Penstemon caryi Pennell (Cary's beardtongue): A Technical Conservation Assessment

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

June 1, 2004

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Peer Review Administered by
Center for Plant Conservation

Heidel, B. and J. Handley. (2004, June 1). *Penstemon caryi* Pennell (Cary's beardtongue): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/penstemoncaryi.pdf [date of access].

ACKNOWLEDGEMENTS

The *Penstemon caryi* status survey completed by Walter Fertig (2002) is central to this assessment. He provided the initial review and comments on this assessment, and he and Robert Thurston produced the potential distribution model for *P. caryi* and provided it for use in this assessment (Fertig and Thurston 2003. Modeling the Potential Distribution of BLM Sensitive and USFWS Threatened and Endangered Plant Species in Wyoming (http://uwadmnweb.uwyo.edu/WYNDD/Reports/pdf_fertig/FinalReport_03BLMmodeling.pdf). Report prepared for the Bureau of Land Management – Wyoming State Office by WYNDD – University of Wyoming, Laramie,WY). Bernie Bornong and Greg Karow provided Shoshone National Forest information. Beth Burkhart provided species assessment information. She and anonymous reviewers provided helpful comments. The information in this report draws from the specimens and label information resources of the Rocky Mountain Herbarium and the studies and information resources of the Wyoming Natural Diversity Database. Funding for this project was provided by the USDA Forest Service, Rocky Mountain Region (Region 2) contract 53-82X9-1-137.

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COVER PHOTO CREDIT

Penstemon caryi (Cary's beardtongue). Photograph by Jennifer Whipple. Used with her permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *PENSTEMON CARYI*

Status

Penstemon caryi (Cary's beardtongue) is endemic to the Bighorn and Pryor mountains of north-central Wyoming and adjacent south-central Montana. It is designated a sensitive species by the Rocky Mountain Region of the USDA Forest Service. The NatureServe Global rank for this species is vulnerable throughout its range (G3). It is ranked vulnerable (S3) in Wyoming and in Montana by the Wyoming Natural Diversity Database and the Montana Natural Heritage Program, respectively. About half of all extant occurrences of the species are in Wyoming, and over half of these (13 of 23) are on the Bighorn National Forest in the Rocky Mountain Region.

Primary Threats

Penstemon caryi is found mainly at foothill and montane elevations on sparsely vegetated slopes, outcrops, and grassland openings in *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush), *Juniperus osteosperma* (Utah juniper), *J. scopulorum* (Rocky Mountain juniper), *Pseudotsuga menziesii* (Douglas-fir), or *Pinus flexilis* (limber pine) communities. It is potentially threatened by loss of habitat from road construction and limestone quarrying; and secondarily threatened from grazing, trampling, and weed competition. Field surveys conducted at 17 of 23 extant Wyoming occurrences from 1999 to 2001 and one monitoring study indicate that the overall threats to *P. caryi* from human activities are likely less imminent or of lower impact than previously suspected. However, the species' limited range, accessible habitat, and habitat specificity make it vulnerable to large-scale habitat modification in the future. One population of *P. caryi* known from a historic collection may be extirpated due to road construction, representing the only suspected case of significant decline that has been reported to date.

Primary Conservation Elements, Management Implications and Considerations

Penstemon caryi is a regional endemic of the Bighorn Mountains in north-central Wyoming and the Pryor Mountains in south-central Montana, with its largest known numbers and most extensive habitat in the Rocky Mountain Region of the USDA Forest Service. Of the 23 extant occurrences in Wyoming, 13 are in the Bighorn National Forest. One of these populations is in the Manning Creek area, which has been evaluated for consideration as a research natural area (Jones and Fertig 1998), and two are in the Medicine Lodge and Trapper Creek wilderness study areas. The largest known population is protected on The Nature Conservancy's Tensleep Preserve. The Nature Conservancy also has a conservation easement on one occurrence on private property. Of the extant occurrences on land managed by the Bureau of Land Management (BLM), at least two occurrences are protected in the Little Mountain and Spanish Point Karst Areas of Critical Environmental Concern. Outside of the Rocky Mountain Region, at least three Montana occurrences are on the BLM's East Pryor Mountains Area of Critical Environmental Concern, which includes rare plant conservation among its multiple objectives. All other public lands occurrences in Wyoming and Montana are on lands managed for multiple-use. Overall population trend appears to be stable or slightly increasing, based on long-term monitoring documented at the Tensleep Preserve (Humphrey 2001) and on short-term increases detected at two populations surveyed in both 1999 and 2002 (Fertig 2002). There is no available information on the species' life history. Maintaining the population viability of *P. caryi* requires maintaining its habitat. Most populations are on accessible multiple-use lands and thus are potentially vulnerable to habitat loss and degradation.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project of the USDA Forest Service (USFS) Rocky Mountain Region (Region 2). *Penstemon caryi* (Cary's beardtongue) is the focus of an assessment because it is designated a sensitive species in the USFS Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in abundance or in habitat capability that would reduce its distribution. A sensitive species may require special management, so knowledge of its biology and ecology is critical.

Goal

Species conservation assessments are produced as part of the Species Conservation Project to provide forest managers, research biologists, and the public 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 but provides the ecological background upon which management must be based. While the assessment does not provide management recommendations, it does focus on the consequences of changes in the environment that result from management (i.e., management implications). Additionally, the assessment cites management recommendations for related species and provides a reference to promote species conservation on USFS lands (Blankenship et al. 2001).

Scope

This assessment examines the biology, ecology, conservation status, and management of *Penstemon caryi* throughout its range with specific reference to the geographic and ecological characteristics of the Rocky Mountain Region under current environmental conditions. Its Rocky Mountain Region distribution corresponds with the state of Wyoming, and information was also compiled throughout the rest of its range in nearby Montana. Survey reports, field notes, and forms represent the most detailed documentation, and collection labels represent the most frequent documentation. Such data has been compiled for over 20 years on this species as a Wyoming plant species of special concern. In producing the assessment, refereed literature, non-refereed literature, herbarium documentation, and other sources were also reviewed, and studies on other members of the *Penstemon* Section *Glabri* were considered. In addition to compiling all of the population data, research reports, and refereed literature, existing distribution data and GIS base layers were used to assess potential distribution and adequacy of existing survey information. A summary of the potential distribution model results are incorporated in the body of this report.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions for the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. These scientific tools are to be used in concert with the most complete species status data to produce a robust analysis. The data and analyses presented in this assessment on *Penstemon caryi* in the Rocky Mountain Region address all information and records produced as documentation of its distribution and biology. The strength of evidence for particular interpretations or ideas is noted, and alternative explanations are described when appropriate.

Publication on the World Wide Web

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

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the web. This assessment of *Penstemon caryi*

was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Federal status

Penstemon caryi was formerly a Category 2 (C2) Candidate for listing under the Endangered Species Act (USDI Fish and Wildlife Service 1993). The C2 list included species that might have warranted listing as Threatened or Endangered, but for which sufficient biological data were lacking to support a listing proposal. The C2 program was eliminated in 1996 (USDI Fish and Wildlife Service 1996). *Penstemon caryi* was listed as a sensitive species by the Rocky Mountain Region (USDA Forest Service 1995, 2003) and by the Bureau of Land Management - Wyoming State Office (USDI Bureau of Land Management 2001). However, it was dropped from BLM sensitive status in 2002.

There are no other laws, regulations, management plans or conservation plans that address *Penstemon caryi* apart from its sensitive species status, which confers some protection from human-caused activities and developments. Potential impacts to Bighorn National Forest populations have not been identified to date in the biological evaluation process prescribed in Forest Service policy for sensitive species (Bernie Bornong personal communication 2002).

Natural Heritage Program ranks

NatureServe (formerly the heritage division of The Nature Conservancy) and the network of natural heritage programs assign *Penstemon caryi* a global rank of G3, indicating that the species is "rare or local throughout its range or found locally in a restricted range" and usually known from 21 to 100 extant occurrences. In Wyoming, this species is tracked as a species of concern and ranked S3, indicating that it is vulnerable statewide (Keinath et al. 2003). In Montana, it is also ranked S3 and regarded as a limited distribution species of potential concern (Heidel 2001). There is no legislation or management policy in either state that accompanies the ranking status.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

In the Rocky Mountain Region, *Penstemon caryi* occurs on National Forest System land on the Bighorn National Forest, on BLM lands administered by the Cody and Worland Field Offices, and on state and private lands. At least four occurrences are protected: one in the BLM's Little Mountain Area of Critical Environmental Concern (ACEC) and one in the BLM's Spanish Point Karst ACEC, one on The Nature Conservancy's Tensleep Preserve and one on private property with a conservation easement to The Nature Conservancy. Rare species conservation is part of the management objectives for each of these four properties. Other potentially protected sites include one population in the Mann Creek area of the Bighorn National Forest, which was evaluated as a prospective research natural area (Jones and Fertig 1998); portions of two occurrences within the Trapper Creek and Medicine Lodge wilderness study areas on the Bighorn National Forest; and one BLM population that may be located on the Five Springs Falls ACEC. There are two designated research natural areas (RNAs) in the vicinity of the historic Shell Creek collection location, Shell Creek RNA and Elephanthead RNA, but neither area is known to harbor the species. In Montana, at least three occurrences are on the BLM's East Pryor Mountains ACEC, which includes rare plant conservation among its multiple objectives. All other public lands occurrences in Montana and Wyoming are on lands managed for multiple-use.

Apart from its sensitive species status, which confers some protection from human-caused activities and developments, there are no other laws, regulations, management plans, or conservation plans that address *Penstemon caryi*. As a sensitive species, *P. caryi* populations on the Bighorn National Forest are considered when evaluating project proposals and management plans. Potential impacts to populations have not been identified in the biological evaluation process to date (Bernie Bornong personal communication 2002). Even though there are no immediate threats in the Rocky Mountain Region, the species is vulnerable to local developments (road construction, quarrying) and landscape changes that foster exotic species encroachment or secondary succession.

Biology and Ecology

Classification and description

Systematics and synonymy

Scientific Name: *Penstemon caryi* Pennell (Pennell 1920). Holotype: USA: Wyoming, Big Horn County, "Big Horn Mountains, alt. 8000 ft.", 4 June 1910, *Cary 504* (US).

Based on Cary's original field notes in the Bureau of Biological Survey archives, the type locality is located somewhere between Cary's camp "... at a Sulphur Spring 8 miles north of Hyattville" on 3 June 1910 and his "permanent camp on Trapper's Creek ... reached the night of June 4." (Payson 1924).

Common Name: Cary's beardtongue, Cary's penstemon.

Family: Scrophulariaceae (Figwort family).

Synonyms: None.

Phylogenetic Relationships: The genus *Penstemon* contains nearly 250 species, primarily centered in western North America (Cronquist et al. 1984). *Penstemon caryi* belongs to Section *Glabri* (Pennell 1920), a group characterized by blue to violet corollas and glabrous to pubescent anther sacs that dehisce from their outer tips towards the connective (Cronquist et al. 1984). Wyoming taxa in Section *Glabri* include *P. cyananthus*, *P. cyaneus*, *P. fremontii*, *P. gibbensii*, *P. paysoniorum*, *P. saxosorum*, *P. scariosus* var. *garrettii*, and *P. strictus*. Payson (1924) noted the similarity of *P. caryi* to specimens from Lincoln and Uinta counties, Wyoming, which were later named as *P. paysoniorum* by Keck (1947). The evolutionary relationships of *P. caryi* and other taxa within Section *Glabri* are currently being investigated using modern genetic techniques by Dr. Andrea Wolfe and her students, particularly Andrew Lutz at Ohio State University. Elsewhere in the western United States, members of the *Penstemon* Section *Glabri* form "geographic replacement series" of closely related, but technically well-marked species (Cronquist, in Hitchcock et al. 1959).

History of the species

Penstemon caryi was first recognized as a distinct species by Francis Pennell in 1920, based on a specimen collected ten years earlier by naturalist Merritt Cary on the Bighorn Range near Trapper and Medicine Lodge canyons in Big Horn County, Wyoming on 4 June 1910 (Pennell 1920). The first collection of *P. caryi* was much earlier, on 7 July 1896 by F.L. and C.E. Moore, in the "Big Horn Mountains" of Wyoming. After it was published, James Thorp collected the species at an unknown site on the "west slope of the Big Horn Mountains" in June 1928 and again along Shell Creek on 4 July 1932. Marion Ownbey discovered a new population near Five Springs Falls in July 1935. Louis and Terua Williams collected *P. caryi* twice near Medicine Mountain in June and July 1936.

Penstemon caryi was not collected again until 1976, when Robert Dorn discovered this species for the first time in Montana, in the Pryor Mountains of Carbon County (Dorn 1978). The majority of subsequent Montana records were documented in formal and informal Pryor Mountains botanical surveys conducted in 1983, 1986, and 1991 (Lesica and Achuff 1992, Montana Natural Heritage Program 2002).

In 1977, Dorn relocated Ownbey's Five Springs Falls population, marking the first documentation of *Penstemon caryi* in Wyoming in 41 years. From 1978 to 1981, Robert Dorn, Barry Johnston, Robert Lichvar, B.E. "Ernie" Nelson, Ron Hartman, and Erwin Evert discovered five new populations in Wyoming and relocated it at a historic collection site. In 1989 and 1990, Hollis Marriott and Mary Neighbours of Wyoming Natural Diversity Database (WYNDD) discovered two new populations and relocated one known occurrence in the Bighorn Range. Michele Girard, Stephanie Mills, and Kathy Zacharkevics of Bighorn National Forest located two new sites and relocated one known population during surveys from 1993 to 1995. Ann Humphrey, Phil Shephard, and Walter Fertig relocated two populations on The Nature Conservancy's Tensleep Preserve in 1992 and initiated an annual monitoring program. From 1999 to 2001, Laura Welp and Walter Fertig of WYNDD, Robert Dorn, Andrew Lutz of Ohio State University, and Bernie Bornong, Tucker Galloway, Kevin O'Dea, and Nathan Gross of Bighorn National Forest discovered 12 new occurrences and relocated seven additional known populations in Wyoming's Bighorn Range, representing all but four of the extant occurrences in Wyoming (Fertig 2002, Wyoming Natural Diversity Database 2003).

Non-technical description

Penstemon caryi is a glabrous perennial herb with flowering stems 10 to 40 centimeters (cm) tall that arise from a caudex. Leaf blades are narrowly linear to lance-shaped, entire, opposite, and 2 to12 cm

long (with the longest leaves at the base of the stem). Flowers have long-tipped sepals 6 to11 millimeters (mm) long and a blue (rarely pink), tubular corolla 20 to 38 mm long. The flowers and inflorescence are usually glabrous, although occasional specimens have sparsely glandular pubescence. Anthers are straw-colored with numerous long, tangled white hairs on the back. The staminode is glabrous or bearded at the tip. Fruits are dry capsules (**Figure 1** and **Figure 2**; Pennell 1920, Clark and Dorn 1979, Marriott and Jones 1989, Fertig et al. 1994, Dorn 2001).

Figure 1. Illustration of *Penstemon caryi*, by Linda Shoemaker, from Fertig et al. 1994.

Figure 2. Photograph of *Penstemon caryi*, by Jennifer Whipple, from Fertig et al. 1994.

The combination of glabrous flowers, anthers with long woolly hairs on the back, and long-attenuate sepals distinguishes *Penstemon caryi* from other members of the genus in Wyoming. It closely resembles *P. strictus*, but the latter has sepals that are rounded or short-acute at the tip, and these species do not overlap in distribution. Payson (1924) noted the similarity of *P. caryi* to specimens from Lincoln and Uinta counties in southwestern Wyoming, which were later named as *P. paysoniorum* by Keck (1947). However, *P. paysoniorum* has anthers with short pubescence and hairs that do not exceed the width of the anther sac, and it has dark brown to dark purplish or black anthers, and generally shorter corollas, 15 to 22 mm long (Dorn 2001). *Penstemon caryi* can be mistaken for other large-flowered species of *Penstemon* in Section *Glabri* but overlaps in distribution only with *P. glaber*. The latter differs in having anthers with short pubescence and hairs that do not exceed the width of the anther sacs (Dorn 2001). *Penstemon caryi* is sympatric with *P. eriantherus* that superficially looks similar, but the latter has a glandular inflorescence. It also occurs with *P. aridus* and *P. attenuatus*, which have smaller, glandular flowers and inflorescences, and with *P. rydbergii*, which has smaller flowers that have glabrous anthers (**Table 1**; Fertig et al. 1994, Fertig 2000, Fertig 2002).

Robert Dorn has observed a "small form" of *Penstemon caryi* from the western foothills of the Bighorn Range near Hyattville that differs in having shorter stems (17 to 22 cm tall), narrower leaves, and corollas 16 to 19 mm long (Dorn personal communication 2001). This population (Element Occurrence 005) is probably not worthy of taxonomic recognition as a new variety or species, but it could represent a distinct and localized genotype (Fertig 2002).

Distribution and abundance

Penstemon caryi occurs in the Bighorn Mountains of Wyoming, spanning Big Horn, Sheridan, and Washakie counties. This represents the extent of its distribution within the USFS Rocky Mountain Region (**Figure 3**; Neighbours and Marriott 1991, Fertig 1993, Fertig et al. 1994, Fertig 1999, University of Wyoming 1998, Beauvais et al. 2000, Fertig 2000, Welp et al. 2000, Dorn 2001, Fertig 2002). It also occurs in the nearby Pryor Mountains of Carbon County, Montana, a smaller mountain range that is geologically related to the Bighorn Mountains.

In Wyoming, *Penstemon caryi* is known from 26 primary occurrences, 23 of which are extant (**Table 2**). The majority of the extant occurrences (13 of 23) are on the Bighorn National Forest. Most surveyed populations consist of two or more subpopulations that are separated by breaks in continuous habitat of 0.1 to 1.5 miles. Wyoming populations consist of at least 64 discrete subpopulations that occupy a total area of approximately 88 hectares (218 acres) (**Table 2**). Individual colonies range in size from 0.1 to 10 acres and contain 20 to 1,500 plants. Based on surveys of 40 subpopulations at 17 occurrences from 1999 to 2001, the total population in Wyoming contains at least 11,935 to 13,585 individuals (**Table 2**). Extrapolating from these samples, the population of *P. caryi* in the state may be as high as 20,600 to 23,300 plants (estimates updated from Fertig 2002). Based on current estimates, approximately 7,555 to 8,150 of all species' numbers in Wyoming (48 to 55 percent) are on the Bighorn National Forest. Population size estimates are not available for two national forest occurrences. The largest occurrence of *P. caryi* in Wyoming, with

Table 1. Distinguishing characteristics of *Penstemon caryi* from other *Penstemon* species.

Taxon	Anther sac opening	Anther pubescence	Sepal tips	Corolla length	Sepal length	Inflorescence glandular?
P. caryi	full length	long and woolly	long-attenuate	15 mm	5 mm	rarely
P. strictus	about 3/4	long and woolly	rounded or short-acute	24 to 32 mm	3 to 5 mm	no
P. glaber	full length	short	rounded or short-acute	24 to 35 mm	2 to 4 mm	no
P. scariosus var. *garretii*	nearly full length	long and relatively straight	acuminate	20 mm	4 to 6 mm	yes
P. paysoniorum	about 4/5	short	acuminate	15 to 22 mm	3 to 7(9) mm	no
P. eriantherus	full length	little or none	acute	15 to 27 mm	7 to 12 mm	usually

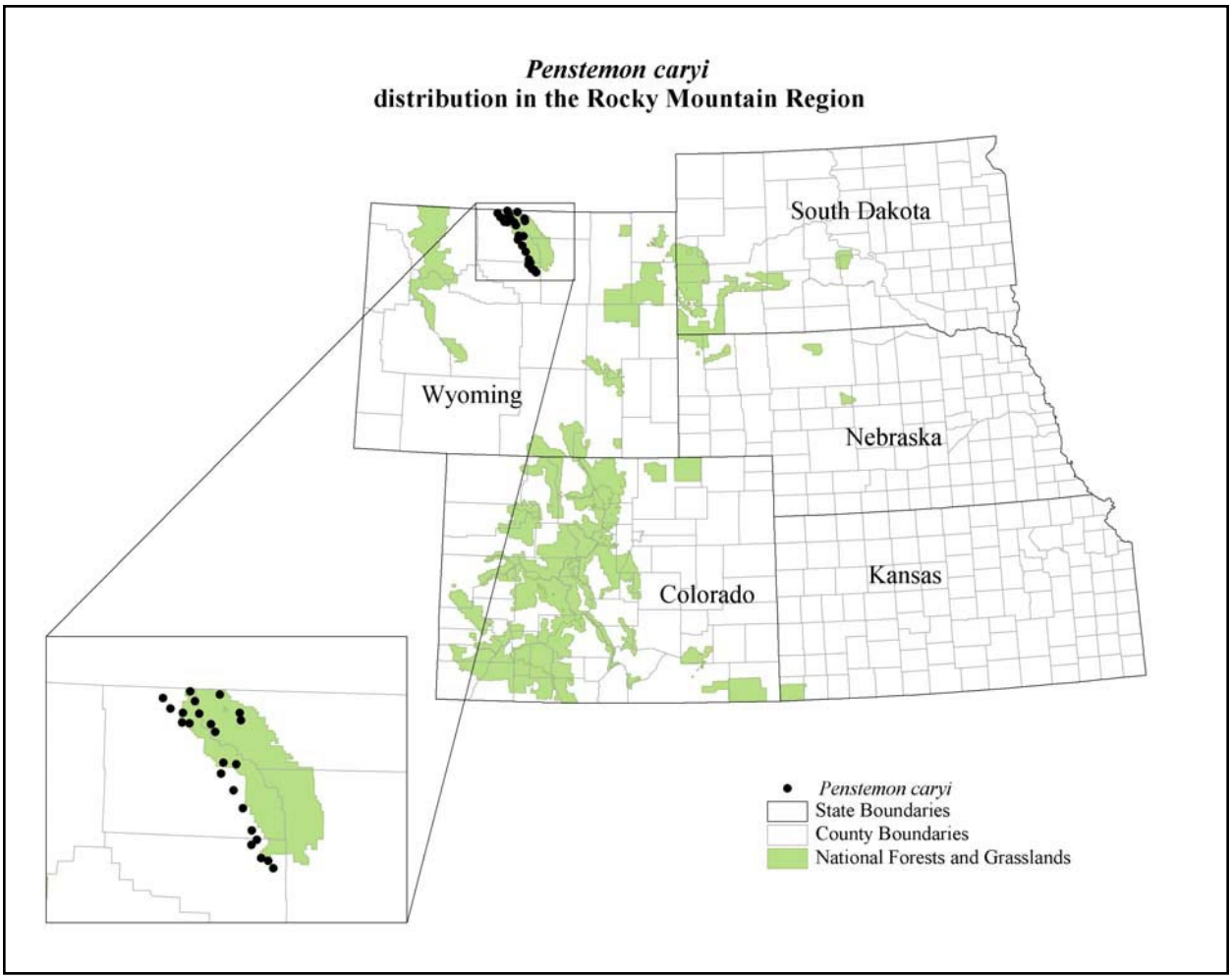

Figure 3. Distribution of *Penstemon caryi* in the Rocky Mountain Region.

estimated population size of 3,400 individuals in 13 subpopulations, is fully protected within the Tensleep Preserve of The Nature Conservancy (TNC; Humphrey and Shepherd 1994, Humphrey 2001) and a second large population on private land is also protected by a TNC conservation easement.

Penstemon caryi population sizes in Wyoming and Montana are limited and consist of widely scattered clumps of two to five individuals that are often restricted to small patches (Fertig 2002). Population density varies depending on habitat quality and moisture availability. Humphrey (2001) measured average densities of 1 to 1.9 plants per square meter at the Tensleep Preserve from 1995 to 2001, while Laura Welp measured densities of 4.5 to 6.6 plants per square meter at sites near Trapper Canyon (from Fertig 2002). Both monitoring studies were subjectively placed in centralized areas typical of the species' density.

Penstemon caryi is known in Montana from 28 records, consisting of over 40 subpopulations documented in or adjoining the Pryor Mountains, collected and surveyed mainly by Peter Lesica and Steve Shelly (Montana Natural Heritage Program 2002). Most of the 28 records fall within the contiguous area of six topographic maps and some may be more appropriately treated as subpopulations. Thus, comparisons between tallies in the two states are preliminary. *Penstemon caryi* was among over 20 species that were addressed in sweeping baseline surveys of BLM-administered lands of the Pryor Mountains in 1991, and it was recommended for deleting as a Montana species of special concern based on its documented widespread distribution and the lack of threats in the area (Lesica and Achuff 1992). Prior to that time there were 14 occurrence records, and records have not been entered since. Approximately one-half of all Montana occurrences are on Custer National Forest (Region 1), including the two largest known

Table 2. Populations and habitats of *Penstemon caryi* in Wyoming.

Site name (Occurrence Number)	Landowner	County	Estimated abundance	Extent (hectares)	Elevation range (ft.)	General habitat description	Associated species
Five Springs Falls (001)	Bureau of Land Management (BLM) Cody	Big Horn	70 plants in three subpopulations	1.4	5,800 to 7,000	Along roadside on shaley bank and on rocky juniper-sagebrush, south-facing slopes with little cover. Substrate derived from Bighorn Dolomite.	*Juniperus* spp., *Artemisia* spp., *Hordeum* spp., *Chaenactis* spp., *Lupinus* spp.
Medicine Mountain (002)	Bighorn National Forest	Big Horn	1,000 or more in four subpopulations	4.3	8,000 to 9,520	Small scattered openings with rocky, clay soils within densely vegetated meadows. On road banks, landslides, and rocky hillsides on shallow, limestone-derived soils. On dry, south slope.	*Oxytropis* spp., *Arenaria hookeri*, *Phlox hoodii*, *Lupinus argenteus*, *Agoseris glauca*, *Taraxacum officinale*, *Geranium viscosissimum*
Shell Canyon (004)	Bighorn National Forest	Big Horn	May be extirpated	NA	5,500 to 6,000	Soil alkaline, derived from pale sandstone. **May have been extirpated by road construction.**	Not reported
Trapper Creek (005)	BLM land, Wilderness Study Area	Big Horn	1,200 or more in ten subpopulations	5.5	6,400 to 8,000	Sparsely vegetated, sandy soil among small calcareous sandstone outcrops in sagebrush grassland. Substrate derived from Tensleep Sandstone and the Amsden Formation.	*Juniperus* spp., *Artemisia* spp., *Oryzopsis hymenoides*, *Bromus tectorum*, *Elymus lanceolatus*, *Phacelia hastata*, *Heterotheca* spp., *Penstemon laricifolius*, *Petrophyton* spp., *Lupinus* spp., *Oenothera* spp., *Erigeron* spp., *Sedum* spp., *Pinus flexilis*
Little Mountain (008)	BLM Cody,Little Mountain ACEC	Big Horn	500 in three subpopulations	6.9	5,400 to 6,100	Known from 3 main habitats: (1) disturbed roadside at edge of burn on dry, rocky limey-sandstone in open, juniper woodlands, (2) stony, grassy slopes, (3) rocky, calcareous banks. Substrates derived from the Tensleep and Amsden Formations.	*Juniperus* spp., *Hymenoxys* spp., *Hordeum* spp., *Arenaria hookeri*, *Elymus lanceolatus*
Dry Fork Ridge (012)	Bighorn National Forest	Sheridan	Not available (NA)	Not available (NA)	8,400	Rocky slope. Substrate derived from Bighorn Dolomite or Madison Limestone.	Not reported
Fisher Mountain (013)	Bighorn National Forest	Sheridan	NA	NA	7,390	Limestone outcrops, probably derived from the Madison Limestone.	Not reported
Tensleep Preserve (014)	The Nature Conservancy	Washakie	3,400 in 13 subpopulations	15.1	5,750 to 6,600	Found in 2 main vegetation types: (1) thin soils on flat, exposed limestone bedrock with shallow erosion pockets and low vegetative cover surrounded by juniper/sagebrush grasslands, (2) large limestone boulders with shallow pockets of soil within limber pine/ ponderosa pine woods. Substrates derived from the Tensleep and Amsden formations.	*Artemisia* spp., *Pinus flexilis*, *P. ponderosa*, *Senecio canus*, *Festuca idahoensis*, *Ivesia gordonii*, *Ipomopsis spicata*, *Arenaria congesta*, *Juniperus osteosperma*, *Koeleria macrantha*, *Petrophyton caespitosum*, *Heterotheca fulcrata*, *Erigeron ochroleucus*, *E. divergens*, *Astragalus spatulatus*, *Penstemon nitidus*, *Mahonia repens*, *Sedum lanceolatum*

Table 2 (cont.).

Site name (Occurrence Number)	Landowner	County	Estimated abundance	Extent (hectares)	Elevation range (ft.)	General habitat description	Associated species
Spanish Point/Medicine Lodge (018)	BLM Worland, Spanish Point Karst ACEC, Wilderness Study Area	Big Horn	300 to 350 in two subpopulations	3.0	6,700 to 6,900	Sandy, sparsely vegetated soil among small calcareous sandstone outcrops in sagebrush grassland on ridgecrest. Also on open knoll with exposed calcareous outcrops and blowouts among rolling sagebrush plains with scattered juniper. Aspect is flat and soil is sandy with coarse gravel and rocks. Substrate derived from Madison Limestone.	*Juniperus* spp., *Artemisia* spp., *Koeleria macrantha*, *Elymus* spp., *Gilia* spp., *Penstemon laricifolius*, *Senecio cana*
(020)	Private	Washakie	NA	17.9	6,160 to 7,200	Limestone cliffs and bedrock outcrops in grassland. Substrate derived from Tensleep Sandstone and the Amsden Formation.	Not reported
Cottonwood Cow Camp (022)	Bighorn National Forest	Big Horn	100	1.5	8,040	South-facing, dry slope on shallow, limestone soils. May be in an old burn site. Substrate derived from Madison Limestone.	*Stipa* spp., *Festuca idahoensis*, *Lupinus* spp., *Achillea millefolium*, *Erigeron* spp.
Shell Canyon (023)	Bighorn National Forest	Big Horn	150 to 200 in four subpopulations	2.9	7,360 to 7,640	(1) In "grassy" sagebrush or sagebrush/juniper communities on a northwest-facing hillside with a slope between 20% and 25%. Occurs on limestone outcrops or gravelly limestone soil. (2) On artificially disturbed, steep, rocky, calcareous slope. Substrate derived from Bighorn Dolomite.	*Juniperus* spp., *Artemisia tridentata* var. *vaseyana*, *Balsamorhiza sagittata*, *Castilleja* spp., *Elymus* spp., *Erigeron allocotus*, *Astragalus miser*, *Penstemon laricifolius*, *Taraxacum officinale*, *Achillea millefolium*, *Cirsium* spp., *Linum* spp., *Poa* spp., *Melilotus* spp., *Verbascum thapsus*, *Phleum pratense*
Ice Creek (024)	Bighorn National Forest	Sheridan	80 to 100	0.6	9,320	Talus road cut composed of light brown clay with a high content of slab-like rocks. Area is actively slumping and eroding with very little vegetative cover and a low soil moisture content. Substrate derived from Bighorn Dolomite.	*Geranium viscosissimum*, *Cirsium* spp., *Campanula* spp.
Cookstove Basin (025)	Bighorn National Forest	Big Horn	25 to 50	1.9	7,680	Actively eroding, clay hillside dominated by Lupinus and bare soil.	*Lupinus polyphyllus*, *Festuca idahoensis*, *Artemisia tridentata*, *Taraxacum officinale*, *Geranium viscosissimum*, *Erigeron* spp.
Fertig Draw (026)	BLM Worland	Big Horn	100 or more in two subpopulations	1.8	5,500 to 5,600	In a relatively restricted area at the base of low dolomite cliffs. Most are on flat aspects. The dolomite substrate is weathered and soft. Soil is sandy with a thick cryptogamic crust. Vegetation is open, low, sparse. Substrate is derived from the Tensleep and Amsden formations.	*Pinus ponderosa*, *Juniperus* spp., *Elymus spicatus*, *Koeleria macrantha*, *Cercocarpus ledifolius*, *Haplopappus nuttallii*, *H. armerioides*, *Senecio cana*, *Opuntia polycantha*, *Cryptantha* spp., *Erigeron allocotus*, *Penstemon laricifolius*

Table 2 (cont.).

Site name (Occurrence Number)	Landowner	County	Estimated abundance	Extent (hectares)	Elevation range (ft.)	General habitat description	Associated species
Bighorn Basin (027)	BLM Worland, Renner Wildlife Habitat Management Unit	Big Horn	500 in five subpopulations	5.3	6,360 to 7,600	(1) Small, flat, limey-sandstone outcrops (Tensleep Sandstone and Amsden formations) within rolling grassland with scattered shrubs or among open stands of ponderosa and limber pine. (2) Sparsely vegetated, steep cutbanks along road in loose calcareous soil in stand of mixed ponderosa pine and subalpine fir. (3) Somewhat atypical habitat with higher vegetative cover of grasses and forbs.	*Pinus ponderosa*, *P. flexilis*, *Abies lasiocarpa*, *Juniperus* spp., *Cercocarpus ledifolius* var. *intricatus*, *Haplopappus* spp., *Gutierrezia sarothrae*, *Petrophyton caespitosum*, *Achillea millefolium*, *Koeleria macrantha*, *Bromus tectorum*, *Erodium cicutarium*, *Penstemon aridus*, *Festuca idahoensis*, *Erigeron* spp., *Senecio* spp., *Castilleja* spp., *Sedum lanceolatum*, *Arenaria hookeri*, *Penstemon laricifolius*, *P. aridus*,
Black Mountain (028)	BLM Worland	Big Horn	50 in two subpopulations	0.9	6,600 to 6,840	South and southeast-facing slopes with calcareous outcrops on dry, rocky, soil. Substrate derived from Madison Limestone.	*Artemisia tridentata* var. *vaseyana*, *Juniperus* spp., *Penstemon aridus*, *Petrophyton caespitosum*, *Koeleria macrntha*, *Festuca idahoensis*, *Erigeron allocotus*
Bucking Mule Creek (029)	Bighorn National Forest	Big Horn	2,200 in four subpopulations	6.3	8,600 to 9,275	Sagebrush grassland at base of calcareous cliffs and rockslides that are slumping and eroding. Slopes range from 10 to 70% and are east to south-facing. Soils dry (Owen Creek-Waybe Association).	*Artemisia tridentata* var. *vaseyana*, *Festuca idahoensis*, *Lupinus* spp., *Penstemon procerus*, *Delphinium* spp., *Polygonum bistortoides*, *Taraxacum* spp.
Little Bighorn River (030)	Bighorn National Forest	Sheridan	1,000	4.9	9,250 to 9,425	Sagebrush grassland on slightly barren, south-facing hillside of ca 45 degrees that is actually slumping and eroding. Soils dry (Owen Creek-Waybe Association).	*Artemisia tridentata* var. *vaseyana*, *Festuca idahoensis*, *Delphinium* spp., *Lupinus* spp.
Duncum Mountain (031)	Bighorn National Forest	Big Horn	500 to 1,000	1.4	9,650	West-facing midslope of calcareous rubble and talus with pockets of dry, whitish-gray, limey clay soil. Substrate derived from Bighorn Dolomite.	*Phlox multiflora*, *Cirsium hookerianum*, *Festuca idahoensis*, *Potentilla ovina*, *Achillea millefolium*, *Myosotis alpestris*, *Leucopoa kingii*, *Erigeron ochroleucus*, *Sedum lanceolatum*, *Galium boreale*, *Phacelia hastata*, *Erigeron compositus*, *Elymus trachycaulus*
Sand Springs (032)	BLM Worland	Washakie	200	0.9	7,000	Flat, weathered limey,-sandstone outcrops (Tensleep or Amsden formations) in open forest with open understory and sandy soil.	*Pinus ponderosa*, *Juniperus* spp., *Sedum lanceolatum*, *Senecio* spp., *Bromus tectorum*, *Koeleria macrantha*, *Poa* spp., *Erigeron* spp.

Table 2 (concluded).

Site name (Occurrence Number)	Landowner	County	Estimated abundance	Extent (hectares)	Elevation range (ft.)	General habitat description	Associated species
Sand Draw Road (033)	Bighorn National Forest	Washakie	1,500	5.3	6,120 to 6,240	Limestone cliffs and bedrock outcrops (derived from the Tensleep and Amsden formations) in open grassland.	*Balsamorhiza* spp., *Lupinus* spp., *Mahonia repens*, *Penstemon glaber* var. *glaber*, *Pinus ponderosa*, *Juniperus scopulorum*,*Pinus flexilis*, *Poa* spp., *Festuca idahoensis*, *Delphinium* spp., *Ipomopsis* spp., *Ivesia gordonii*, *Opuntia polyacantha*, *Thermopsis rhombifolia*, *Oenothera* spp.
Big Horn/Owl Creek H1 (034)	Bighorn National Forest	Big Horn (unmappable)	NA	NA	6,000	Light brown soil derived from limestone.	Not reported
Big Horn/Owl Creek H2 (035)	Bighorn National Forest	? (unmappable)	NA	NA	7,000	Not reported	Not reported
Fool Creek (036)	Bighorn National Forest	Sheridan	1,000	0.2	7,625 to 7,638	Limestone outcropping. South-facing, 20 to 30% slope in full light with low soil moisture.	*Anemone patens* var. *multifida*, *Juniperus* spp., *Geranium viscosissimum*, *Campanula* spp., *Artemisia* spp., *Achillea millefolium*, *Sedum lanceolatum*
Simmons Canyon (037)	BLM Cody	Big Horn	7	NA	4,725	Grass/juniper/mountain mahogany community with no slope, no cover and dry soil on a limestone gravel/ loam substrate.	*Juniperus* spp., *Cercocarpus ledifolius* var. *ledifolius*, grasses
TOTAL	**26 records**		**13,875 to 14,520**	**88.3**			

occurrences with population numbers in the range of 200 to 1,000 plants (Montana Natural Heritage Program 2002). Survey information representing the majority of records (23 of 28) documented 2,000 to 4,550 *P. caryi* individuals in an area of approximately 110 acres. This estimate, compared to Wyoming estimates, indicates that 12 to 25 percent of all known species' numbers are in Montana.

Work was conducted for the Wyoming BLM on modeling the potential distribution of BLM sensitive plant species, in addition to Threatened and Endangered species in the state (Fertig and Thurston 2003). In modeling the potential distribution of *Penstemon caryi* in Wyoming, over 11,100 square kilometers (km) of potential habitat were identified, representing approximately 4.4 percent of the state's area (**Figure 4**). Most of this potential habitat is restricted to the northern, western, and southern slopes of the Bighorn Mountains, but large areas of suitable environments were also mapped in the Bridger-Owl Creek Mountains, the east slope of the Wind River Range, the east slope of the Absaroka Range, the Gros Ventre Range, southern Teton Range, the Wyoming-Salt River Ranges, and scattered locations in the Laramie Range. These areas are part of the Shoshone and Medicine Bow national forests, in addition to national forests in Region 4. To date, no populations have been located outside of the Bighorns, despite very extensive floristic surveys across most of Wyoming (Hartman 1992). It is hypothesized that the apparent restriction of *P. caryi* to the Bighorn Mountains is consistent with distribution patterns among other endemic *Penstemon* Section *Glabri* in Wyoming with their patterns of "geographic replacement series" of closely related, but technically well-marked species that sort out geographically (Cronquist, in Hitchcock et al. 1959).

Population trend

Long-term trend data are unavailable for most populations of *Penstemon caryi* in Montana and Wyoming, with the exception of TNC's Tensleep Preserve along Canyon Creek on the west slope of the Bighorn Range (Element Occurrence 014), where monitoring studies have been conducted since 1993 (Humphrey 2001). The monitoring plots at Tensleep were selected non-randomly, so they may not indicate trends throughout the preserve. However, the results suggest that the number of plants has remained stable or increased over the last nine years, with some inter-annual variability in response to climatic conditions. Short-term population increases have also been detected at two other populations on BLM lands in the Bighorn Mountains that were re-surveyed in 1999 and 2000 (Fertig 2002). Additional monitoring plots were established at three BLM sites in 2000, but they have not been re-read. One Wyoming population (Element Occurrence 004) on the Bighorn National Forest has not been relocated since 1932 and may be extirpated (Andrew Lutz personal communication 2000). Trend data are not available for any occurrences of *P. caryi* on the Bighorn National Forest. The most recent survey and relocation of species occurrences (1999 to 2001) provide the detailed mapping and size estimates that are needed as baselines for future trend determinations. Despite the incomplete baseline information, Fertig (2000, 2002) made the preliminary interpretation that species' numbers in Wyoming appear stable or increasing overall.

There are challenges in making population size and trend estimates. First, it is easier to discern flowering plants than non-flowering plants, and the ratio of flowering to non-flowering plants would be expected to change between years, introducing a possible measure of error in evaluating trends. The population size census or estimate information for the majority of Wyoming records addresses both flowering and non-flowering plants. Second, the monitoring investigators on the Tensleep Preserve also noted difficulty in distinguishing discrete plants, and they referred to the species as having rhizomes rather than a single caudex. For that reason, they tallied individual flowering stems rather than discrete individuals, despite the fact that individual plants can have one to 10 or more flowering stems. However, most population census and size estimates represent tallies of discrete individuals. These matters are discussed further under life history and research needs.

Habitat

Penstemon caryi is most frequently found on sparsely vegetated outcrops, on rocky slopes of limestone or dolomite, in small grassland openings at foothill to montane elevations, often with *Elymus spicatus* (bluebunch wheatgrass), or in grassland openings among *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush), *Juniperus osteosperma* (Utah juniper), *J. scopulorum* (Rocky Mountain juniper), *Pseudotsuga menziesii* (Douglas-fir), or *Pinus flexilis* (limber pine) communities (**Figure 5** and **Figure 6**). It has also been found in seral habitat associated with semi-barren roadcuts, slumping clay banks, talus, and rubble. At all of these sites vegetative cover is well under 20 percent. Other commonly associated species include *Eremogone hookeri* (Hooker's sandwort), *Ivesia gordonii* (alpine

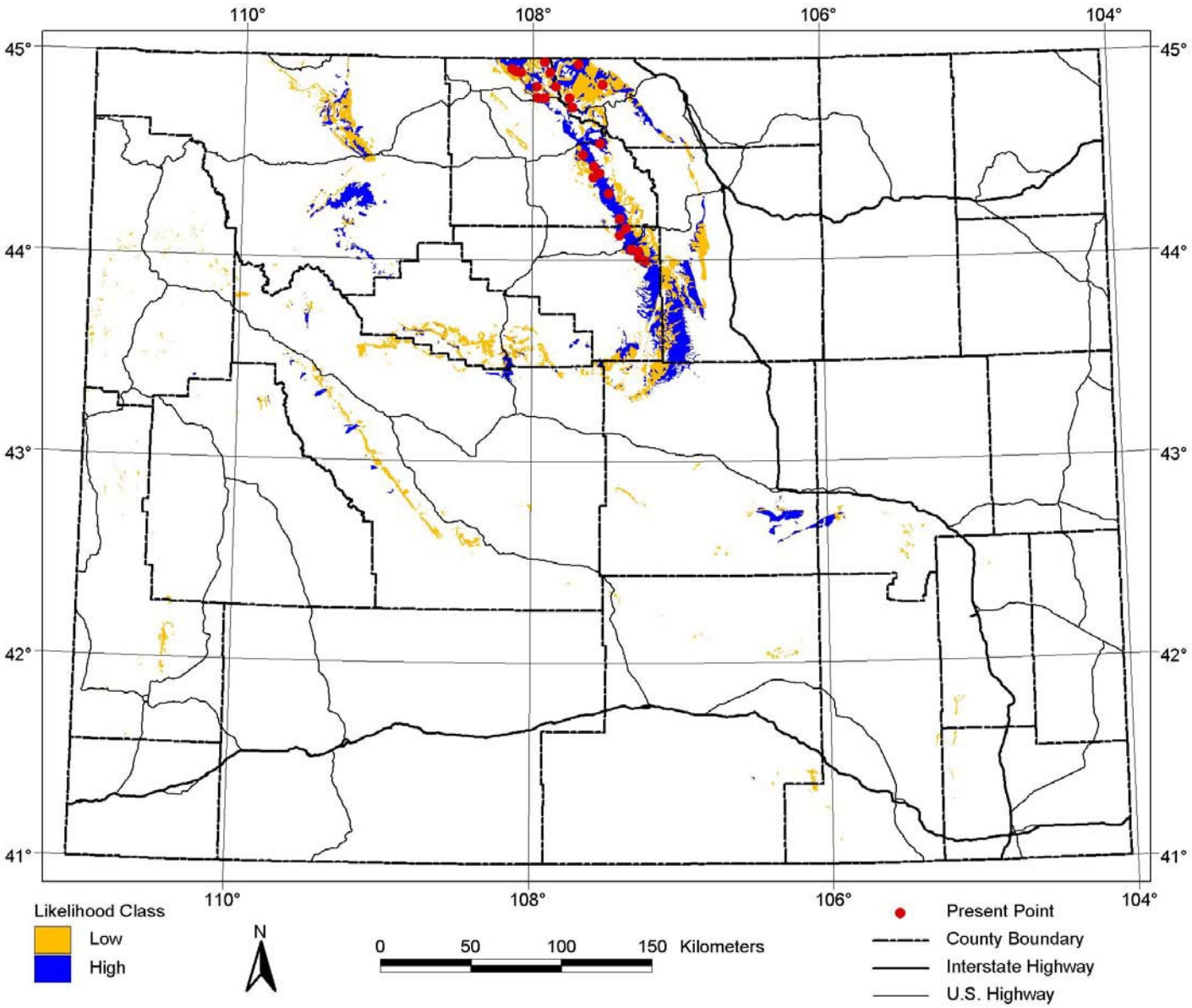

Figure 4. Potential distribution map of *Penstemon caryi* in Wyoming (Fertig,W. and R. Thurston 2003. Modeling the Potential Distribution of BLM Sensitive and USFWS Threatened and Endangered Plant Species in Wyoming (http://uwadmnweb.uwyo.edu/WYNDD/Reports/pdf_fertig/FinalReport_03BLMmodeling.pdf).

Figure 5. Habitat of *Penstemon caryi* among *Juniperus osteosperma* (Utah juniper), by Laura Welp.

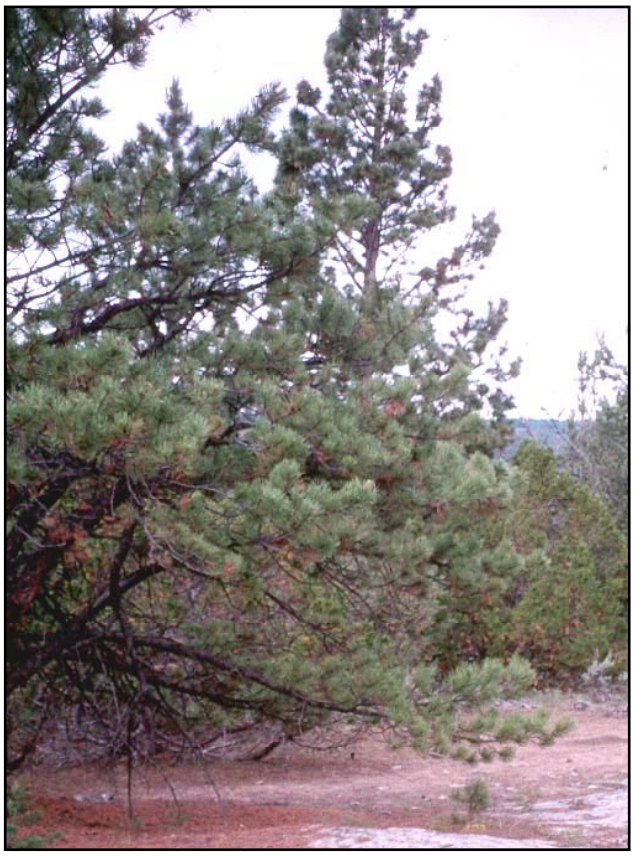

Figure 6. Habitat of *Penstemon caryi* in *Pinus flexilis* (Limber pine) opening, by Laura Welp.

mousetail), *Penstemon laricifolius* (larch-leaved beardtongue), and *Senecio nanus* (woolly groundsel). Associated species vary with elevation and setting, and one high montane population (Element Occurrence 031) was dominated by *Phlox multiflora* (Rocky Mountain phlox), *Festuca idahoensis* (Idaho fescue), and *Potentilla ovina* (sheep cinquefoil). Wyoming populations range in elevation from 5,200 to 9,650 feet (1,585 to 2,940 meters), and Montana populations have a somewhat narrower range of 5,800 to 8,080 feet (1,770 to 2,460 meters). The range of elevations and associated species are presented in **Table 2**.

Penstemon caryi is found on thin, calcareous soils that have weathered directly above shallow bedrock or have been exposed by natural- or human-induced erosion (Entisols or Inceptisols). Most of these soils are derived from Bighorn Dolomite, Madison Limestone, Tensleep Sandstone or the Amsden Formation (Love and Christensen 1985), with a range of silty and gravelly textures. Less commonly, *P. caryi* can be found on loamy soils with deeper, cryic Mollisols or on soils with a dense layer of moss or lichens. These generally fall within the Owen Creek – Tongue River – Gateway soil unit or Cloud Peak – Starley and Rock Outcrop soil units (**Figure 7**). Populations usually occur on slopes of 0 to 25 percent and with a southern or southeastern aspect. One high elevation population in the Bighorn Range occurs on a west-facing dolomite talus slope on pockets of whitish-gray limey clay soil. The environmental parameters that correlated most closely with *P. caryi* distribution and were used to predict its potential distribution included calcareous bedrock geology, shallow soil depth, a negative correlation with summer temperature, and a positive correlation with fall precipitation (Fertig and Thurston 2003)

Average annual precipitation within the Wyoming range of *Penstemon caryi* varies from 304 to 508 mm (12 to 20 inches), with peaks from April through June. Average annual temperature ranges from 2.2 to 5.5 °C (36 to 42 °F). Average maximum and minimum temperatures for January are - 0.5° and - 14.4 °C (31° and 6 °F). Average maximum and minimum temperatures for July are 26.7 to 30° and 6.7 to 11 °C (80 to 86° and 44 to 52 °F) (Martner 1986).

Data on the disturbance regimes of *Penstemon caryi* habitat are lacking. The poorly developed soils and sparse vegetation represent a harsh, seral habitat. Populations are capable of colonizing or persisting in disturbed roadside areas, especially if competing vegetation is unable to become re-established. Steve Shelly (personal communication 2001) has noted that Montana populations may actually prefer habitats that receive light and periodic disturbance. Natural disturbance regimes in *P. caryi* habitat may include frost action and associated weathering. Though forage and fuels for fire are limited, there is also expected to be a natural disturbance regime associated with grazing and fire. Key habitat requirements of *P. caryi* are summarized in **Figure 8**.

Reproductive biology and autecology

Reproduction

Penstemon caryi flowers from late May to late July depending on elevation (Fertig et al. 1994, Fertig 2002). It reproduces exclusively by seed, and fruits are produced from mid-June into mid-August. The majority of species in the Scrophulariaceae studied to date have adaptations that encourage cross-fertilization and are protogynous (Kampny 1995). Different species groups in the *Penstemon* genus are adapted to pollination by various genera and families of Hymenoptera, which includes bees and wasps, as well as to hummingbirds (Crosswhite and Crosswhite 1966). More recent research into pollen presentation theory proposes that the *Penstemon* genus, with its array of anther structures, has evolved divergent pollination syndromes to favor pollinators with differential rates of removal and deposition (Thomson et al. 2000). The work in the *Glabri* Section of the *Penstemon* genus provides strong evidence for pollination by Hymenoptera, with their overall high rates of pollen removal and low rates of deposition, including the following examples: visitation to *P. speciosus* in Colorado was heaviest by *Osmia* bees, with few *Anthophora* bees and *Pseudomasaris* wasps, and occasional bumblebees and longhorn beetles (Thompson et al. 2000); visitation to *P. strictus* in Colorado was primarily by bumblebees, with few *Pseudomasaris* wasps and *Osmia* bees (Williams and Thomson 1998); visitation to *P. lemhiensis* was by a species of *Pseudomasaris* wasp (Ramstetter 1983 in Elzinga 1997). The pollination vectors for *P. caryi* are not known, but its anther structure with incomplete and gradual dehiscence is consistent with the high pollen removal/low deposition exhibited by bees and wasps.

The corolla shape and staminode function may also reflect divergent evolutionary directions within the genus (Walker-Larsen and Harder 2001 from Lesica 2002). The staminodes of tubular corollas such as those of *Penstemon caryi* act as barriers to pollinators, while those of pouch-like flowers act as levers, prolonging the visit or putting the pollinators in direct contact with the fertile stamens, respectively. The staminodes

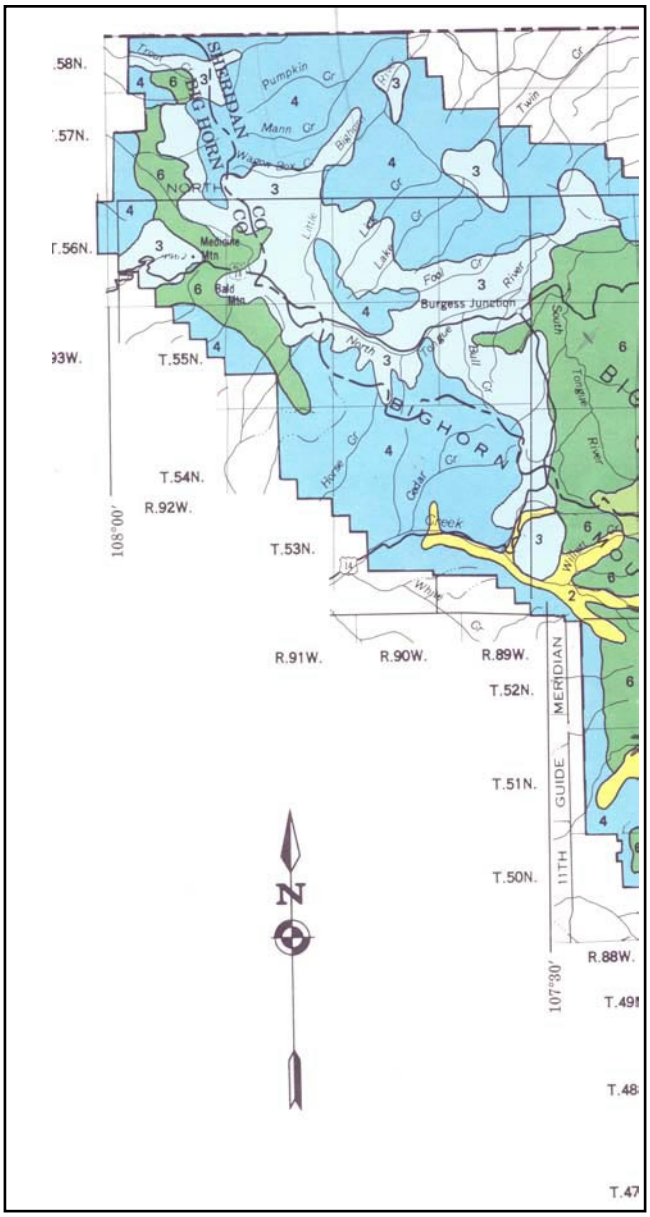

Figure 7. General soil map of Bighorn National Forest, Wyoming. The blue units include formations with limestone or dolomite. From USDA Forest Service and Natural Resources Conservation Service (1985).

of bee-pollinated species of *Penstemon* are often hairy, while all staminodes of hummingbird-pollinated species of *Penstemon* are glabrous. The long hairs help ensure contact, and the bees deposit more pollen on the stigmas of flowers with a staminode than in flowers with the staminode removed. While staminode characteristics are narrowly-defined in most species of Penstemon, the staminode of *P. caryi* can be either hairy or glabrous (Pennell 1920, Fertig 2002). Research into the pollination of *P. caryi* may shed light on the adaptive radiation in the *Penstemon* genus with anther traits and staminode traits in tandem.

Each capsule produces many seeds, which are released passively through slits in the outer walls of the capsule. The number of flowering and fruiting stalks per individual ranges from one to 10 or more, with higher production during moister years (Humphrey 2001). The number of flowers per inflorescence also varies by an order of magnitude (two to 20 or more), as indicated by specimen review at Rocky Mountain Herbarium (RM; Heidel personal observation). Flowering is indeterminate, from the base to the apex of the inflorescence, and appears to be prolonged in moist years and curtailed in drought years.

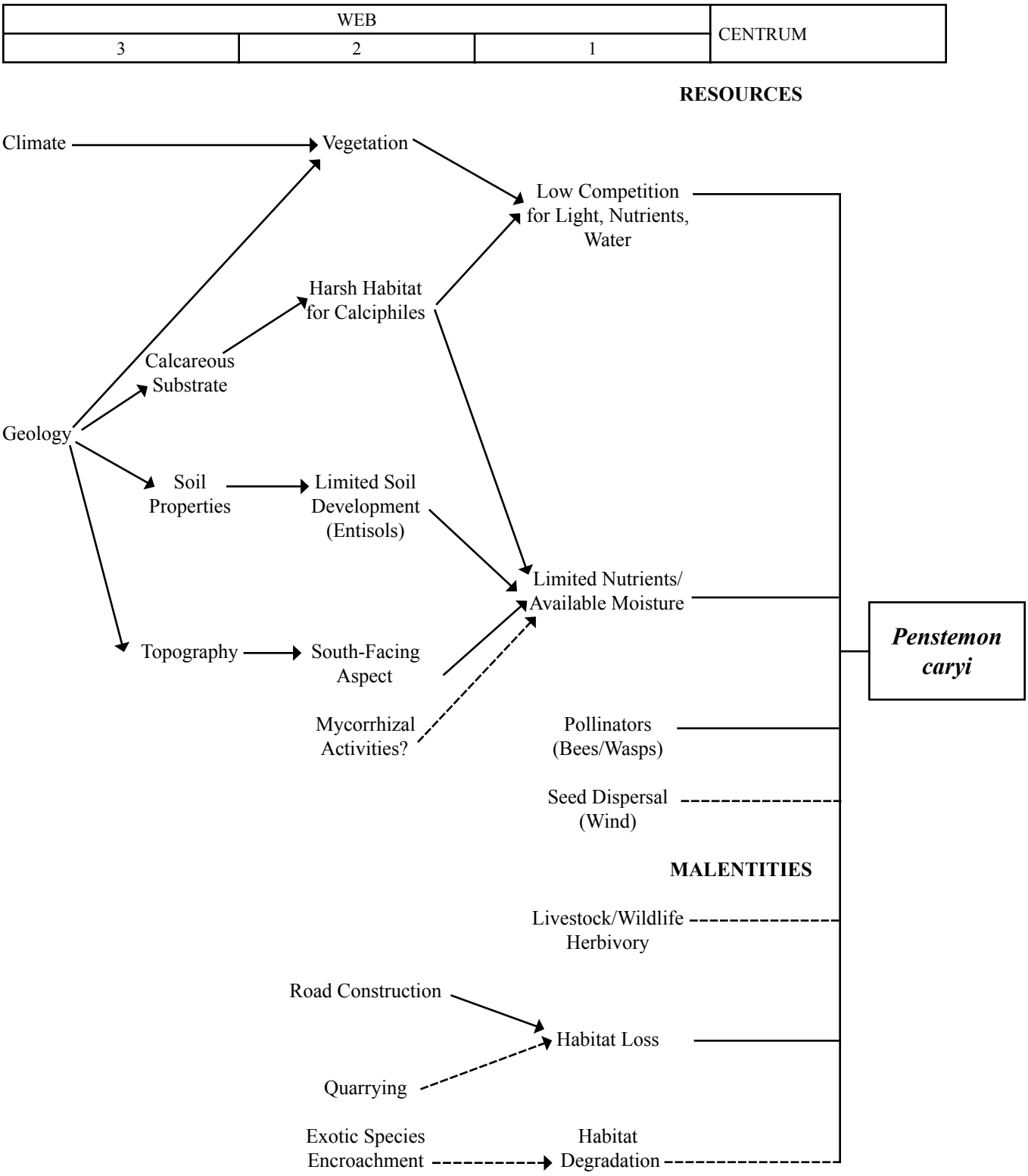

Figure 8. Envirogram of key resources and malentities for *Penstemon caryi.* Dashed lines indicate resources or malentities that are possible but not proven to be key variables.

There are no notes on abortion among fruiting capsules of *Penstemon caryi*, but the relatively few RM specimens of this species that are in fruit among those that are past flowering indicate that aborted fruits are present (Heidel personal observation). It appears that different shoots on the same plant may produce inflorescences that have all fruits aborted and inflorescences with all fruits fertile and developed. The question of pollination-limited seed production has not been addressed.

Dispersal mechanisms

Penstemon caryi seeds are thought to be dispersed by gravity and wind and likely do not travel long distances from the parent plant under ordinary conditions (Fertig 2002). *Penstemon caryi* populations in Wyoming and Montana are typically small, and not all patches of suitable habitat are occupied, further indication that population increase and spread may be limited by dispersal. The habitat of *Penstemon caryi* often includes areas of bare rock, so the success of the seeds in reaching suitable microhabitat is an additional factor in the clustered distribution patterns and species' absence from areas of apparently suitable but unoccupied habitat.

Hybridization

No evidence of hybridization between *Penstemon caryi* and other species in the genus has been detected in the field.

Phenotypic plasticity

Variable morphology is evident among RM specimens of *Penstemon caryi* that may reflect environmentally-driven ("phenotypic") plasticity. Among the more variable characteristics are basal and cauline leaf width, basal and cauline leaf length, flowering stem height, the number of inflorescences per plant, and the number of flowers per inflorescence. This species occupies a range of elevations, moisture regimes, and growing season conditions, which are likely factors in the range of morphological traits expressed by the species. Variation among specimens may also be due to the differences that reflect plant age and development, ecotypic differences between populations associated with habitat differences, or genetic forms or races as indicated by the small-flowered form of a population near Hyattville. Common garden experiments conducted in greenhouse research would be needed to separate environmentally-induced variation from developmental differences and genetically-induced variation.

Life history

Penstemon caryi is an iteroparous, short-lived perennial with one to many rosettes of leaves surmounting the branched caudex. The basic life history stages of *P. caryi* include seed, seedling, and mature plant stages (vegetative and flowering phases). The age of individual plants cannot be determined except at seedling stages. The mature plant stage may be represented by a single rosette stage or multiple rosettes. One specimen sheet (*Nelson 3744*) had a single rosette plant that was flowering. This is the basis for deducing that both single- and multiple-rosette stages can produce flowers. The number of years required for a seedling to develop into a single rosette plant that produces flowers is not known. Since the species flowers early in the growing season and there was little vestige of leaves from past years, this may have represented a 2 to 3 year old plant.

Established vegetative plants have one or more basal rosettes with erect, narrow, linear or lance-shaped leaves. They are more difficult to discern than the flowering plants because without an apparent flowering stalk they resemble a graminoid. The size and flowering status of *Penstemon caryi* plants can probably not be used to determine age. This was the case for the related *P. lemhiensis* (Shelly and Heidel 1995). The illustration in **Figure 1** represents one individual plant (genet) of *P. caryi* with three flowering stems (ramets) that may be mistaken for three individuals. In addition, there are one or two rosettes at the base of the plant that can only be discerned by close inspection. This individual has four or five apical buds, though only three are flowering. There is not complete information on stage classes, so a basic life history model for *P. caryi* without size-based stage classes is presented in **Figure 9**.

At any given population where a survey has been conducted, both flowering and non-flowering plants have been reported. The fraction of flowering plants among total plant numbers ranges from 2 percent to 80 percent, and it often comprises the majority of the population. The most intense surveys for the species in Wyoming took place from 1999 to 2001, a time period that corresponds with a general drought period, which may have affected the wide range of ratios between flowering and non-flowering plants. These surveys are more likely to represent a low estimate of population numbers rather than a high estimate.

Germination requirements and seedling biology are not known for this species, but they are likely to be limited to suitable microhabitat with adequate moisture

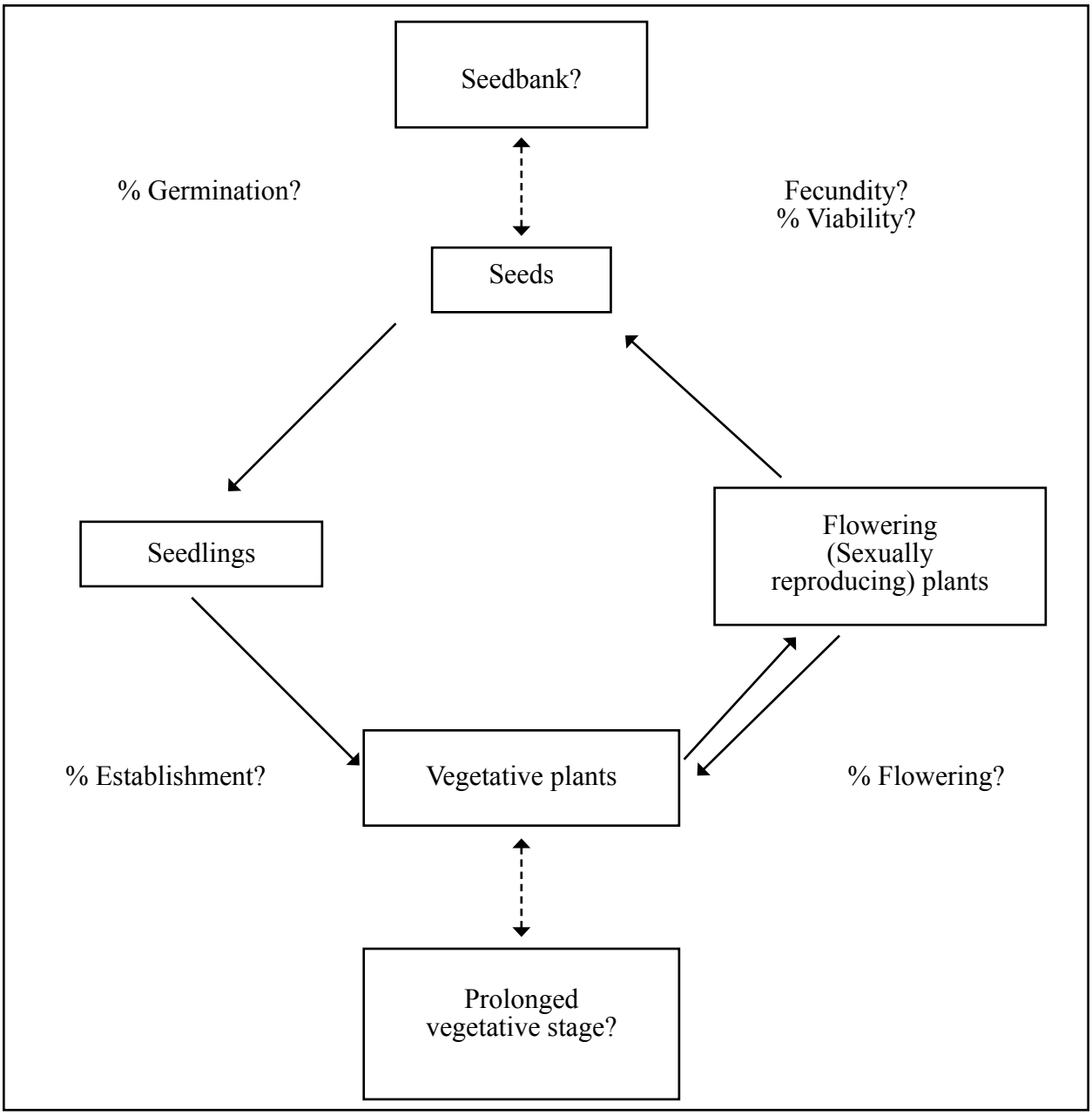

Figure 9. Life cycle diagram for *Penstemon caryi.* Dashed lines indicate pathways that are possible but not proven.

but low cover. No seedling plants were encountered in three demographic plots established by Laura Welp in June 2000, the seedling stage was not addressed in monitoring on Tensleep Preserve, and seedlings were not noted on any survey forms for the species. It is possible that seedlings are not present during the time of the growing season when survey and monitoring work has been conducted, or that germination is episodic.

Research into the germination requirements of intermountain species of *Penstemon*, including members in Section Glabri, suggests that seeds of most species of *Penstemon* are dormant at dispersal and require a period of moist chilling in order to germinate. Those species of *Penstemon* from habitats with severe winters, as found in the range of *P. caryi*, require long chilling periods (Meyer and Kitchen 1994, Meyer et al. 1995). Delayed germination of seeds can result in a seed bank, which provides a stable seed source in spite of environmental conditions that may be unfavorable for seed germination for many years (Rees 1994).

Germination of the related species, *Penstemon lemhiensis*, was so low over seven years of monitoring (Shelly and Heidel 1995) that germination could not be included in stage-based transition matrices. The few incidents of germination that did occur were in years that were cool and wet early in the growing season (April-June mean climate values; Elzinga 1997). The low frequency of germination, patterns of vegetation encroachment, appearance of the species after fire, and its affinity for secondary succession settings lead researchers to hypothesize that germination was fostered by disturbances such as fire (Shelly and Heidel 1995). Later prescribed burn research corroborated the hypothesis, although effectiveness was very much affected by habitat and accompanying disturbance (Heidel and Shelly 2001). If there is evidence of vegetation encroachment in *P. caryi* habitat, then the *P. lemhiensis* example as it relates to *P. caryi* warrants further evaluation.

Community ecology

Mycorrhizal relationships

No research on the mycorrhizal relationships of *Penstemon* section *Glabri* has been published.

Competition

Penstemon caryi occurs in open habitat, either for low-competition settings or for high light conditions. There is little or no shadow cast by nearby woody vegetation into its habitat, and the species is typically found on south-facing slopes. Its linear leaves may be an adaptation for maximizing photosynthetic activity while reducing heat stress. It flowers during high summer temperatures, though the rhizosphere conditions are moderate by comparison. *Penstemon caryi* generally fits the pattern of a stress-tolerant species of unproductive habitat, in the sense of Grimes (2001).

The dominant species in *Penstemon caryi* habitat are bunchgrasses, often *Elymus spicatus*, which form tight clumps that tap nutrient and water resources in the immediate vicinity, but which leave large areas of unoccupied habitat. The resulting vegetation patterns are patchy, and the intervening spaces are suited to species that are poor competitors.

Herbivory

In the course of surveys for *Penstemon caryi* in Wyoming, it has frequently been noted that the species appears to be browsed by a variety of herbivores. The browse patterns and local animal signs suggest herbivory by deer, elk, rodents, rabbits, insects, and domestic livestock (especially cattle and horses). In most cases, herbivory is restricted to inflorescences, upper stems, or fruiting pods (Fertig 2002).

Many of the Montana populations of *Penstemon caryi* fall within the Pryor Mountains Wild Horse Range, and local signs of horse use were noted on the most recent field forms although grazing was not mentioned. The effects of wild horses on this species have not been systematically evaluated.

In research on the related *Penstemon lemhiensis*, a species of similar habitat though more robust in stature, one of the highest levels of browse among several baseline monitoring study sites was found in a livestock exclosure during a drought year, where mule deer and elk had evidently entered, as indicated by their signs. When small-scale prescribed burning was later applied to some study sites, the highest levels of herbivory were found among *P. lemhiensis* that was grazed by livestock drawn to an unfenced study site, which had become an oasis of green after fire treatment within a large allotment (Heidel and Shelly 2001). This research suggests that although *P. lemhiensis* is not usually a preferred forage, herbivory may be elevated during drought and affected by disturbance patterns and landscape context. If herbivory of *P. caryi* fluctuates with climate and disturbance as it appeared to for *P. lemhiensis*, then the presence of a seed bank may help to buffer the effects.

CONSERVATION

Threats

Overall, there are no immediate threats known to *Penstemon caryi* from human activities, although the species' limited range and high habitat specificity make it vulnerable to large-scale habitat modification in the future (Fertig 2002). Most Bighorn National Forest occurrences are on lands managed for multiple-use. One extant population of *P. caryi* on the Bighorn National Forest is in the Mann Creek area that was evaluated as a prospective research natural area (Jones and Fertig 1998), and two are within the BLM Trapper Creek and Medicine Lodge wilderness study areas (Marriott and Jones 1989, Fertig 1991). Elsewhere in Wyoming, two are currently protected within the BLM's Little Mountain and Spanish Point Karst ACECs with establishment objectives that include rare plant conservation. One additional BLM population may be located in the Five Springs Falls ACEC. The largest occurrence of *P.*

caryi in Wyoming is on the Tensleep Nature Preserve managed by TNC, and a second population on private land is protected by a conservation easement through TNC. A portion of one occurrence is within the Wyoming Game and Fish Department's Renner Wildlife Habitat Management Unit (summarized in Fertig 1999). In Montana, at least three occurrences lie within the East Pryor Mountain ACEC, and the rest are on the Custer National Forest (Region 1) and BLM lands administered for multiple-use.

Penstemon caryi is potentially threatened by loss of habitat from road construction and limestone quarrying. Of the 23 extant occurrences in Wyoming, including the majority on the Bighorn National Forest, up to 18 are situated in part or in full along improved or unimproved roadways. It occupies gentle, open slopes and its population is sometimes oriented in bands along a contour, so road and quarry developments potentially target *P. caryi* habitat. Road development, maintenance (e.g., grading or recontouring) and corridor management (e.g., herbicide treatment) are practices that potentially impact the species. The disturbance practices associated with roads also make them a corridor for exotic species introduction and encroachment. There are no occurrences known from quarry sites, but the bedrock characteristics of this species' habitat and its similarities with established quarries make it likely that there has been habitat loss in the past and there is potential for habitat loss in the future. In some areas, however, small colonies have been able to persist or become established on roadcuts that expose suitable substrates and restrict competition from other vegetation. The full extent of the population and the suitability of adjoining habitat need evaluation to interpret whether these colonies are part of a larger population. Monitoring is needed to determine whether they are viable and if they are in fact separate and new populations. In the case of *P. lemhiensis*, one roadcut population that was monitored had no recruitment, though it had high flowering plant numbers, and appeared to fit the pattern of a waif that did not contribute to viability (Shelly and Heidel 1995). The major malentities of *P. caryi* are shown in **Figure 8**.

Livestock may impact some populations, either through direct herbivory on flowering stems or by trampling. The majority of Bighorn National Forest populations lie within active grazing allotments. Long-term studies of grazed and ungrazed plots on the Tensleep Preserve suggest that cattle grazing may be less significant than previously thought and that much herbivory is the result of smaller animals, especially rodents and rabbits (Humphrey 2001). Observational evidence from other populations, however, suggests that grazing by cattle, horses, or sheep may be important in reducing flower and fruit production. Impacts from deer and elk herbivory are poorly understood but could be significant in certain areas. The information gleaned from *Penstemon lemhiensis*, a related species of similar habitats though taller in stature, indicates that grazing by big game is heaviest in drought conditions or if there is disturbance (fire) that concentrates the livestock use in its habitat. If seed production is not a limiting factor, and it is less likely to be if the species has a seed bank for stockpiling seeds, and if grazing or trampling does not cause mortality, then livestock impacts to *P. caryi* may be secondary.

Several populations of *Penstemon caryi* surveyed from 1999 to 2001 may be impacted by competition from exotic plants, especially *Melilotus* spp. (sweet-clover), *Verbascum thapsus* (mullein), and *Phleum pratense* (timothy), as reported on Bighorn National Forest in Section 14 of the Shell Canyon occurrence (Element Occurrence 023). Tall, rhizomatous plants such as *Phleum pratense* often form high density and tall stature vegetation. Nitrogen-fixing plants such as *Melilotus* spp. potentially shift the vegetation composition in favor of ruderal species. *Bromus tectorum* (cheatgrass) has also been reported at two low elevation BLM populations (Element Occurrences 005 and 033). Low elevation populations, including a minority of the Bighorn National Forest populations, are most vulnerable to competition from exotic species. Populations along roadsides are particularly vulnerable to exotic species encroachment, and this includes a majority of the Bighorn National Forest populations.

Some of the more accessible populations could be become threatened if they are excavated by gardeners or gardening retailers. There are no known instances of *Penstemon caryi* being excavated for transplanting, though it is showy and other showy stress-adapted species of *Penstemon* are commonly used in rock garden plantings. There are no other known or suspected consumptive uses of this species for commercial, recreational, scientific, or educational purposes.

Conservation Status in the Rocky Mountain Region

Penstemon caryi is a habitat specialist in two mountain ranges near the Wyoming-Montana line that fits the pattern of a stress-tolerant species and poor competitor. Wyoming harbors the majority of *P. caryi* numbers, and the Bighorn National Forest contains approximately half (48 to 55 percent) of all known numbers in the state. Four of the eight largest-known

populations rangewide (i.e., population numbers greater than or equal to 1000 individuals) are on the Bighorn National Forest. A couple of the small populations (100 or fewer plants) are also on the Bighorn National Forest and may be the most vulnerable to localized road and quarrying disturbance and to the effects of grazing and weed invasion.

The majority of *Penstemon caryi* occurrences and population numbers in the Rocky Mountain Region are in accessible settings that fall within multiple-use management area, and many are located close to roadways. *Penstemon caryi* has no conservation status in the Rocky Mountain Region or on the Bighorn National Forest, apart from its status as a sensitive species. Potential impacts to the species have not been identified to date in USFS project reviews (Bernie Bornong personal communication 2002).

Potential Management in the Rocky Mountain Region

The elements necessary for maintaining *Penstemon caryi* viability in the Rocky Mountain Region center on maintaining population numbers and habitat. There is a solid body of information documenting the species' distribution across the range of settings (e.g., elevation range and east-side / west-side locations). A conservation framework has been developed for a related *Penstemon* species that occupies a similar range of habitats; it is structured to maintain the largest populations across the array of natural habitats (Elzinga 1997).

Trend information is lacking for *Penstemon caryi* on the Bighorn National Forest, and monitoring is a tool for identifying potential management needs and evaluating effectiveness of actions. A baseline monitoring program would target the largest populations across the range of elevations and locations, and an implementation monitoring program would target species as potentially affected by management actions and project developments. Management actions for *P. caryi* habitat have not been identified. The species may require disturbance regimes of some form and intensity in some settings, but information is too sketchy at present for direct application.

Revisions are in progress on the Bighorn National Forest plan, and the prospect of research natural area designation for Mann Creek will be reviewed. The planning process will also provide the framework for transportation planning, wilderness study area review, and weed management planning that indirectly affect species' management.

Tools and practices

Aerial photo-interpretation and Global Positions System (GPS) readings would be of benefit in survey work, adding detail to the location information collected in past surveys. The 17 populations that were recently surveyed (Fertig 2002) have all been mapped onto field maps. This has been digitized, and the resulting electronic information is available from WYNDD for reference and revision in future surveys.

Any project planning, survey, or monitoring work would also benefit from noting and characterizing levels of aborted fruits, heavy browse, or signs of stress on *Penstemon caryi*, and signs of habitat stability as indicated by presence/absence of woody species recruitment, presence/absence of invasive species, and presence/absence of bare ground.

The monitoring of *Penstemon caryi* on the Tensleep Preserve has provided valuable trend information, but it has not addressed the seedling stage or followed the fate of individual plants. The three monitoring transects established on BLM lands were likewise set up as trend transects (Fertig 2002). If census results or resurveys to known populations indicate significant downward trends, then demographic monitoring to identify life history bottlenecks for *P. caryi* is important to pursue, using the monitoring techniques outlined in Lesica (1987) for demographic monitoring purposes.

Information and Research Needs

Surveys are needed for the two *Penstemon caryi* occurrences on Bighorn National Forest known only from collection records. In light of the extensive surveys that were conducted for the species from 1999 to 2001, there is limited need to expand survey efforts on either BLM lands or the Bighorn National Forest. The highest probabilities for finding new populations would be in the more remote, unsurveyed, upper elevation reaches of the Bighorn Mountains. Probable areas could be identified by overlaying the potential distribution map with aerial photos or vegetation maps. Aerial photo-interpretation and GPS units might also be used to add greater detail and possibly to expand existing survey data on a local scale.

Trend data are needed for occurrences on the Bighorn National Forest. The non-random distribution

of populations poses a difficulty in censusing or sampling population numbers, so that census of population numbers is either labor-intensive or a simple presence/absence documentation. The detailed mapping of subpopulations could be refined with GPS technology. Baseline presence/absence monitoring might include all large populations (1,000 or more plants) and a subset of populations that represents the range of elevations and locations on the Forest for a minimum of three years. This represents the most basic gauge of trend (Menges and Gordon 1996, Elzinga et al. 1998), and it could be used to determine whether census monitoring is warranted. If a decline is documented from census monitoring then demographic monitoring is needed to seek the underlying causes and possible solutions. Demographic monitoring plots are not randomly placed to represent the population but may be subjectively placed in relatively high-density portions of the population for efficiency (Lesica 1987). These plots provide data on life history and the limiting factors in the species' life cycle that affect trend, can be expanded for formal population viability analyses, and may also point to underlying causes.

In addition, there are two monitoring needs tied to management and project plans. The contribution of roadcut populations to species' viability needs to be addressed by complete surveys around the roadcuts, and monitoring of the roadcut population if most of the local population is in the roadcut to evaluate persistence. Second, any prescribed burns would ideally have baseline monitoring and controls before the burn treatment. Valuable fire-response information might also be acquired after-the-fact if there are populations occurring in wildfires and monitoring is initiated in the following year.

The other immediate information need concerns more detailed documentation of existing and potential disturbance regimes in *Penstemon caryi* habitat. There are no records of fires, fire scars, or patterns of erosion or surface disturbance, and information on signs of browsing or grazing is sporadic. Documentation of disturbance might be initiated in combination with monitoring key populations on Bighorn National Forest.

There are also many opportunities and secondary needs for *Penstemon caryi* species biology research. They might be pursued in tandem with monitoring studies, greenhouse studies, or separate field studies. The pollination vector has yet to be identified as a bee or wasp, the limiting effects of pollination have yet to be evaluated, and the habitat requirements of the pollinator have not been considered. Since *P. caryi* individuals have either hairy or glabrous staminodes, the pollination biology of *P. caryi* may help shed light on the adaptive values of these typically divergent traits among other species in the genus. In other life history research, the potential presence of a seedbank and germination requirements have yet to be evaluated. Also, the mean length of time until flowering and the species' mean longevity have yet to be documented.

Finally, the evolutionary relationship of *Penstemon caryi* with other members in Section *Glabri* has yet to be elucidated. The origins may shed light on the patterns of endemism among plants and animals of the Bighorn Mountains area, and contribute to management objectives that maintain their viability.

DEFINITIONS

Anther sacs — pollen-bearing units

Apical bud — the growing tip of a stem or primordial stem

Calcareous — containing calcium carbonate

Capsule — a dry, dehiscent fruit

Caudex — the persistent root crown from which new stems arise each year, at or below ground level

Cauline — on the stem

Connective — the tissue that connects the pollen sacs of an anther

Dehisce — to burst or split open at maturity

Dolomite — metamorphic rock composed of calcium magnesium carbonate

Entire — smooth margined

Extant — currently known to exist

Extirpate — destroy

Genet — a unit or group derived by asexual reproduction from a single oricinal zygote, such as a seedling or a clone

Genotype — the genetic constitution of an organism

Geographic replacement series – closely-related species that are geographically isolated and restricted to discrete landforms, with possible evolutionary common ancestors

Glabrous — smooth, lacking hairs

Graminoid — pertaining to grasses, sedges, or rushes

Hymenoptera — the insect order that includes the ants, bees, wasps, and sawflies

Iteroparous — having repeated reproductive cycles within the lifetime of an individual

Life history bottleneck — a critical developmental stage in the life history of a species that exerts the greatest constraint on population trend

Perennial — a plant that normally lives for more than two seasons

Phenotypic plasticity — the capacity for marked variation in the morphology of an organism as a result of environmental influences

Protogynous — having the female flower parts develop first

Pubescent — covered with hair

Ramet — an individual member of a clone

Rhizomatous — possessing creeping, underground stems

Rosette — a cluster of leaves radiating out from the base of the stem or primordial stem

Ruderal — inhabiting disturbed sites

Seral — pertaining to an early stage of succession

Staminode — a sterile stamen

Stress-resistant — able to survive exposure to an unfavorable environmental factor

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