrequently.

In **Table 4**, reproductive rate is the number of plants producing inflorescences per number of mature plants. Mortality rate is the number of dead plants in year t per number of plants in year t-1. Recruitment rate is the number of new plants in year t per number of plants in year t-1. Mature plants are those over 16 cm^2 that Lesica (1992) considers potentially capable of reproduction.

Plant size changes were also monitored from 1991 to 1993, and in 1999. The surface area of plants increased or decreased from 0 to 12 cm during this period. The largest plants experienced the most growth while the smallest plants in 1991 were generally the same size in 1999. The largest plant in 1991 had a diameter of 488 cm and grew 80 cm over the nine years from 1991 to 1999, suggesting that, if this growth rate were constant in the past, the plant would be more than 50 years old (Heidel 2001). While the total surface area at Grove Creek remained fairly constant and the total surface area Mystery Cave Ridge increased slightly, the area of the plants in the Mystery Cave Road transect declined slightly. Heidel (2001) suggests that this decline could be due to shading effects.

Table 3. Locations of *Shoshonea pulvinata* monitoring transects in the Pryor Mountains, Carbon County, Montana (Heidel 2001).

Transect	Aspect	Slope (estimated percent)	Tree canopy cover (estimated percent)	Description
Grove Creek	northwest	5	5	Very open limber pine woodland, on limestone pavement
Mystery Cave Ridge	southwest	1	1	Exposed rim outcrop adjoining forest, on limestone pavement
Mystery Cave Road	west	1	35	Open Douglas-fir forest, on limestone covered by soil duff

Table 4. Summary statistics for *Shoshonea pulvinata* at three monitoring sites in 1991-1993 and 1999. (Lesica 1992, Heidel 2001).

	Grove Creek				Mystery Cave Ridge				Mystery Cave Road			
	1991	**1992**	**1993**	**1999**	**1991**	**1992**	**1993**	**1999**	**1991**	**1992**	**1993**	**1999**
Total Established Plants	57	68	66	67	32	23	22	19	50	47	47	45
Mature Plants	28	26	29	33	31	19	19	16	44	38	38	41
Reproductive Plants	16	11	15	29	21	12	16	14	30	14	30	26
Reproductive Rate	57%	42%	52%	87%	71%	65%	84%	87%	68%	37%	79%	51%
Seedlings	—	—	—	13	—	—	—	—	—	—	—	11
Mortality	—	3	7	4	—	10	2	3	—	4	1	4
Mortality Rate	—	5%	10%	6%	—	30%	9%	14%	—	8%	2%	9%
Recruitment	—	14	5	5	—	1	1	0	—	1	1	2
Recruitment Rate	—	25%	7%	8%	—	3%	4%	0%	—	2%	2%	4%

The study also analyzed mortality values with regard to annual precipitation levels and found that mortality rates were highest for the Grove Creek and Mystery Cave Ridge occurrences in 1992 even though precipitation levels were at or above the mean as recorded at the Lovell, Wyoming weather station. Heidel noted further that at the Mystery Cave Ridge site, mortality affected flowering and non-flowering plants in the size range from 4 to 28 cm. Although the habitat did not vary across the site, mortality was concentrated in half of the transect, indicating a localized mortality factor (Heidel 2001). Plants experienced 100 percent mortality in two adjacent quadrat sampling frames. No cause for the mortality was detected (Heidel 2001).

Recruitment and flower production rates are not understood. The Grove Creek occurrence had the highest recruitment rate, but a relatively low mean number of flowers per inflorescence in the years 1991 to 1993, suggesting that something about this occurrence may promote seed germination and seedling production. The proportion of hermaphroditic and male flowers may play a significant role. Heidel (2001) points out that the Grove Creek occurrence also has the highest number of smaller plants, suggesting a younger age structure. Further study of pollination mechanisms, production of male and hermaphroditic flowers, and seed set rates could determine the reasons for the differing recruitment rates among occurrences. Diggle (1994), who studied the morphology and development of *Solanum hirtum*, suggests that plants initiate floral buds as much as three years prior to blooming and that precipitation in preceding years may be an important factor related to future reproductive success. *Shoshonea pulvinata* may be subject to similar constraints that relate past precipitation to flowering in subsequent years.

Heidel (2001) believes that the critical life history transition may be different for each of the three occurrences. Seed germination may be the critical life history transition at Mystery Cave Ridge, seedling recruitment may be the critical life history transition at Mystery Cave Road, and fecundity (number of seeds produced per year) may be the critical life history transition for the Grove Creek occurrence.

Heidel (2001) noted the episodic nature of some key life history transitions. For example, the numbers of plants in the Grove Creek and Mystery Cave Road occurrences have been relatively stable since the initiation of monitoring in 1991. The Mystery Cave Ridge occurrence, however, underwent a decline in the total number of established plants between 1991 and 1992, and then stabilized. Also, mortality and recruitment were low at all three sites, except for 1992, when the Grove Creek occurrence had a recruitment rate of 25 percent while the other two occurrences had recruitment rates of 3 percent (Mystery Cave Ridge) and 2 percent (Mystery Cave Road) in 1992. Mortality was high at Mystery Cave Ridge (30 percent) in 1992. Heidel (2001) reported that the mortality was localized, but no cause was evident. In contrast to between-year events, mortality and recruitment were generally fairly low for the entire nine-year interval (1991-1999) compared to the episodic bouts just noted. These data suggest that the occurrences act in a manner that is consistent with expectations for long-lived perennial cushion plants (Heidel 2001).

Community ecology

The habitat of *Shoshonea pulvinata* is relatively remote and inaccessible, leaving most occurrences

undisturbed save for occasional recreational hikers and botanists. The limestone cliffs and limestone-derived soils of the wind-swept ridges and talus slopes support plant communities that are usually dominated by scattered *Pinus flexilis* and *Pseudotsuga menziesii* and by calcareous cliff and talus specialists such as *Aquilegia jonesii* (Jones' columbine), *Kelseya uniflora* (oneflower kelseya), and *Carex rupestris*. *Festuca idahoensis* (Idaho fescue), *F. hallii* (Hall's fescue), *Leucopoa kingii*, and *Koeleria macrantha* (prairie junegrass) are common associates (**Table 1**). Community ecology factors, including interspecific and intraspecific competition, predation and parasitism, disease, mutualistic interactions, and allelopathic or toxic interactions are largely unknown for *S. pulvinata*. The species is limited to mid- to high elevation, exposed habitats with a calcareous substrate. Plants of *S. pulvinata* grow in open sites and appear to respond negatively to shade (Montana Natural Heritage Program 2002).

The envirogram is a graphic representation of the environmental components that affect the condition of a species and influence its growth, reproduction, and survival (Andrewartha and Birch 1984). Very little information about the community ecology of *Shoshonea pulvinata* is known. Therefore, the envirogram shown in **Figure 6** and **Figure 7** is largely speculative. Bold-line boxes indicate factors where some evidence exists while dashed-line boxes indicate that the factors are speculative. The environmental resources that directly affect *S. pulvinata* comprise the centrum, and the indirect impacts comprise the web.

The centrum includes the two components that directly impact the species: resources and malentities. Resources represent positive impacts and include soil water, calcareous soil, nutrients, photosynthetically active radiation, temperature, pollinators, and seed dispersers. These resources are the result of web factors such as climate, geography, topography, and geology. Intermediate strands of the web include rainfall and snowpack, erosion rates, and vegetative decomposition that will provide nutrients for plant growth.

Malentities represent negative influences and include competition from other plant species; disease; predators such as insects, birds, and rodents; invasion of exotic plant species; human interference through activities such as fire and fire-line construction, mining, grazing, and recreation. The Heart Mountain occurrence, for example, has a hiking trail through the west slope occurrence that is harming plant mats. The fire on Bald Ridge in 1991 and the fire-line constructed to contain it passed through a part of the *Shoshonea pulvinata* occurrence, but the effects may not have been permanently negative (Houston personal communication 2003). Houston believes that resprouting occurred after the construction of a fire-line, suggesting that *S. pulvinata* can recover from some stresses. Heidel (2001) observed a plant rust on plants of *S. pulvinata* in the Pryor Mountains occurrence, but nothing is known about its impact on plant vigor. There are active grazing allotments in Wyoming that include known *Shoshonea pulvinata* occurrences (Houston pers comm. 2003). However, the species is located in terrain that is generally too rugged for grazing impacts as there is limited available forage and water for livestock (Fertig 1995, Welp et al 2000). Some of the plant occurrences in Montana are within the territory used by wild horses, but impacts from wild horses on these occurrences have not been formally studied.

Pollinators

Plant pollinators are unknown, but Dorn (1989) observed flies in the Syrphidae family on *Shoshonea pulvinata* flowers. Pollinator studies carried out on another group of species in the Apiaceae that shares the andromonoecious breeding system with *S. pulvinata*, and that is adapted to a similar climatic regime, offer some useful insight into the types of studies that could be undertaken with *S. pulvinata*. Schlessman (1982) studied tuberous lomatiums (Apiaceae), an andromonoecious sagebrush steppe plant group that occurs from central California through eastern Oregon, east to Montana and south to Arizona. The members of this group are adapted to a short, early spring growing season followed by long summer drought. The plants are visited by tachinid flies, syrphid flies, muscid flies, bee flies, and solitary bees. These insects are most active at mid-day, and they all carried pollen of the tuberous lomatium species (Schlessman 1982).

Competitors

There has been no formal study of the interspecific relationships of *Shoshonea pulvinata*. The exposed sites where *S. pulvinata* occurs are continuously disturbed by strong winds, shifting soils, and wasting slopes. Individual mats of *S. pulvinata* are separated by patches of limestone outcrop or loose limey gravels and soils. Such severe conditions probably exclude many potential plant competitors; however, there are other cespitose species, such as *Eritrichium howardii*, that grow intermingled with *S. pulvinata*.

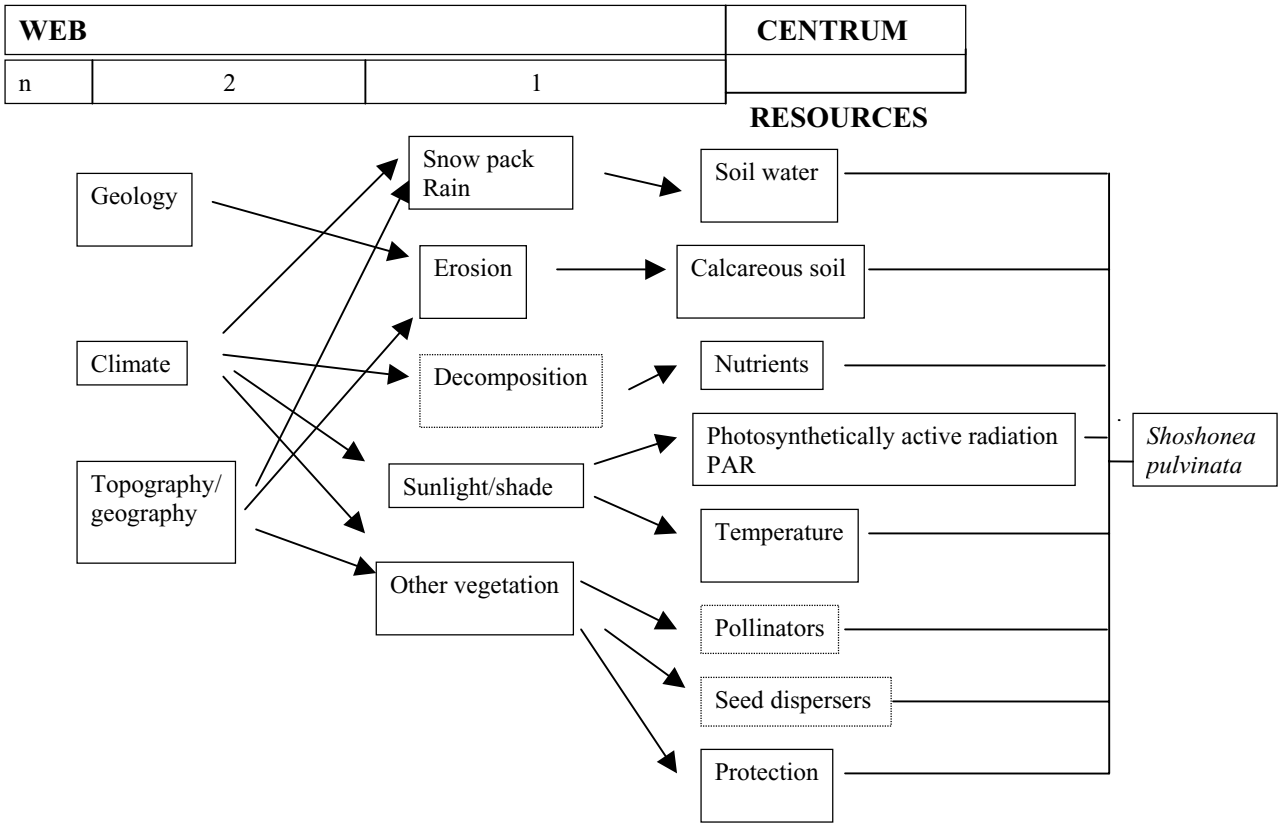

Figure 6. Envirogram of the resources of *Shoshonea pulvinata*.

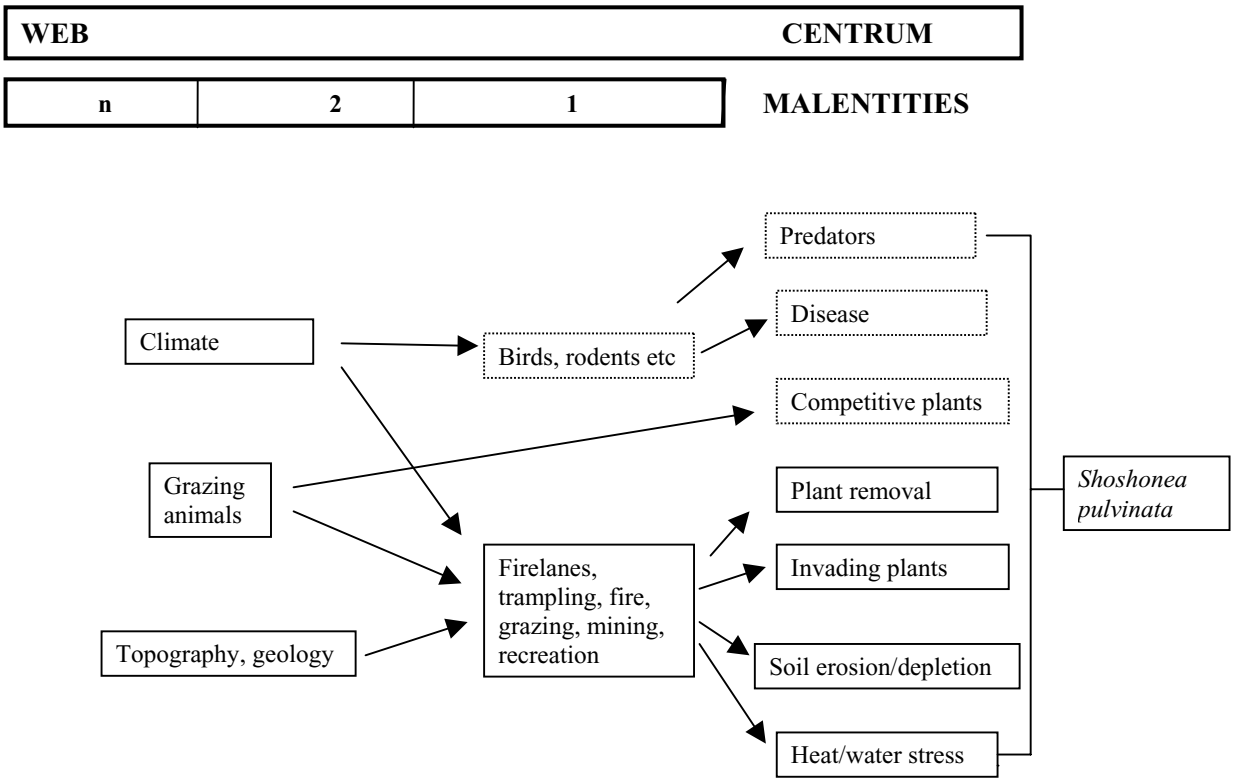

Figure 7. Envirogram of the malentities of *Shoshonea pulvinata*.

Herbivory, parasites, disease, and mycorrhizal associations

During monitoring of three occurrences of *Shoshonea pulvinata* in Montana, Heidel (2001) observed a plant rust on some leaves in one occurrence, but nothing is known about its effects on plant vigor. Heidel (2001) did not observe any signs of herbivory in any of the three occurrences in 1999. Herbivorous impacts from grazing horses have not been documented (Lesica 1992, Reid personal communication 2003). Evidence of mycorrhizal associations within the root system has not been documented. *Shoshonea pulvinata* is an aromatic plant in the family Apiaceae (carrot or parsley family), in which many species are known to contain varying levels of plant toxins, including alkaloids and coumarins. Although the chemical components of *S. pulvinata* have never been analyzed, the plants are aromatic, and it is possible that the aromatic chemicals deter herbivory.

CONSERVATION

Threats

Regional catastrophic events and global climate change are probably the most likely threats to the persistence of *Shoshonea pulvinata* over its range. Over the last century, average temperatures in Laramie, Wyoming have increased 1.5 degrees Fahrenheit (U.S. Environmental Protection Agency 1998). Using models based on the Intergovernmental Panel on Climate Change and UK Hadley Center models for greenhouse gases and aerosols, the U.S. Environmental Protection Agency predicted that by 2100, temperatures in Wyoming could increase by 4 degrees Fahrenheit in spring and fall, 5 degrees Fahrenheit in summer, and 6 degrees Fahrenheit in winter. Precipitation could decrease slightly in summer and increase 10 percent in spring and winter. The result of more hot days in summer and more rainfall and less snowfall in winter could be higher evaporation and lower streamflows, and earlier, more rapid snowmelt in winter. These changes in turn could impact nutrient cycling, plant reproductive patterns, and a host of other ecosystem factors. Currently, there are no known incidences of rangewide impacts to *S. pulvinata* from regional or global climate changes. The climate change issue is complex, and there is little certainty about what specific changes will take place in the future. As far as we know, *S. pulvinata* has very few populations, and these populations occur in isolated habitats where gene flow may be quite low. It is suspected that alpine plants and other plants, like *S. pulvinata*, with discontinuous habitat may have difficulty adjusting to new ecological conditions resulting from the effects of global warming. Their very fundamental reproductive processes, such as flowering and seed production, may be altered with changing environmental conditions. No specific information about global climate change effects in *S. pulvinata* habitat was found in the literature. Large changes in amount and seasonality of precipitation are possible outcomes. An international group of scientists recently has initiated a project to investigate the long-term effects of global climate change on alpine plants and their habitats. This project, the Global Observation Research Initiative in Alpine Environments (GLORIA Project 2004), will provide information of the type that is needed to improve our understanding of the potential responses of *S. pulvinata* to global climate change.

A number of resource-use activities have occurred in the past and will continue to occur at the locations of the three occurrences of *Shoshonea pulvinata* that are found on Shoshone National Forest and adjacent BLM lands, and the three occurrences that are managed solely by BLM in Wyoming. Similar activities occur in Montana on USFS Region 1 and BLM lands. Livestock grazing is permitted on both USFS and BLM lands (Houston personal communication 2003, Blymer personal communication 2003). A 1995 report prepared for the Shoshone National Forest Supervisor's Office in Cody, Wyoming found that the grazing intensity in *S. pulvinata* habitat in the Rattlesnake and Logan mountains was minimal because the species is found on limestone outcrops, shallow calcareous soils, ridgetops, and talus slopes. The report gave *S. pulvinata* a low vulnerability rating because of "its rugged habitat, adaptations to disturbance, and low palatability" (Fertig 1995). Blymer (personal communication 2003) noted that elk are present on at least one BLM occurrence, but the impacts from grazing by elk are not known. In Montana, two occurrences are found on the Pryor Mountain Wild Horse Range. Herbivorous impacts from grazing horses or trampling have not been documented (Lesica 1992, Reid personal communication 2003).

There are no specific regulations against oil and gas leasing or mineral development on either USFS Region 2 or BLM lands because of the presence of *Shoshonea pulvinata*. No mining presently occurs in any of the areas occupied by *S. pulvinata*, and there are no current applications for permits in these areas, probably because of the relative inaccessibility of the sites. The current market for limestone may be saturated by nearby sources of high-quality material from the Pryor Mountains in Montana that are close to the railhead at Warren. Because of the multiple-use

nature of USFS lands, activities associated with mining and/or oil and gas activities could occur in the future. Any significant soil disturbance in habitats occupied by *S. pulvinata* could threaten its persistence. Specific No Surface Occupancy (NSO) restrictions on BLM lands are discussed below.

The *Pinus flexilis* and *Pseudotsuga menziesii* that are associated with *Shoshonea pulvinata* occupy rugged limestone outcrops and talus slopes. Therefore, these areas provide a poor source for large quantities of marketable timber and cannot support large-scale logging operations. There are no active timber sales in *S. pulvinata* habitat on either BLM or USFS Region 2 lands (Blymer personal communication 2003, Houston personal communication 2003). Because of the scattered nature of the *Pinus flexilis* stands, proposals for forest-thinning projects are unlikely within *S. pulvinata* occurrences. However, fuel reduction programs have been conducted (e.g., Pat O'Hara Mountain in 2001 and Bald Ridge in 2003) at lower elevations on the same mountains where *S. pulvinata* occurs.

In the future it is possible that horticultural enthusiasts may seek out this perennial species for decorative landscape purposes, but no information about efforts to cultivate it was found. In the event that *Shoshonea pulvinata* is sought after by horticulturalists, occurrences would be vulnerable to damage from large-scale collection efforts. At this time, however, there are no known threats posed by horticultural collectors in any part of the taxon's range

On a rangewide basis, the harsh abiotic factors associated with *Shoshonea pulvinata* habitat are probably not conducive to invasions of most current exotic plant species even though abundant open sites are available for colonization. Although the habitat of *S. pulvinata* is a stressful one, it is possible that in the future, exotic plant species adapted to early seral successional environments could colonize the open, exposed sites where *S. pulvinata* occurs. Because of increased fire management activities (e.g., Bald Ridge), and more frequent foot, mountain bicycle, and vehicle traffic, more vectors for distribution of exotic species exist now than in the past. To date, there is no evidence that exotic plant species have encroached on *S. pulvinata* occurrences to form competitive interactions. Neither WYNDD nor MNHP element occurrence records have documented the presence of exotic species within *S. pulvinata* occurrences.

Off-road vehicle (ORV) and mountain biking travel have been increasing in many areas of lands managed by the USFS and the BLM. Even though *Shoshonea pulvinata* occurrences occupy habitats in rough country, rangewide disturbance could occur in the future. Proliferation of unsanctioned ORV trails, bike trails, or roads across *S. pulvinata* habitat could disrupt root systems, compact soils, alter soil water regimes, and introduce exotic weed seeds into the habitat of *S. pulvinata*. While there are no reported impacts of these types to occurrences of *S. pulvinata* in Region 2 at this time, ORV users and mountain bikers continually look for more challenging terrain, and they may in the future discover the limestone outcrops and ridges of *S. pulvinata* habitat. The Bald Ridge fire-line, for example, may encourage ORV users and mountain bikers.

Occurrences of *Shoshonea pulvinata* are remote from any major sources of air pollution. The nearest major city with substantial air pollution is Billings, Montana. Forest fires in recent years probably have produced more air pollution than any of the regional industrial centers. Air pollution is thus probably a low priority threat.

Threats to single populations

The primary threats to single occurrences of *Shoshonea pulvinata* come from activities associated with natural disturbances such as wild fires and localized drought, and human-related disturbances such as roads, ORV activity, livestock grazing, exotic species invasion, subdivision development, mountain bike activity, recreational hiking, and resource development. Some types of natural disturbances are an integral part of the habitat dynamics affecting *S. pulvinata*. Strong winds sweep over the exposed ridges, moving snow in winter and soil particles in summer. According to Dorn (1989), frequent episodes of these natural disturbances prevent the habitat from moving to successively later seral stages. While *S. pulvinata* has apparently adapted to the rhythm and intensity of these natural disturbances, it is unlikely that it will persist as well if exposed to extraordinary or prolonged impacts.

Occurrences of *Shoshonea pulvinata* on the Shoshone National Forest are found in remote locations far from roads and development activity. However, in 1991 an occurrence on Bald Ridge was disturbed by wildfire and the construction of a fire-line (**Figure 8**). The placement of the fire-line within the *S. pulvinata* occurrence apparently resulted from a lack of communication between the resources group and the fire management team. No distribution maps of *S. pulvinata* were provided to the fire management team, who responded quickly to the wildfire by dispatching

heavy equipment and workers with hand tools to construct the fire-line. A recent site visit found that individual plants are still present on the site among burned trees, in the fire-line, and on unburned sites (Heidel personal communication 2003). Plants within the fire-line persisted either through sprouting from the woody root crown or by means of germination of seeds in the seed bank of the topsoil, the topsoil having been replaced after the fire (Heidel personal communication 2003, Houston personal communication 2003). No quantitative pre- and post-fire data are available to assess the impact of fire.

On BLM lands, threats from recreational activities are limited because much of the *Shoshonea pulvinata* habitat is surrounded by private ranches at lower elevations and access to public lands is limited (Blymer personal communication 2003). The Cody BLM Field Office manages land on Cedar Mountain, where an occurrence of *S. pulvinata* is found near the summit. The access road is currently closed by a locked gate at the entrance to private inholdings on the lower slope of the mountain so access is limited to administrative use only. No Surface Disturbance Occupancy (NSO) restrictions apply to 120 surface acres surrounding the entrance to Spirit Mountain Cave on Cedar Mountain. BLM wildlife biologist Dennis Seville noted that some types of surface disturbance restriction apply to areas where *S. pulvinata* occurs even though the restrictions were not specifically designed to protect sensitive plant habitat. These restrictions are part of the Cody Resource Management Plan (Seville personal communication 2003).

An occurrence on private land on the west side of Heart Mountain is located on a large land parcel that is under development planning. Hiking and horseback trails leading to the west summit of the mountain may be incorporated in development plans. If such trails are built, the occurrence of *Shoshonea pulvinata* on Heart Mountain may become vulnerable to trampling impacts from horses and people. The Nature Conservancy's Heart Mountain Reserve is being developed as a center for natural history education. The Nature Conservancy is also improving the trail to the east summit of Heart Mountain. In past years the number of hikers that climbed to the summit was relatively low. Despite the low hiker numbers, the limestone substrate has been visibly loosened and disturbed near the summit, and individual plants within the occurrence have been damaged. The Nature Conservancy is considering ways to reroute the trail to prevent further harm to individual *S. pulvinata* plants, and to forestall invasions of exotic plant species (Bell personal communication 2003).

The occurrence on the Wind River Indian Reservation was surveyed once in 1982. Botanists have not been permitted to revisit that occurrence so there is no current information about its status.

Figure 8. *Shoshonea pulvinata* within the Bald Ridge fire-line (photograph by Kent Houston, USDA Forest Service Ecologist, Shoshone National Forest).

The occurrences in Montana are found in USFS Region 1 on the Custer National Forest and on BLM lands (**Table 1**). The Lost Water Canyon occurrence is within the boundaries of an RNA, and *Shoshonea pulvinata* is identified as one of the management goals of the RNA. In Montana, ORV use is on the rise and in the future may impact some occurrences there (e.g., Pryor Mountains). Other threats to occurrences in Montana include grazing of sheep and wild horses, and development for mining, oil, and gas.

Conservation Status of Species in Region 2

In USFS Region 2 *Shoshonea pulvinata* grows on land managed by the USFS, the BLM, the Wind River Indian Reservation, The Nature Conservancy, and private individuals. Three of the 12 *S. pulvinata* occurrences are on the Shoshone National Forest and adjacent BLM lands. The Shoshone National Forest has responded to the need to ensure the persistence of *S. pulvinata* occurrences by funding several studies that focus on conservation issues with regard to *S. pulvinata*. These include surveys of known occurrences (Marriott 1988, Fertig 1998, Welp et al. 2000), surveys for potential habitat (Rosenthal 1999), evaluation of the impact of grazing on sensitive species including *S. pulvinata* (Fertig 1995), and assessment of the Bald Ridge and Pat O'Hara Mountain areas for potential RNAs that could provide long-term monitoring study sites for calciferous species including *S. pulvinata*. The Shoshone National Forest will consider the RNA proposals during the upcoming process of revising its forest plan (Houston personal communication 2003).

During the most recent surveys of Shoshone National Forest, occurrences appear to be present and stable (Welp et al. 2000). However, it is clear that the occurrences are not invulnerable to impacts, as shown by the Bald Ridge fire in the Shoshone National Forest, or to potential impacts from activities such as water development. Unfortunately, the lack of data on the genetic variability of these occurrences, and their specific allelic composition compared to other *Shoshonea pulvinata* occurrences, makes it difficult to evaluate the impacts to population genetic composition from a conservation biology perspective. Also, so little is known about the life history traits of *S. pulvinata* that managers cannot predict how individual plants of *S. pulvinata* would respond or recover from disturbance.

Other occurrences could become threatened if management activities (including fire management, development of livestock watering systems, expansion of recreational activities, or development of mining and oil and gas resources) increase in intensity, type, or frequency.

Five occurrences of *Shoshonea pulvinata* are located on BLM lands administered by the Cody Field Office, and one occurrence is located on lands managed by the Worland Field Office. BLM action plans are tiered to a resource management plan, which, in turn, was developed based on the National Environmental Policy Act requirements. The relevant resource management plan in this case is the Cody Resource Management Plan (Bureau of Land Management 1990). Any proposed actions out of the Cody and Worland field offices are subject to pre-project surveys for sensitive plant species. The threatened and endangered species specialist forwards conservation recommendations to the field office for final decisions. One of the potential weaknesses of this approach is that field biologists may understand the level of fragility and sensitivity of rare plant occurrences, but they may not be successful in conveying that message to office managers who must synthesize a variety of data during the decision-making process.

Three occurrences of *Shoshonea pulvinata* are found in areas where the BLM and the Shoshone National Forest manage adjacent land parcels. How much management coordination occurs between the two agencies with regard to *S. pulvinata* conservation is difficult to determine. Some published reports indicate there have been some proposals for shared management. For example, a report (Jones 1991) to the USFS recommended the creation of a SBA on USFS lands at Bald Ridge to protect sensitive calciferous species, including *S. pulvinata*. The report also made a recommendation to change the status of the SBA to an RNA in the future if the BLM designated its adjacent lands as an ACEC. However, a proposal to create the SBA or an ACEC on Bald Ridge was never submitted to the Cody Field Office (Blymer personal communication 2003).

Management of the Species in Region 2

Implications and potential conservation elements

Shoshonea pulvinata is a regional endemic imperiled due to its low number of occurrences and its highly restricted nature. Its rarity is not due to past destruction or modification of habitat, so recovery plans are unnecessary.

While monitoring of occurrences is vitally important for assessing the status of occurrences, including determining whether or not the occurrences are declining, it does not add to our knowledge of the life history traits or community ecology factors relevant to *Shoshonea pulvinata*. Designation of one or more occurrences within RNAs that include conservation of the species as a management goal would encourage research and special studies that would enhance the ability of managers to develop appropriate conservation plans. Karron's (1991) survey of genetic variation in rare plant species shows that geographically restricted species are often, but not always, genetically less diverse than widespread congeners, even if the populations of geographically restricted species are large. At this point the genetic variability within and among *S. pulvinata* occurrences is unknown. Without this information it is impossible to develop recommendations regarding the numbers of individuals and occurrences that would sustain the species in the future. Levels of genetic variability within and between occurrences will suggest whether or not there is a need to develop an *ex situ* genetic seed bank for *S. pulvinata* to forestall the possibility of extinction.

Tools and practices

Species inventory

Compared to many plant species, there has been a considerable amount of interest and attention given to survey for *Shoshonea pulvinata*. However, systematic surveys of potential habitat within Region 2 would be extremely useful. Spatial descriptions of the distribution of occurrences have been documented using terminology such as "mats" and "colonies". It would be helpful to develop a formal methodology for describing the size and geographic distribution of occurrences so that there is consistency in data collection.

Most occurrences of *Shoshonea pulvinata* have been surveyed at least once since the first documented visit (**Table 1** and **Table 5**). Generally, subsequent botanists discovered other colonies and subcolonies, in addition to those recorded during the first site visit. There is no evidence or documentation of a decline in numbers of individuals or numbers of occurrences. However, life stages are important indicators of occurrence persistence. Heidel (2001) reported that seed germination and seedling establishment appear to be critical phases in the life cycle of *S. pulvinata*. Future surveys need to collect these important recruitment data on a regular basis.

Site-specific inventories are part of a federal agency's assessment process. The National Environmental Policy Act requires that every significant federal project, including timber sales, range allotment management, development of mining claims, and construction of pipelines or powerlines, be assessed relative to potential environmental consequences. The USFS provides employees who work in the field with the *Wyoming Rare Plant Field Guide* (Fertig et al. 1994) to assist them in identifying rare plants within a project boundary. Both USFS botanists and contract botanists use this resource and other pertinent floras during field surveys.

Habitat inventory

The element occurrence records (WYNDD 2003b) generally provide detailed descriptions of habitat and associated species. Unfortunately, there is little information about specific potential habitat that has been surveyed but found to be unoccupied by *Shoshonea pulvinata*. Surveys of potential habitat are needed to improve our knowledge of *S. pulvinata*'s distribution and abundance throughout its range.

Population monitoring

Population monitoring occurs and data are collected on an irregular basis when WYNDD botanists or others survey an occurrence and complete and submit an element occurrence form to the WYNDD. **Table 1** shows the dates of the most recent data submissions for *Shoshonea pulvinata* occurrences. Information about occurrence size, including area occupied and

Table 5. USDA Forest Service Region 2 occurrences of *Shoshonea pulvinata* with date of first and most recent botanical survey, and number of site visits (WYNDD 2003b).

Shoshone National Forest occurrence location	Date of first visit	Date of most recent visit	Total number of site visits
Rattlesnake Mountain – west slope	1979	1996	10
Bald Ridge – Eastern Absaroka Range	1988	1996	4
Logan Mountain - Absaroka Range	1980	1995	6

number of individuals, is documented. Long-term monitoring studies for three Montana colonies of *S. pulvinata* indicate that data on seed germination and seedling establishment would contribute valuable information about the potential long-term persistence of occurrences (Heidel 2001). Establishment of a long-term monitoring program of the Shoshone National Forest occurrences would contribute valuable information about the lifecycle factors contributing to occurrence sustainability.

Population or habitat management approaches

The past land uses of *Shoshonea pulvinata* habitat have been minimal. Until relatively recently, *S. pulvinata* occurrences remained undisturbed, or affected by occasional grazing, as described previously. However, prolonged regional drought in recent years has resulted in dry forest conditions that led to the Bald Ridge fire in 1991 and associated disturbances (**Figure 8**). Restoring species health to the Bald Ridge occurrence should include focusing on understanding the impacts of soil disturbance to the condition of the soil seed bank and the fate of injured plants. Monitoring would allow documentation of recovery or the lack of recovery from this natural disturbance and associated USFS activities.

Current management plans and practices in USFS Region 2 are guided by the agency's policy directing that sensitive plant species not be impacted by management activities such that decline leading to listing as threatened or endangered by the U.S. Fish and Wildlife Service would result. However, management options may not always preclude impacts to the occurrences, particularly if field surveys for biological evaluations are not completed. Because there are only 12 known occurrences of *Shoshonea pulvinata* throughout its range, the loss of any one occurrence would be significant. Management approaches that avoid impacts to *S. pulvinata* occurrences, and that provide opportunities for biological and ecological studies that will aid in restoration, are vital if the occurrences of this rare plant species are to remain healthy and sustainable.

Today it is relatively easy to use Geographic Information System/Global Positioning Satellite mapping techniques to produce map layers of the boundaries of the USFS Region 2 *Shoshonea pulvinata* occurrences. This information can be used by fire and other resource managers to develop action plans that avoid impacts.

Information Needs

Continuing field surveys of potential habitat throughout the range of *Shoshonea pulvinata*, including on USFS Region 2 lands, are needed to locate all occurrences and to document potential habitat where *S. pulvinata* is absent. This information is vital to discovering more precisely the specific habitat requirements of *S. pulvinata*.

Much more needs to be known about the response of *Shoshonea pulvinata* to disturbance. Because it is a slow-growing and long-lived perennial, impacts to any occurrence might have serious and permanent consequences. Even though management strategies currently place a priority on avoiding impacts from management actions or developments, there are times when this may not be possible. If such impacts are unavoidable, efforts must be made to ensure that the actions do not cause a downward trend in occurrence numbers or area. Much can be learned by initiating post-fire and post-activity monitoring that compares demographic factors such as seed germination, seedling establishment, and re-sprouting in impacted versus undisturbed sites. The *S. pulvinata* occurrence at Bald Ridge provides an excellent place for monitoring studies that look at *S. pulvinata*'s response to impacts from heavy equipment, trampling, hand tools, litter and topsoil removal, canopy changes, and wild fire. No studies have formally determined the mechanisms of recolonization. Similarly, the effects of fire suppression on *S. pulvinata* and its associated habitat remain unknown. No information is known about how fire on adjacent habitats in proximity to *S. pulvinata* occurrences might impact the species. Informal observations after the Bald Ridge fire suggest that perhaps fire or its indirect impacts may enhance post-fire growth and reproduction of *S. pulvinata* at certain levels of intensity. If so, what are the mechanisms that stimulate plant growth of *S. pulvinata*?

Studies that monitor occurrences after an impact event and studies that include long-term monitoring of undisturbed sites will help to clarify population dynamics and points of vulnerability in *Shoshonea pulvinata*'s life history (**Figure 5**). Formal long-term monitoring studies could provide critical information for future management decisions. Although somewhat limited in scope, the Montana study documents seedling germination and establishment, and growth in area of individual plants in three occurrences. Changes in these factors from one monitoring period to the next allow calculation of growth, mortality, and recruitment rates.

However, there are still critical lifecycle components that need study. For example, seed production and seed germination rates are not known. The Montana study documented flower production, but it did not distinguish between production of male flowers and hermaphroditic flowers (Heidel 2001). Because the flowers of *S. pulvinata* are small and numerous, a study of this type would be feasible as part of an academic research project that focuses on the breeding system. The gene flow arrows of the lifecycle diagram are composed of dashed lines because the mechanisms for gene flow among occurrences are not understood. At present, even genetic variability within and among occurrences is not known, and so it is not possible to assess the level of genetic diversity that may buffer the occurrences from environmental disturbance.

Currently there is no information available about the pollination ecology of this species. It is unknown what, if anything, pollinates *Shoshonea pulvinata*. Consequently, nothing is known about the mechanisms of gene flow within and among occurrences. Furthermore, while we know that occurrences of *S. pulvinata* have been subject to wildfires and drought, there is no information about how these impacts have affected either individuals of *S. pulvinata* or other species that interact with *S. pulvinata*.

Heidel (2001) noted that recruitment efforts varied among the occurrences that she monitored in the Pryor Mountains. An understanding of these variations may result from examining the andromonoecious breeding system to see how the production of male and hermaphroditic flowers varies among occurrences and over time. Environmental conditions such as temperature and rainfall regimes may affect the quantity and type of flower production. Other studies of andromonoecious species indicate that environmental conditions such as sunlight, nutrients, water availability, and temperature affect the numbers of male and hermaphroditic flowers, and this in turn determines the level of fruit production (Chamberlain and Hubert 2001).

It is also important to answer other questions that relate to the breeding system. For example, is *Shoshonea pulvinata* self-compatible or obligately outcrossing? Is the pollen of both perfect and male flowers fully functional? What is the timing of stigma receptivity for perfect flowers and pollen maturation within plants for both types of flowers? Is production of male flowers influenced by resource limitations? Development of management strategies that protect not only the species but those resources that contribute to its ecological health depend on an understanding of its reproductive ecology.

Studies on seed longevity in the seed bank and seed germination and storage requirements will provide useful information for restoration purposes and for evaluating the effectiveness of including *Shoshonea pulvinata* in an *ex situ* seed conservation collection such as that of the Center for Plant Conservation (1991).

Development of appropriate management strategies does not depend on finding answers to all of these questions immediately. However, anything that is learned about the ecology and genetics of this rare, endemic plant species will contribute to more effective management decisions relative to supporting this species' viability.

Definitions

Andromonoecy — breeding system that produces both bisexual and male flowers on the same plant.

Carpophore — an extension of the floral axis between adjacent carpels, as in the fruit of the Apiaceae.

Caudex — a largely underground stem base that persists from year to year and each season produces leaves and flowering stems of short duration.

Commissure — the surface along which two or more locules are joined to each other.

Congener — belonging to the same genus.

Dimorphic — the condition of having two distinct forms.

Gene flow — exchange of genetic traits between populations by movement of individuals, gametes, or spores.

Hermaphroditic flower — contains both male and female sex organs = perfect.

Holotype — the original specimen designated by the author as typical of the taxon.

Isotype — any specimen other than the holotype that duplicates the holotype. The isotype must come from the same collection, with the same locality, date, and number as the holotype.

Lignin — a plant polymer that is one of the most important constituents of the secondary cell wall.

Monotypic genus — a genus composed of a single species.

Pedicel — the stalk of a single flower within an inflorescence.

Pericarp — the fruit wall, which develops from the mature ovary wall.

Pulvinate — cushion-like habit.

Scaberulous — slightly rough to the touch.

Scabrous — rough to the touch with minute rough projections.

Sessile — without a stalk.

Umbel — An inflorescence with the pedicels of the flowers arising from approximately the same point.

Umbellet — A secondary umbel within a compound umbel.

Vittae — Oil tubes in the carpel walls of the fruits of members of the Apiaceae.

Ranking System used by Natural Heritage Programs, Natural Diversity Databases, and NatureServe.

Global imperilment (G) ranks are based on the rangewide status of a plant species. State (S) imperilment ranks are based on the status of a species in an individual state.

G1/S1	Critically imperiled globally/state because of rarity (5 or fewer occurrences in its range/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.
G2/S2	Imperiled globally/state because of rarity (6-20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G3/S3	Vulnerable throughout its range or found locally restricted (21 to 100 occurrences).
G4/S4	Apparently secure globally/state, though it might be quite rare in parts of its range, especially at the periphery.
G5/S5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GX	Presumed extinct.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but not verified for an extended period, usually.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.

Notes: where two numbers appear in a G or S rank (e.g. S2S3), the exact status of the element is uncertain.

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