Penstemon harringtonii Penland (Harrington's beardtongue): A Technical Conservation Assessment

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

June 30, 2006

Susan Spackman Panjabi and David G. Anderson
Colorado Natural Heritage Program
Colorado State University
Fort Collins, CO

Peer Review Administered by
Society for Conservation Biology

Panjabi, S.S. and D.G. Anderson. (2006, June 30). *Penstemon harringtonii* Penland (Harrington's beardtongue): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/penstemonharringtonii.pdf [date of access].

Acknowledgments

This research was facilitated by the helpfulness and generosity of many experts, particularly Carla Scheck, Peggy Lyon, Barry Johnston, Carol Dawson, Andy Kratz, Keith Giezentanner, Joe Doerr, David Buckner, Tom Grant, Bill Jennings, Mike Klish, and Andy Dworak. Their interest in the project and time spent answering questions were extremely valuable, and their insights into the distribution, habitat, and ecology of *Penstemon harringtonii* were crucial to this project. Thanks also to Greg Hayward, Gary Patton, Jim Maxwell, and Joy Bartlett for assisting with questions and project management. Jane Nusbaum provided crucial financial oversight. Carla Scheck provided valuable insights based on her observations of many occurrences of *P. harringtonii*. Barry Johnston, Keith Giezentanner, and Joe Doer provided information specific to the White River National Forest. Annette Miller provided information for the report on seed storage status. Drs. Ron Hartman and Ernie Nelson provided access to specimens of *P. harringtonii* at the Rocky Mountain Herbarium, and Jennifer Ackerfield provided access to specimens from the CSU Herbarium. Nan Lederer and Tim Hogan provided valuable assistance and insights at the CU Herbarium. Thanks to Kimberly Nguyen for the work on the layout and for bringing this assessment to Web publication. Michael Stevens and Jessica Andersen and assisted with data analysis and literature acquisition. Special thanks to Karin Decker and Arvind Panjabi who reviewed part or all of the first draft of this document and offered input. Thanks also to Jen Krafchick, Cleome Anderson, Melia Anderson, Arvind Panjabi, Cameron Panjabi, and Donovan Panjabi for their support during the synthesis of this document.

Authors' Biographies

Susan Spackman Panjabi is a Botanist with the Colorado Natural Heritage Program (CNHP), at Colorado State University in Fort Collins. Ms. Panjabi's work at CNHP includes building the international Biological Conservation Data System with information on the location and condition of 500 rare, threatened, and endangered plant species known to occur in Colorado. She has conducted biological inventories and rare plant surveys for various public agencies and private organizations such as the Bureau of Land Management, the U.S. Forest Service, Summit and Pitkin county planning departments, The Nature Conservancy, and the American Mountain Foundation. She has worked with CNHP for eleven years. Ms. Panjabi received her B.A. in Environmental Conservation from the University of Colorado, Boulder (1982) and her M.S. in Botany from the University of Vermont, Burlington (1993).

David G. Anderson is the botany team leader with the Colorado Natural Heritage Program (CNHP). Mr. Anderson's work at CNHP includes inventory and mapping of rare plants throughout Colorado, mapping weeds, maintaining and updating CNHP's database, and writing reports on the rare plants of Colorado. He has worked with CNHP since 1999. Much of Mr. Anderson's prior experience comes from five years of fieldwork studying the flora and ecosystem processes of the Alaskan and Canadian Arctic. Mr. Anderson also served in the Peace Corps as a science teacher in the Solomon Islands from 1996 to 1998. Mr. Anderson received his B.A. in Environmental, Populational, and Organismic Biology from the University of Colorado, Boulder (1991) and his M.S. in Botany from the University of Washington, Seattle (1996).

Cover Photo Credit

Penstemon harringtonii (Harrington's beardtongue). Photograph by Peggy Lyon. Used with permission.

Summary of Key Components for Conservation of *Penstemon harringtonii*

Penstemon harringtonii Penland (Harrington's beardtongue) is a narrowly endemic vascular plant with a global range limited to an 82 by 48 mile area in the Colorado River drainage in northwestern Colorado. It is known from 74 occurrences in Eagle, Garfield, Grand, Pitkin, Routt, and Summit counties and is found primarily in dry, sagebrush-dominated communities between 6,400 and 9,400 ft. (1,951 and 2,865 m) elevation. Five of the 74 occurrences are partially or entirely located on lands managed by the USDA Forest Service. The total population of *P. harringtonii* is estimated to be at least 43,000 plants within 10,000 acres (roughly 15 square miles) of occupied habitat. Although it is likely that more occurrences will be found with additional surveys, it is not likely that the species will be found to be common outside of its narrow range. NatureServe and the Colorado Natural Heritage Program both rank this species as vulnerable (G3 and S3). USDA Forest Service Region 2 has designated *P. harringtonii* a sensitive species; it is also included on the Bureau of Land Management Colorado State Sensitive Species List. It is not listed as threatened or endangered under the Federal Endangered Species Act, nor is it currently a candidate for listing.

There are several threats to the persistence of *Penstemon harringtonii* including residential and agricultural development, off-road vehicle use, exotic plant species invasion, over-grazing by domestic and wild ungulates, oil and gas development, and climate change. The concentration of these activities within the range and habitat of *P. harringtonii* suggests that this species has experienced a significant downward trend over the past 25 years. Thirty-three percent of the known occupied habitat for *P. harringtonii* is on private lands, and most of these areas are in high demand for residential development because of their proximity to resort communities such as Vail, and rapidly growing communities such as Eagle, Avon, Gypsum, and Edwards. Sagebrush shrublands on private lands within the range of *P. harringtonii* have been developed for agricultural uses; including their conversion to pasture to increase grazing productivity. Motorized recreation is rapidly increasing within the range of *P. harringtonii*, and it can be difficult to enforce regulations or close access to protect occurrences. Oil and gas development are also increasing dramatically within the range of *P. harringtonii* and have already negatively affected at least four occurrences. Over-grazing and weed invasions are also clearly evident in this species' habitat. The primary threats to *P. harringtonii* on National Forest System lands appear to be off-road vehicle use and exotic species invasion.

Land ownership is complex within the range of *Penstemon harringtonii* and even within individual occurrences. This species occurs on lands administered by the Bureau of Land Management (51 percent of the total occupied habitat), the State of Colorado (Division of Wildlife and State Land Board, 8 percent), White River National Forest (8 percent), and hundreds or thousands of private landowners (33 percent). These land ownership patterns make conservation design challenging. Three occurrences are partially within Areas of Critical Environmental Concern administered by the Bureau of Land Management, but these are not designated specifically for the protection of *P. harringtonii*.

Table of Contents

ACKNOWLEDGMENTS 2
AUTHORS' BIOGRAPHIES 2
COVER PHOTO CREDIT 2
SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *PENSTEMON HARRINGTONII* 3
LIST OF TABLES AND FIGURES 6
INTRODUCTION 7
Goal of Assessment 7
Scope of Assessment 7
Treatment of Uncertainty in Assessment 7
Treatment of This Document as a Web Publication 7
Peer Review of This Document 8
MANAGEMENT STATUS AND NATURAL HISTORY 8
Management Status 8
Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies 8
Biology and Ecology 9
Classification and description 9
History of knowledge 10
Non-technical description 11
Published descriptions and other sources 11
Distribution and abundance 13
Population trend 17
Habitat 17
Reproductive biology and autecology 21
Pollinators and pollination ecology 22
Phenology 22
Fertility and propagule viability 22
Dispersal mechanisms 22
Phenotypic plasticity 23
Mycorrhizal relationships 23
Hybridization 23
Demography 23
Community ecology 24
Herbivores 25
Competitors 25
CONSERVATION 26
Threats 26
Habitat conversion to pasturelands 26
Residential development 26
Motorized recreation 27
Exotic species invasions 27
Grazing by domestic and wild ungulates 28
Oil and gas development 28
Global climate change 29
Conservation Status of *Penstemon harringtonii* in Region 2 29
Is distribution or abundance declining in all or part of its range in Region 2? 29
Do habitats vary in their capacity to support this species? 29
Vulnerability due to life history and ecology 30
Evidence of populations in Region 2 at risk 30
Management of *Penstemon harringtonii* in Region 2 30
Implications and potential conservation elements 30
Tools and practices 30
Species inventory 30

Habitat inventory 31
Population monitoring 31
Habitat monitoring 32
Habitat management 32
Beneficial management actions 33
Seed banking 34
Information Needs 34
Distribution 34
Life cycle, habitat, and population trend 34
Response to change 34
Metapopulation dynamics 35
Demography 35
Population trend monitoring methods 35
Restoration methods 35
Research priorities for Region 2 35
DEFINITIONS 37
REFERENCES 39

EDITORS: Janet Coles, Beth Burkhart, and Kathy Roche, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Table 1. Summary information on the 74 known occurrences of *Penstemon harringtonii*. 15

Table 2. List of 143 vascular plant taxa that have been documented one or more times in association with *Penstemon harringtonii*. 19

Figures:

Figure 1. Close up photograph of *Penstemon harringtonii*. 11

Figure 2. Habitat photograph of *Penstemon harringtonii*..... 12

Figure 3. Technical illustration of *Penstemon harringtonii*. 12

Figure 4. Global distribution of *Penstemon harringtonii* in the Rocky Mountain Region (Region 2) of the USDA Forest Service. 13

Figure 5. Distribution of *Penstemon harringtonii* in west-central Colorado. 14

Figure 6. Hypothetical life cycle graph for *Penstemon harringtonii*..... 24

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Penstemon harringtonii* is the focus of an assessment because it is a sensitive species in 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 significant current or predicted downward trends in habitat capability that would reduce its distribution (USDA Forest Service 2002a). A sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *P. harringtonii* throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

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, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

The *Penstemon harringtonii* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of Region 2. Because basic research has not been conducted on many facets of the biology of *P. harringtonii*, literature on its congeners was used to make inferences. Although a majority of the literature on the genus may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *P. harringtonii* 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, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. The assessment emphasizes refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment, however, when information was unavailable elsewhere; these reports were regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of *Penstemon harringtonii*. These data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty in Assessment

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

Treatment of This Document as a Web Publication

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing

them as reports. More importantly, Web publication facilitates the revision of assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project were peer reviewed before their release on the Web. Peer review for this species assessment was administered by the Society for Conservation Biology. Two anonymous reviewers provided input to the draft document. 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

Penstemon harringtonii is a sensitive species in Region 2 (USDA Forest Service 2002a). Within the National Forest System, it is found on the White River National Forest, in the Eagle, Dillon, Holy Cross, and Sopris Ranger Districts. *Penstemon harringtonii* is considered a species of viability concern on the White River National Forest because there are few, relatively small, occurrences on the forest that are vulnerable (USDA Forest Service 2002b) because of anticipated increases in land use and management demands in areas where this species grows (Johnston 2001). Although it has not been documented on the Arapaho-Roosevelt or Routt national forests, occurrences are located less than 2 miles from their boundaries.

Penstemon harringtonii is found on lands administered by the Bureau of Land Management (BLM), Kremmling and Glenwood Springs Field Offices, and it is listed on the BLM Colorado State Sensitive Species List. While it is found on lands managed by the State of Colorado, it does not have any state-level status. *Penstemon harringtonii* is not listed as threatened or endangered under the Federal Endangered Species Act (U.S.C. 1531-1536, 1538-1540) although it was at one time a Category 2 (C2) candidate for listing (O'Kane 1988, Spackman et al. 1997a), a category that is no longer recognized. Category 2 status indicated that although the species may be threatened or endangered, there was not enough information available to substantiate listing under the Endangered Species Act (Spackman et al. 1997a).

NatureServe (2005) considers *Penstemon harringtonii* to be globally vulnerable (G3). Because it is only found in Colorado, it is also considered vulnerable (S3) by the Colorado Natural Heritage Program (2006). It is considered vulnerable because only 19 of the 74 extant occurrences include 500 or more individuals. It is also considered to be vulnerable because much of its habitat is subject to residential and agricultural development, motorized recreation, exotic plants, oil and gas development, over-grazing, and climate change. For explanations of NatureServe's ranking system, see the **Definitions** section of this assessment.

Three occurrences are partially within Areas of Critical Environmental Concern (ACEC), managed by the BLM. Most of one occurrence falls within the Bull Gulch ACEC, and small portions of two occurrences fall within the Deep Creek and Thompson Creek ACECs. Although these ACECs were not designated to protect *Penstemon harringtonii*, they are managed "to provide for natural ecological changes only" (Scheck personal communication 2004). Deep Creek is closed to oil and gas surface facilities and mineral sales. Bull Gulch is closed to oil and gas leasing, and Bull Gulch and Thompson Creek are closed to off-road vehicles. While enforcement of the no-leasing and ecological change restrictions should not be difficult, enforcement of the travel restrictions presents a significant challenge (Scheck personal communication 2004). Most of the Deep Creek and Thompson Creek occurrences fall outside the ACEC boundaries. Residential development is occurring just outside the Thompson Creek ACEC, and the area is being considered for oil and gas development (Scheck personal communication 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

USFS mandates require that activities be managed to avoid disturbances that would result in a trend toward the federal listing or loss of population viability of sensitive species, including *Penstemon harringtonii* (Johnston 2001). Potential habitat must be surveyed before activities that could affect sensitive species (Johnston 2001).

Inclusion of *Penstemon harringtonii* on the Colorado BLM State Director's Sensitive Species List (U.S. Department of the Interior 2002) calls attention to the species as a potential management concern. BLM managers are directed to "conserve sensitive

species and the ecosystem on which they depend, and to ensure that actions authorized or approved by BLM do not contribute to the need to list any special status species" (Scheck personal communication 2004). BLM managers are responsible for collecting and maintaining information on sensitive species "to determine if designation as a candidate or listed species is warranted or if special management considerations are needed" (U.S. Department of the Interior 2002).

There are no laws to protect *Penstemon harringtonii* on state or private lands where much of the known population resides. Thus, current laws and regulations protecting this species may be inadequate to conserve it within its native range.

No management plans have been drafted that specifically address the conservation needs of *Penstemon harringtonii*. As of this writing, a conservation strategy has not been written for this species by the USFS or any other agency. Legal protections in place for this species pertain only to federal public land, but many occurrences are on private or state lands. Because of current human population growth trends and land use plans within the entire global range of this species, extinction is a possibility but not likely given the remote nature of some of the occurrences and the ability of this species to occupy anthropogenically modified areas. Changes in existing land use plans are needed to ensure the long-term viability of occurrences of *P. harringtonii*.

Penstemon harringtonii occurs in about 25 Potential Conservation Areas (PCAs) identified by the Colorado Natural Heritage Program (2006). A PCA is an estimate of the primary area supporting the long-term survival of targeted species and plant communities, based on an assessment of the biotic and abiotic factors affecting the persistence and viability of the targets within the area (Colorado Natural Heritage Program 2006). The 25 identified PCAs include most of the known occurrences of *P. harringtonii*. The Colorado Natural Heritage Program (CNHP) has provided information about these areas to the USFS (Colorado Natural Heritage Program 2003), Summit County (Spackman et al. 1997b), Pitkin County (Spackman et al. 1999), Garfield County (Lyon et al. 2001), and Eagle County (Fayette et al. 2000) to facilitate awareness of this species and its habitat during planning and management activities. PCAs have *not* been delineated for some *P. harringtonii* occurrences, especially in Grand County.

Biology and Ecology

Classification and description

Penstemon harringtonii Penland is a member of the Scrophulariaceae (Snapdragon or Figwort family), a large family that encompasses approximately 3000 species (Cronquist et al. 1984, Zomlefer 1994) and 220 genera (Zomlefer 1994). The Scrophulariaceae is in class Magnoliopsida (dicots), subclass Asteridae, order Scrophulariales (USDA Natural Resources Conservation Service 2004). This family is most diverse in northern temperate regions (Zomlefer 1994). It is characterized by having perfect, showy flowers, which have a superior ovary and a nectariferous disc; the fruit is usually a capsule (Nold 1999) with many small seeds (Zomlefer 1994). The Scrophulariaceae includes popular garden plants such as snapdragons (*Antirrhinum*), veronica (*Veronica*), foxglove (*Digitalis*), monkeyflower (*Mimulus*), and others (Nold 1999).

Schmidel first described the genus *Penstemon* in 1763 (Weber and Wittmann 1992); it is now thought to be one of the largest genera of flowering plants that is (mostly) endemic to North America (Nold 1999). While plants in this genus are found south to Guatemala, their primary distribution is found in Canada, the continental United States, and most Mexican states (Nold 1999). The genus is most diverse in western North America (Buckner and Bunin 1992). The genus *Penstemon* includes approximately 270 species (Nold 1999); 42 species, including *P. harringtonii*, are known from the western slope of Colorado (Weber and Wittmann 2001). One of the most notable characteristics that separate *Penstemon* from other genera in the Scrophulariaceae is that in *Penstemon*, one of the five stamens lacks an anther and instead has a tuft of golden hairs (Weber and Wittmann 2001).

The genus *Penstemon* is divided into six subgenera, which are subdivided into sections and sometimes into subsections. *Penstemon harringtonii* is in the subgenus *Penstemon*, section *Courulei*, which is not divided into subsections (Nold 1999). The closest relatives to *P. harringtonii* are apparently other members of the section *Courulei*, including *P. cyathophorus*, *P. osterhoutii*, *P. pachyphyllus* var. *mucronatus*, *P. fendleri*, *P. secundiflorus*, *P. arenicola*, and *P. angustifolius* var. *vernalensis* on the western slope of Colorado.

History of knowledge

There has been little uncertainty or discussion regarding the taxonomy of plants described as *Penstemon harringtonii*, and contemporary sources agree on the taxonomic placement of these plants (Weber and Wittmann 1992, Kartesz 1999, Weber and Wittmann 2001, USDA Natural Resources Conservation Service 2004, NatureServe 2005).

William Penland of Colorado College first discovered *Penstemon harringtonii* in 1952, 3 to 5 miles north of Green Mountain Reservoir in Grand County, Colorado. Penland used this specimen to describe *P. harringtonii* in a 1958 issue of Madroño (Penland 1958), naming the species for his colleague, who was also one of Colorado's premier botanists, Professor H.D. Harrington of Colorado State University. While reviewing specimens for publication of this new taxon, Penland evidently discovered two other collections of *P. harringtonii* from 1951 that are noted in the original description (Penland 1958). One of these collections was made by H.D. Harrington 5 miles east of Wolcott, in Eagle County, and the other was made by Norton and Norton 2 miles north of McCoy, in Routt County.

From the time of its discovery in the early 1950s until 1982, *Penstemon harringtonii* was documented at only one other location; in 1955 Harrington collected a specimen 5 miles northeast of State Bridge in Eagle County, Colorado. In 1982, Western Resource Development Corporation of Boulder, Colorado conducted a regional study of the distribution of *P. harringtonii* and identified several new locations (Western Resources Development Corporation 1982). Other botanists such as Scott Peterson, John Anderson, Betsy Neely, Sandy Righter, Tamara Naumann, David Buckner, and Jane Bunin identified additional locations in the 1980s, and William Weber and Ronald Wittmann collected a specimen at the only documented location for Summit County (Colorado Natural Heritage Program 2006).

By this time *Penstemon harringtonii* had been given Category 2 (C2) status and was being considered by the U.S. Fish and Wildlife Service (USFWS) for listing under the federal Endangered Species Act (Buckner and Bunin 1992). Although this category is no longer used, C2 status was assigned to taxa for which appropriate or substantial biological information was inadequate to support listing (Spackman et al. 1997a).

In 1988, Steve O'Kane published *Colorado's Rare Flora*, which included *Penstemon harringtonii*. At this time, a total of 13 *P. harringtonii* occurrences had been documented (Colorado Natural Heritage Program 2006). O'Kane (1988) suggested that although several occurrences of *P. harringtonii* were threatened by grazing, vacation home, and ski resort development, if additional habitat was found that was not threatened, then the species could be lowered to category 3C. Category 3C was used by the USFWS to designate taxa that proved to be more abundant or widespread than was previously believed (Spackman et al. 1997a).

From 1988 to 1992, 13 more occurrences of *Penstemon harringtonii* were located, bringing the total to 26 occurrences (Colorado Natural Heritage Program 2006). In 1992, David Buckner and Jane Bunin wrote a status report for *P. harringtonii* for the U.S. Fish and Wildlife Service (Buckner and Bunin 1992) and recommended that *P. harringtonii* be listed as Threatened under the Endangered Species Act. They based their recommendation on known threats, especially to occurrences in the Eagle River Valley, and their expert opinion that although there was additional potential habitat for *P. harringtonii* that had not been surveyed, it was unlikely that additional research would discover enormous numbers of plants (Buckner and Bunin 1992). At this time population estimates totaled approximately 8,000 to 10,000 individuals (Buckner and Bunin 1992) within 26 occurrences (Colorado Natural Heritage Program 2006).

During the remainder of the 1990s, numerous botanists who were aware of the significance of *Penstemon harringtonii* conducted surveys within its known range and the surrounding areas (Spackman et al. 1997b, Spackman et al.1999, Fayette et al. 2000, Scheck personal communication 2004, Colorado Natural Heritage Program 2006). In all, 23 new locations were documented, bringing the total to 49 occurrences. Also during this time, *P. harringtonii* was documented in Garfield and Pitkin counties, increasing the total county distribution to six.

Between 2000 and 2005, the BLM and USFS conducted surveys for *Penstemon harringtonii*, and 24 additional locations were documented (Dworak personal communication 2004, Klish personal communication 2004, Lyon personal communication 2004, Scheck personal communication 2004, Colorado Natural Heritage Program 2006), bringing the totals to 40,000 to 43,000 plants in 74 occurrences.

Non-technical description

Penstemon harringtonii plants are perennial and 30 to 70 cm tall, typically with a single unbranched stem. Flowers are pink to purple to blue, bilaterally symmetrical, and arranged in loose spikes on the upper half of the stems. An easily recognizable flower feature is that the two lower stamens are exserted (stick out of the flower tube). The leaves of *P. harringtonii* are thick, rounded and elongate in shape, bluish gray in color, and are arranged opposite each other along the flowering stem and also in a basal rosette at the base of the plants. The largest leaves are those in the basal rosette (Buckner and Bunin 1992, Spackman et al. 1997a, Lyon et al. 2001).

Penstemon harringtonii is most similar in appearance to *P. osterhoutii* (Osterhout's beardtongue) and *P. cyathophorus* (sagebrush beardtongue). All three species grow in sagebrush habitats in central Colorado and are sometimes found growing together. The most reliable characteristic for distinguishing these species is the position of the stamens in the corolla throat. In *P. harringtonii*, two stamens are exserted. In *P. osterhoutii*, the stamens are not or are scarcely exserted, and *P. cyathophorus* has four stamens exserted (Penland 1958, Spackman et al. 1997a). These three species are difficult to identify with certainty unless in full bloom, as their rosettes are indistinguishable to the untrained eye.

Three other *Penstemon* species often found with *P. harringtonii* include *P. watsonii*, *P. strictus*, and *P. caespitosus*. However, these species are easily distinguished from *P. harringtonii*, even when the flowers are not present (Lyon personal communication 2004).

Published descriptions and other sources

The best source for a description, range map, illustration, and photographs of *Penstemon harringtonii* and its habitat is the *Colorado Rare Plant Field Guide* (Spackman et al. 1997a). **Figure 1**, **Figure 2**, and **Figure 3** are photographs of *P. harringtonii* and its habitat and the illustration included in Spackman et al. (1997a). A close-up photograph and a range map appear in *Rare Plants of Colorado* (Colorado Native Plant Society 1997), and photographs of the plant and its habitat are also included in the USFWS *P. harringtonii* status report (Buckner and Bunin 1992). The original description in Penland (1958) also includes an illustration, and descriptions are available in floras and other references (e.g., Nold 1999). Weber and Wittmann (2001) is the most readily available and up-to-date source with keys for field identification, but it does not include a full description.

The type specimen of *Penstemon harringtonii* is housed at the Colorado College Herbarium, with isotypes stored in herbaria at the University of Colorado, Colorado State University, Harvard University, New York Botanical Garden, Rocky Mountain Herbarium, University of California, and the Smithsonian (Buckner and Bunin 1992). A digital image of Penland's isotype specimen is available from the New York Botanical Garden's website (New York Botanical Garden 2003).

Figure 1. Close up photograph of *Penstemon harringtonii* by Peggy Lyon. Used with permission.

Figure 2. Habitat photograph of *Penstemon harringtonii* by Peggy Lyon. Used with permission.

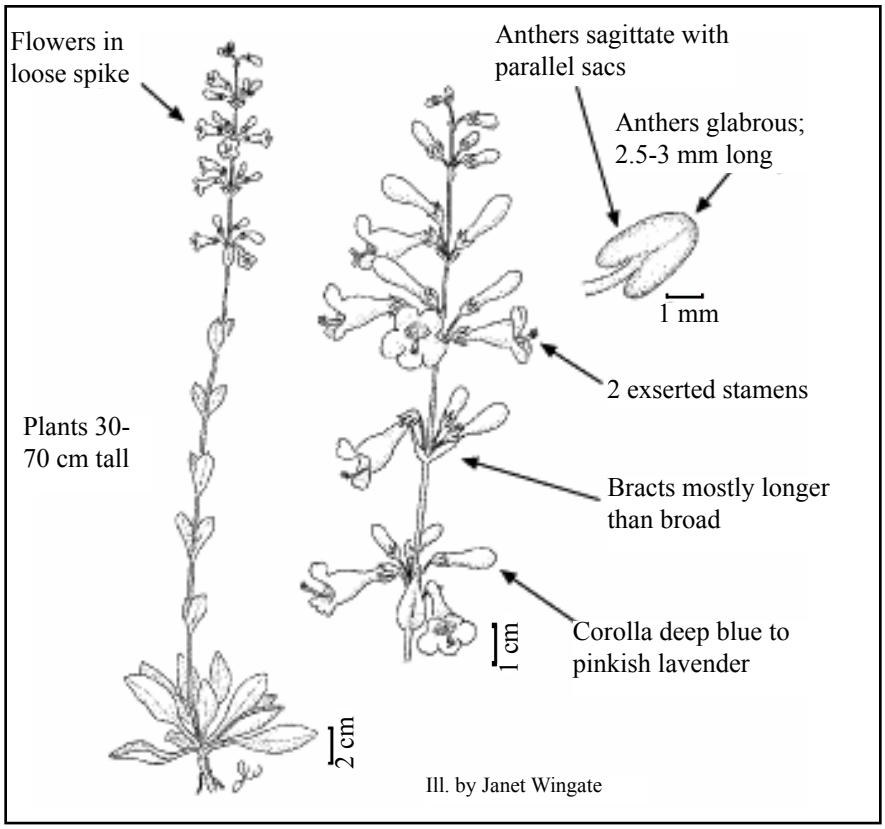

Figure 3. Technical illustration of *Penstemon harringtonii* by Janet Wingate from the Colorado Rare Plant Field Guide (Spackman et al. 1997a). Used with permission.

Distribution and abundance

Penstemon harringtonii is a narrowly endemic species known from 74 occurrences in an approximately 82 by 48 mile range in northwestern Colorado (**Figure 4**, **Figure 5**). Fifty occurrences of *P. harringtonii* are in Eagle County, nine are in Garfield County, four are in Grand County, five in Pitkin County, five in Routt County, and one in Summit County. The known occurrences are estimated to contain a total of 40,000 to 43,000 individuals occupying less than 10,000 acres (Colorado Natural Heritage Program 2006). Only parts of this species' range have been thoroughly inventoried, and many population estimates are based on observations of only a portion of the occurrences (Scheck personal communication 2004, Colorado Natural Heritage Program 2006). For this reason, while it is possible that some of the population estimates are optimistic, it is also possible that some of the occurrences are much larger than the reported numbers. For example, the BLM has conducted many surveys for *P. harringtonii* over the past 10 years that target specific areas of management concern (e.g., proposed pipelines or gas wells). *Penstemon harringtonii* is documented only from the area of concern although surveyors sometimes indicate that the occurrence size is probably much larger (Scheck personal communication 2004). Another example is during a 1992 survey for *P. harringtonii* in Eagle County (Western Resource Development 1992), the researchers extrapolated population size estimates based on counts in randomly located plots within sagebrush habitat identified from aerial photographs (Johnson personal communication 2002). They estimated 300,000 to 500,000 individuals

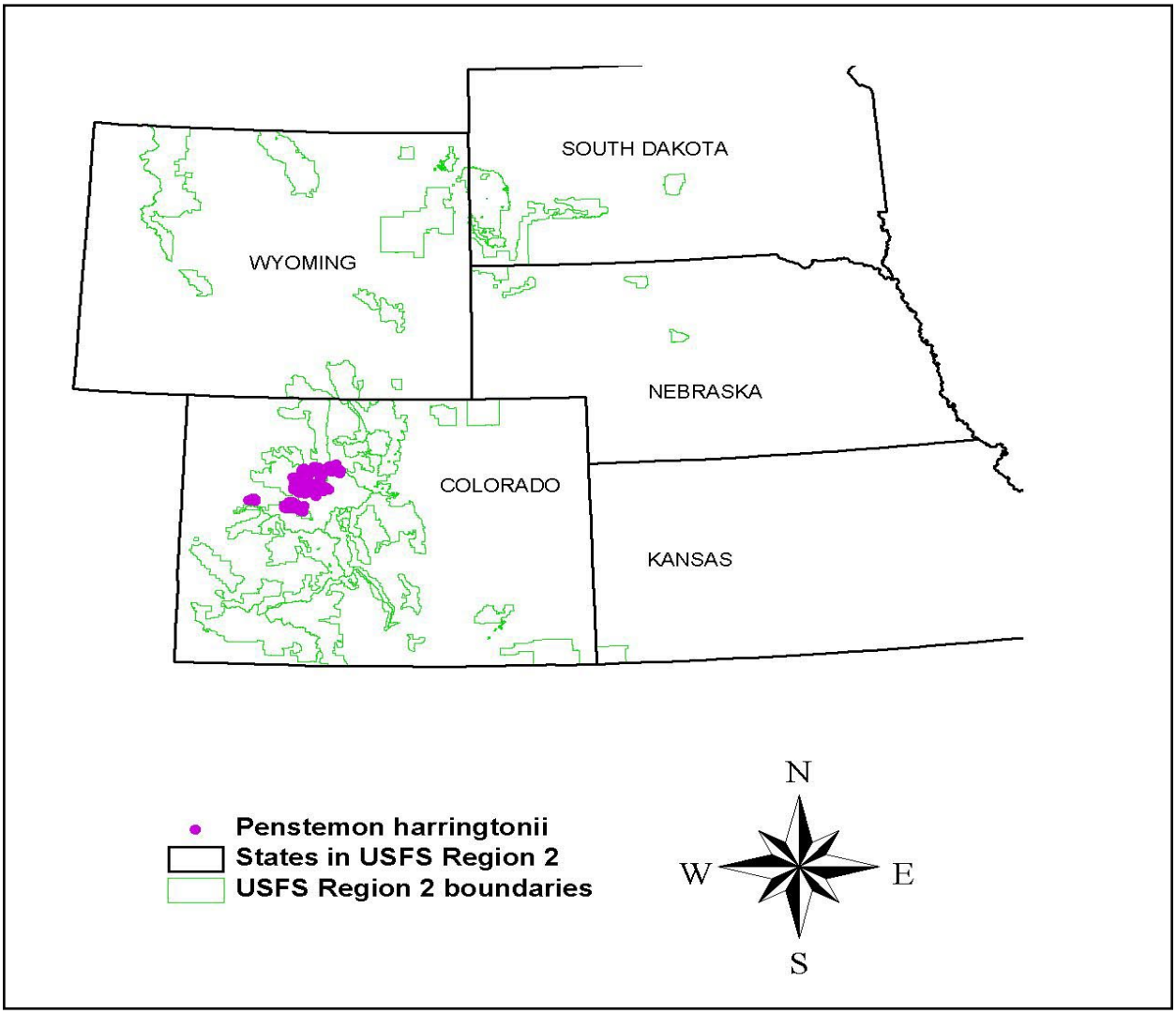

Figure 4. Global distribution of *Penstemon harringtonii* in the Rocky Mountain Region (Region 2) of the USDA Forest Service.

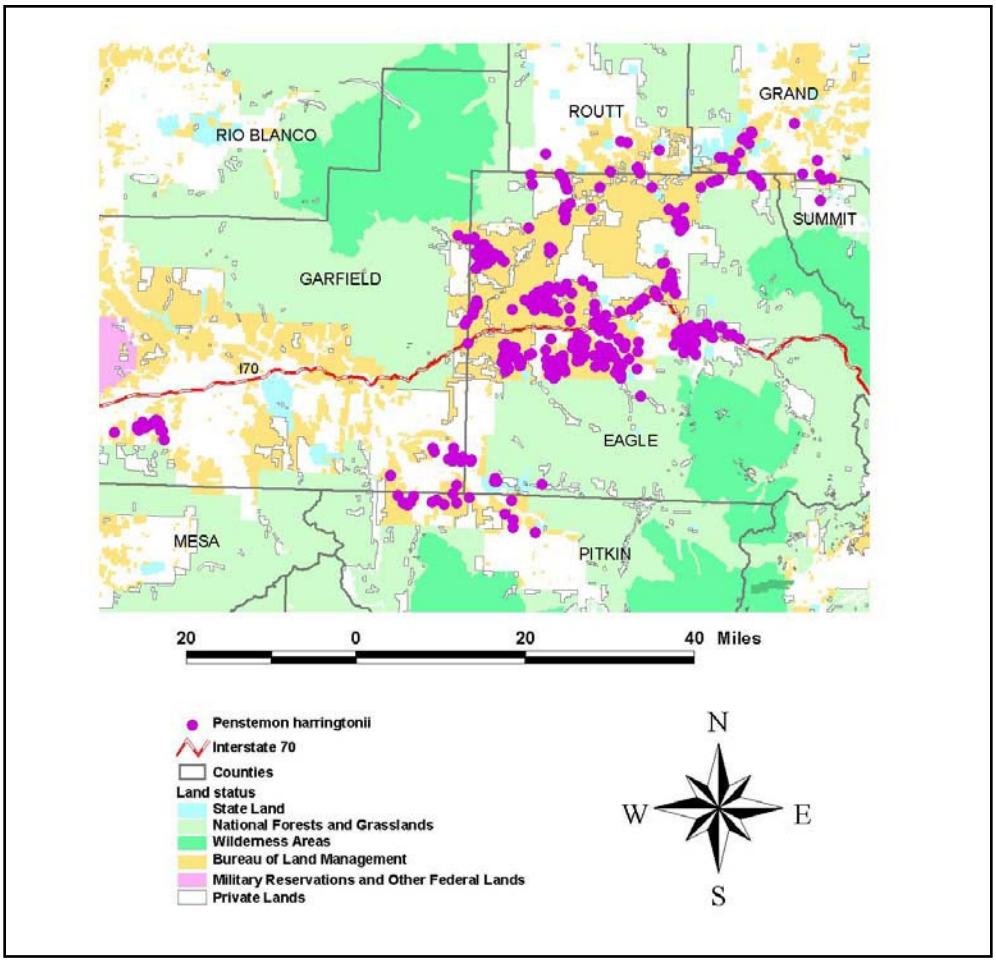

Figure 5. Distribution of *Penstemon harringtonii* in west-central Colorado.

of *P. harringtonii* in a 132-acre area (Western Resource Development 1992). However, their estimates assumed a uniform distribution of *P. harringtonii* and are thought to be far too high (Scheck personal communication 2004). Western Resource Development's extrapolated numbers are not included in the estimated totals used in this report; rather, we include only totals for areas actually observed. Carla Scheck, BLM ecologist, has documented numerous occurrences of *P. harringtonii*, and she believes that with additional inventory, the global population of *P. harringtonii* may be around 300,000 to 500,000 individuals (Scheck personal communication 2004). An additional complication to obtaining a total population count is the fact that the abundance of *P. harringtonii* varies dramatically from year to year (Buckner and Bunin 1992, Denver Botanic Garden 2003, Dawson personal communication 2004, Lyon personal communication 2004, Scheck personal communication 2004).

Penstemon harringtonii has been found on USFS, BLM, State of Colorado, and private lands (**Figure 4**, **Figure 5**, **Table 1**). Only five occurrences are on National Forest System land, and all of these are managed by the White River National Forest. At least one of these occurrences is only partially on National Forest System land. Many occurrences are close to National Forest System boundaries of the White River, Routt, and Arapaho-Roosevelt national forests (**Figure 5**). In particular, four additional of the 74 occurrences are likely to occur on National Forest System land (**Table 1**). Observers of these occurrences indicated that the plants were on National Forest System land (Colorado Natural Heritage Program 2006); however, the maps provided by the observers do not overlap USFS boundaries (Colorado Natural Heritage Program 2006). White River National Forest biologist Keith Giezentanner (personal communication 2004) confirmed that potential habitat for *P. harringtonii* exists on National Forest System land near all of the occurrences that are possibly on National Forest System land (**Table 1**).

Table 1. Summary information for the 74 known occurrences of *Penstemon harringtonii*. There may be more than one observer for each occurrence. All USDA Forest Service (USFS) occurrences are on the White River National Forest, and are listed in bold. For the occurrences listed as possibly on USFS, the observers indicated that the occurrence was on USFS lands. However, the maps provided by the observers do not currently overlap with the USFS boundaries. In all cases, these are in closest proximity to the White River National Forest.

CNHP EO number[1]	County	Land ownership/management	Estimated number of individuals	Estimated area (acres)[2]	Date last observed
1 ("North of Edwards and Avon" in Johnston 2001)	**Eagle**	**USFS; private**	**2970 (about 172 on USFS)**	**59.3**	**06/25/2001**
2	Grand	Colorado Division of Wildlife (CDOW), Radium State Wildlife Area; private	250 to 393	1,000 to 1,200	07/05/2005
3	Routt	State of Colorado	20 to 50	1.5	06/11/1993
4	Grand	State of Colorado	50	11	07/05/2005
5	Grand	Colorado Department of Transportation; private	237	30	06/21/2005
6 (listed as 15 in Buckner and Bunin 1992)	Eagle	Private; **possibly USFS**, (Buckner and Bunin 1992)	2,400	3,046	06/11/2001
7	Grand	Bureau of Land Management (BLM)	50	6	06/27/2005
8	Eagle, Routt	BLM	200	20 to 80	06/06/1999
9 ("Southeast of Eagle" in Johnston 2001)	Eagle	Private; BLM; **possibly USFS** (Johnston 2001)	4,144 to 5,144	1,133	06/27/2003
10	Eagle	Private	53	40	06/13/2003
11	Eagle	BLM; private	1,000	331	06/10/2003
13	Eagle	BLM	300 to 500	12	06/26/2003
14	Garfield	BLM; private	not available (NA)	NA	08/13/1997
16	Eagle	BLM	800	27	06/09/2001
17	Routt	Private	150	30	06/21/1991
18	Eagle	Private	70	0.1	06/11/1991
19	Routt	Private	7	0.05	06/11/1991
20	Eagle, Garfield	BLM	3,000	NA	06/06/1999
21	Garfield	Private	51	0.3	06/16/1997
22	Pitkin	BLM	86	15 to 20	1997
23	Summit	Unknown	NA	NA	06/24/1982
24	Garfield, Pitkin	BLM	806 to 956	90	06/16/1998
25	Pitkin	BLM	45 to 50	25	June 1995
26 (listed as 30 in Buckner and Bunin 1992)	Routt	Private; **possibly USFS** (Buckner and Bunin 1992)	96	15	June 1991
27	Eagle	Private	30	0.1	07/05/1995
28	Eagle	CDOW, Christine State Wildlife Area	50 to 100	3	06/25/1997
29	Garfield	BLM	100	20 to 30	07/02/1995
30	Eagle, Garfield	BLM	1,000 to 1,400	510	06/06/2000
31 ("East of Basalt" in Johnston 2001)	**Eagle**	**USFS, Taylor Creek**	**75 to 100**	**2.5**	**06/11/1998**
32	Pitkin	BLM	100	10	1997
33	Pitkin	BLM; private	100	10	06/23/1993
35	Garfield	BLM; private	6,294 to 6,494	200	07/01/2004
36	Pitkin	BLM	200	30	06/16/1998
38	Eagle	BLM	1	NA	06/15/1993
39	Routt	Private; BLM	710	12 to 17	06/16/2004

Table 1 (concluded).

CNHP EO number[1]	County	Land ownership/management	Estimated number of individuals	Estimated area (acres)[2]	Date last observed
40	Eagle, Garfield	Private	280	NA	June 1999
41	Eagle	BLM	100	NA	06/20/1999
42	Eagle	BLM	1	NA	06/12/1999
43	Eagle	Private	50	NA	07/06/1999
44	Eagle	BLM	4	NA	06/18/1999
45	Eagle	BLM	40	NA	06/20/1999
46	Eagle	BLM	100	NA	06/21/1999
90	Eagle	BLM	265	9	06/03/2001
91	Garfield	BLM	415	36	06/17/2004
92	Eagle	BLM	1,000	50	06/09/2003
93	Eagle	BLM; private	50	40	06/13/2003
94	Garfield	BLM	4,770	53 to 63	06/08/2003
95	Eagle	BLM	0 to 30	10	08/05/2004
96	Eagle	BLM	100	40	06/12/2003
97	Eagle	BLM	50 to 75	5 to 10	06/06/2002
98	Eagle	BLM	50	5	06/25/2002
99	Eagle	BLM	151	30	06/01/2001
100	Eagle	BLM; private	1,500	15	06/04/2001
101	Eagle	BLM; private; State of Colorado; **possibly USFS** (Buckner and Bunin 1992)	102	1,170	06/09/1999
102	Eagle	Private	22	1	06/11/1991
103	Eagle	BLM	4	NA	06/27/2003
104	Eagle	BLM	189	NA	06/27/2003
105	Eagle	BLM	439	15	06/26/2003
106	Eagle	BLM	21	NA	06/27/2003
107	Eagle	BLM	17	NA	06/26/2003
108	Eagle	BLM	38	NA	06/24/2003
109	Eagle	BLM	17	NA	06/20/2003
110	Eagle	BLM	25	NA	06/25/2003
111	Eagle	BLM	422	NA	06/25/2003
112	Eagle	BLM	544	NA	06/25/2003
113	Eagle	BLM	851	NA	06/26/2003
114	Eagle	BLM	109	NA	06/18/2003
115	Eagle	BLM	325	NA	06/20/2003
116	Eagle	Private	400	1	06/24/2003
117	Garfield	Private; BLM	968	1.5	July 2004
118	Eagle	BLM	600 to 1,000	30	06/24/2004
new	**Garfield**	**USFS, White River NF, Eagle Ranger District; private**	**500**	**50**	**06/06/2005**
new	**Eagle**	**USFS, White River NF, Holy Cross Ranger District**	**4**	**NA**	**06/07/2005**
new	**Eagle**	**USFS, White River NF, Holy Cross Ranger District**	**19**	**1.5**	**06/21/2005**
Total of 74 occurrences	**Eagle, Grand, Routt, Pitkin, Summit, Garfield**	**BLM; private; State of Colorado; USFS.**	**39,997-42,645 total individuals documented**	**8252 to 8548 acres total occupied habitat reported**	**1982-2005**

[1]Colorado Natural Heritage Program Element Occurrence Number (Colorado Natural Heritage Program 2004)

[2]Estimates of occurrence area are the visual estimates provided by observers. The total area mapped by observers and then calculated using ArcView is 10,126 acres.

Several botanical surveys since 1995 have targeted *Penstemon harringtonii* (e.g., Spackman et al. 1997b, Spackman et al. 1999, Fayette et al. 2000, Lyon et al. 2001, Lyon and Huggins 2003, Dworak personal communication 2004, Klish personal communication 2004, Scheck personal communication 2004). These surveys led to the discovery of many additional occurrences and sub-occurrences; the conclusion is that there is much habitat that remains to be searched, and there are many more occurrences to be documented (Lyon personal communication 2004, Scheck personal communication 2004). Limited access to remote areas and private land makes it difficult to search some areas thoroughly. While it is possible that the species is limited to the range as we know it, additional inventory is necessary to confirm this assumption.

There has been no rigorous quantification of the abundance of *Penstemon harringtonii*. It is known from 74 occurrences, but the majority of the individuals are found in about 20 occurrences, and only 19 occurrences are thought to have 500 or more individuals (**Table 1**). The total number of individuals is estimated to be between 40,000 and 43,000 plants (Colorado Natural Heritage Program 2006) but may be as high as 300,000 to 500,000 (Scheck personal communication 2004). Most occurrences have between 20 and 300 plants (Colorado Natural Heritage Program 2006). The approximate total known from National Forest System land is fewer than 4,000 individuals (Johnston 2001) and may be as few as 770 individuals (Colorado Natural Heritage Program 2006).

There has been no rigorous quantification of the total area occupied by *Penstemon harringtonii*. While some botanists have reported estimates of total occurrence extent, others have drawn polygons on maps that represent larger areas (Colorado Natural Heritage Program 2006). The estimate of total occupied area for the species ranges from 8,200 to 10,000 acres (roughly 15 square miles; **Table 1**). Based on conversations with people doing field surveys, it is likely that actual occupied habitat is larger (Scheck personal communication 2004).

Population trend

Human impacts to *Penstemon harringtonii* individuals and habitat resulting from residential and infrastructure development, agricultural and recreational use, exotic species invasion, over-grazing, and oil and gas development activities suggest that there has been a significant downward trend (Buckner personal communication 2006, Colorado Natural Heritage Program 2006, Grant personal communication 2006, Jennings personal communication 2006). While loss of habitat and anthropogenic disturbance of habitat has probably caused a downward trend since the area was settled approximately 140 years ago, the rate of decline has probably increased in the past 25 years, keeping pace with property and natural resource development.

The Denver Botanic Gardens, in cooperation with the BLM, began a 10-year population monitoring program of *Penstemon harringtonii* at two occurrences on BLM lands in 1996. Preliminary results presented in 2003 (after eight years of monitoring) indicate that there have been statistically significant population increases and decreases among years at both study sites (Denver Botanic Gardens 2003). More information is needed to infer the population trend of *P. harringtonii* range-wide. The density of sagebrush, and the amount and timing of seasonal precipitation are thought to influence numbers of *P. harringtonii* (Denver Botanic Gardens 2003). Sagebrush density within the habitat of *P. harringtonii* may have a strong influence because the sagebrush may compete with *P. harringtonii* for a limited supply of soil moisture (Denver Botanic Gardens 2003, but see Nielson 1998).

Populations fluctuate naturally due to annual climatic variation (Buckner and Bunin 1992). As *Penstemon harringtonii* is apparently a stress-tolerant species, juvenile and adult plants may be capable of surviving years with low precipitation. In favorable years, large numbers of plants flower (Buckner and Bunin 1992, Dawson personal communication 2004, Lyon personal communication 2004, Scheck personal communication 2004). At two study sites, Denver Botanic Garden researchers observed more plants and rosettes in years with higher annual rainfall (Denver Botanic Gardens 2003). These annual population fluctuations make it difficult to assess long-term population trends accurately without a great deal of data gathered from sites throughout the range of *P. harringtonii*.

Habitat

Penstemon harringtonii is usually found in open sagebrush shrublands on gentle slopes between 6,400 and 9,400 ft. (1,951 and 2,865 m) elevation (Colorado Natural Heritage Program 2006). This community type is a part of the Inter-Mountain Basins Big Sagebrush Shrubland ecological system (NatureServe 2005), in the north-central portion of the Southern Rocky Mountain Ecoregion (Bailey 1995).

The habitat for *Penstemon harringtonii* has been described as sagebrush shrubland and as mixed mountain shrubland (Colorado Natural Heritage Program 2006). *Penstemon harringtonii* is usually found in open stands of *Artemisia tridentata* ssp. *vaseyana* (mountain sagebrush) or *A. tridentata* ssp. *wyomingensis* (Wyoming sagebrush) with a diverse understory. Researchers have documented *P. harringtonii* as occurring with *A. tridentata* without recording the subspecies, which can be difficult to differentiate. Peggy Lyon (personal communication 2004) has only found *P. harringtonii* with the two sagebrush subspecies mentioned above, and not with *A. tridentata* ssp. *tridentata* (basin big sagebrush). Some of the largest populations of *P. harringtonii* are found in areas where sagebrush is mixed with *Cercocarpus montanus* (mountain mahogany) and *Amelanchier utahensis* (Utah serviceberry).

Mature pinyon-juniper woodlands often surround the shrublands that support *Penstemon harringtonii*, and *Pinus edulis* (pinyon pine) and *Juniperus osteosperma* (Utah juniper) are frequently scattered within the sagebrush habitat. Most *Penstemon harringtonii* plants occur within sagebrush shrublands while adjacent pinyon-juniper areas tended to have *P. osterhoutii*. However, *P. harringtonii* plants very rarely have been documented in pinyon-juniper woodlands, and in some cases *P. osterhoutii* plants are mixed with *P. harringtonii* in sagebrush (Colorado Natural Heritage Program 2006).

The vascular plant species most commonly associated with *Penstemon harringtonii* include *Artemisia tridentata* var. *wyomingensis*, *A. tridentata* var. *vaseyana*, *Juniperus osteosperma*, Cercocarpus montanus, *Amelanchier utahensis*, *Quercus gambelii* (Gambel's oak), *Chrysothamnus viscidiflorus* (yellow rabbitbrush), *C. nauseosus* (rubber rabbitbrush), *Phlox hoodii* (spiny phlox), *Castilleja flava* (yellow Indian paintbrush), *Eriogonum umbellatum* (sulphur flower buckwheat), *Heterotheca villosa* (hairy goldenaster), *Mahonia repens* (Oregon grape), *Oreocarya flava* (yellow cats-eye), *Penstemon caespitosus* (mat penstemon), *P. strictus* (Rocky Mountain penstemon), *Poa fendleriana* (muttongrass), *Achnatherum hymenoides* (Indian ricegrass), *Pascopyrum smithii* (western wheatgrass), *Pseudoroegneria spicata* (bluebunch wheatgrass), *Koeleria macrantha* (junegrass), *Hesperostipa comata* (needle and thread grass), and *Elymus elymoides* (squirreltail) (Buckner and Bunin 1992, Colorado Natural Heritage Program 2006). Biological soil crust or ground lichen is also common. The total bare ground/rock/lichen cover is often as high as 20 to 30 percent (Fayette et al. 2000). **Table 2** is a complete list of all 143 vascular plants that have been documented with *Penstemon harringtonii*.

It is not known whether *Penstemon harringtonii* is limited to specific geologic substrates or soils. The soils where it is found are typically loams and clay loams derived from calcareous parent materials, especially Pleistocene gravels, but also limey shales, limestones, and other rocks (Buckner and Bunin 1992). One researcher notes that *P. harringtonii* is found very predictably on Pleistocene terraces and pediments where the shale substrate is covered by a layer of coarse alluvium (Coles personal communication 2006). The soils in *P. harringtonii* habitat have also been described as dry, rocky, stony, gravelly, sandy, gritty, deep, shallow, red, reddish tan, brown, gray, clod-like, hard packed, porous, and firm (Colorado Natural Heritage Program 2006). The parent material has been described as sandstone, granite, basalt, volcanic, and colluvial (Colorado Natural Heritage Program 2006). Several occurrences document the Niobrara Formation as the parent material (Colorado Natural Heritage Program 2006).

Penstemon harringtonii has been documented on all aspects (Colorado Natural Heritage Program 2006) and on slopes as steep as 50 percent, but it is usually found on slopes of less than 20 percent (Colorado Natural Heritage Program 2006).

Penstemon harringtonii is occasionally found along roadsides and in disturbed areas such as cow trails or naturally eroding slopes (Buckner and Bunin 1992, Nold 1999, Lyon and Huggins 2003, Colorado Natural Heritage Program 2006). In disturbed sites, it may be associated with non-native species such as yellow sweet clover (*Melilotus officinalis*), smooth brome (*Bromopsis inermis*), and musk thistle (*Carduus nutans*). In most of the sagebrush parks on BLM land in Eagle County, the sagebrush has been removed by a rotary chopper within the last 30 years, sometimes more than once; *P. harringtonii* is known to occur in many of these areas (Scheck personal communication 2004). The habitat supporting *P. harringtonii* also has a long history of grazing by wild ungulates and domestic livestock (Buckner and Bunin 1992). These and other associated activities may have influenced local soil and vegetation patterns, and may be partially responsible for the conditions to which *P. harringtonii* is adapted.

Characteristics of high-quality and marginal habitat are not clearly defined for *Penstemon harringtonii*. Areas with natural vegetation and minimal

Table 2. List of 143 vascular plant taxa that have been documented one or more times in association with *Penstemon harringtonii* (Colorado Natural Heritage Program 2004). Eleven plants listed in bold are not native to Colorado (Weber and Wittmann 2001). Three plants on the Colorado Noxious Weed List are indicated following the common name (Colorado Department of Agriculture 2003). *Penstemon cyathophorus*, underlined, is rare in Colorado (Colorado Natural Heritage Program 2004).

Scientific name	Common name	Scientific name	Common name
Abronia elliptica	fragrant white sand verbena	*Castilleja chromosa*	northwestern Indian paintbrush
Agoseris laciniata var. *dasycephala*	false dandelion	*Castilleja flava*	yellow Indian paintbrush
Agropyron cristatum	**crested wheatgrass**	*Castilleja linariifolia*	Wyoming Indian paintbrush
Agropyron sp.	wheatgrass	*Castilleja* sp.	Indian paintbrush
Agropyron spicatum = Pseudoroegneria spicata	bluebunch wheatgrass	*Cercocarpus montanus*	Alderleaf mountain mahogany
Allium sp.	onion	*Chaenactis* sp.	pincushion
Amelanchier sp.	serviceberry	*Chaetopappa ericoides*	rose heath
Amelanchier utahensis	Utah serviceberry	*Chrysothamnus nauseosus*	rubber rabbitbrush
Androsace sp.	rockjasmine	*Chrysothamnus parryi*	Parry's rabbitbrush
Antennaria rosea	rosy pussytoes	*Chrysothamnus* sp.	rabbitbrush
Antennaria sp.	pussytoes	*Chrysothamnus viscidiflorus*	ellow rabbitbrush
Artemisia frigida	prairie sagewort	*Chrysothamnus viscidiflorus* var. *lanceolatus*	yellow rabbitbrush
Artemisia sp.	sagebrush	*Clematis* sp.	leather flower
Artemisia tridentata = Seriphidium tridentatum	big sagebrush	*Comandra umbellata*	bastard toadflax
Artemisia tridentata ssp. vaseyana	mountain big sagebrush	*Crepis acuminata*	tapertip hawksbeard
Artemisia tridentata ssp. wyomingensis	Wyoming sage	*Crepis intermedia = Psilochenia intermedia*	limestone hawksbeard
Astragalus lonchocarpus	rushy milkvetch	*Cryptantha fendleri*	sanddune cryptantha
Astragalus sp.	milkvetch	*Cryptantha* sp.	cryptantha
Astragalus tenellus	looseflower milkvetch	***Dactylis glomerata***	**orchardgrass**
Astragalus wingatanus	Fort Wingate milkvetch	*Delphinium* sp.	larkspur
Balsamorhiza sagittata	arrowleaf balsamroot	*Descurainia* sp.	tansymustard
Bromus inermis	**smooth brome**	*Elymus elymoides=Sitanion hystrix*	squirreltail
Bromus tectorum	**cheatgrass, noxious weed**	*Elymus trachycaulus*	slender wheatgrass
Calochortus nuttallii	sego lily	*Erigeron concinnus*	Navajo fleabane
***Cardaria* sp.**	**whitetop**	*Erigeron* sp.	fleabane
Carduus nutans	**nodding plumeless thistle, noxious weed**	*Eriogonum* sp.	buckwheat
Carex filifolia	threadleaf sedge	*Eriogonum umbellatum*	Arrowleaf buckwheat
Carex nubicola	cloud sedge	*Erysimum* sp.	wallflower
Carex sp.	sedge	*Festuca idahoensis*	Idaho fescue
Carex stenochlaena	northern singlespike sedge	*Frasera speciosa*	elkweed
Castilleja angustifolia	northwestern Indian paintbrush	*Geranium* sp.	geranium

Table 2 (cont.).

Scientific name	Common name	Scientific name	Common name
Geum triflorum	old man's whiskers	*Penstemon watsonii*	Watson's penstemon
Gilia sp.	gilia	*Phlox longifolia*	longleaf phlox
Gutierrezia sarothrae	threadleaf snakeweed	*Phlox* sp.	phlox
Gutierrezia sp.	snakeweed	*Physaria acutifolia*	sharpleaf twinpod
Hedysarum boreale	Utah sweetvetch	*Pinus edulis*	twoneedle pinyon
Hedysarum boreale	hairy false goldenaster	*Poa fendleriana*	muttongrass
Juniperus communis	common juniper	***Poa pratensis***	**Kentucky bluegrass**
Juniperus (= *Sabina*) *osteosperma*	Utah juniper	*Poa secunda*	Sandberg bluegrass
Juniperus scopulorum	Rocky Mountain juniper	*Poa* sp.	bluegrass
Koeleria cristata = macrantha	prairie Junegrass	*Potentilla* sp.	cinquefoil
Koeleria sp.	Junegrass	*Pseudotsuga menziesii*	Douglas-fir
Krascheninnikovia lanata	winterfat	*Purshia tridentata*	antelope bitterbrush
Lappula redowskii	flatspine stickseed	*Quercus gambelii*	Gambel oak
Leptodactylon pungens	granite prickly phlox	*Sedum lanceolatum*	spearleaf stonecrop
Linum sp.	flax	*Senecio multilobatus*	lobeleaf groundsel
Lithospermum ruderale	tern stoneseed	*Senecio* sp.	ragwort
Lupinus sp.	lupine	***Sonchus arvensis***	**field sowthistle, noxious weed**
Lygodesmia grandiflora	largeflower skeletonplant	*Sphaeralcea coccinea*	scarlet globemallow
Machaeranthera grindelioides	rayless tansyaster	*Sphaeralcea parvifolia*	smallflower globemallow
Mahonia repens	creeping barberry	*Sporobolus contractus*	spike dropseed
Melilotus officinalis	**yellow sweetclover**	*Sporobolus* sp.	dropseed
Mertensia sp.	bluebells	*Stanleya pinnata*	desert princesplume
Opuntia fragilis	brittle pricklypear	*Stenotus armerioides*	thrift mock goldenweed
Opuntia polyacantha	plains pricklypear	*Stipa comata = Hesperostipa comata*	needle and thread
Opuntia sp.	pricklypear	*Stipa lettermanii = Achnatherum*	Letterman's needlegrass
Oryzopsis hymenoides = Achnatherum hymenoides	Indian ricegrass	*Stipa* sp.	needle and thread
Oryzopsis sp.	ricegrass	*Symphoricarpos albus*	common snowberry
Oxytropis lambertii	purple locoweed	*Symphoricarpos occidentalis*	western snowberry
Oxytropis sp.	locoweed	*Symphoricarpos rotundifolius*	roundleaf snowberry
Pascopyrum smithii = Agropyron smithii	western wheatgrass	***Taraxacum officinale***	**common dandelion**
Pascopyrum sp.	wheatgrass	*Tetradymia canescens*	spineless horsebrush
Pediocactus simpsonii	Simpson hedgehog cactus	*Tetradymia* sp.	horsebrush
Penstemon caespitosus	mat penstemon	***Thlaspi arvense***	**field pennycress**
Penstemon cyathophorus	sagebrush beardtongue	*Townsendia incana*	hoary Townsend daisy
Penstemon osterhoutii	Osterhout's beardtongue	*Townsendia* sp.	Townsend daisy
Penstemon strictus	Rocky Mountain penstemon	*Toxicoscordion venenosum*	meadow deathcamas

Table 2 (concluded).

Scientific name	Common name	Scientific name	Common name
Trifolium gymnocarpon	hollyleaf clover	*Wyethia sp.*	mule-ears
Trifolium sp.	clover	*Zigadenus sp.*	deathcamas
Vicia sp.	vetch		

impact from human activities and that support dense populations probably are the best examples of high quality habitat. From this standpoint, the best sites are at Hardscrabble (CNHP occurrences 9 and 103 through 115), the South Ridge of Greenhorn Mountain (CNHP occurrence 11), Sheep Creek (CNHP occurrence 20), Deep Creek (CNHP occurrence 30), Flatiron Mesa (CNHP occurrence 35) and the Crown (CNHP occurrence 24) (**Table 1**; Colorado Natural Heritage Program 2006). Documentation of these and similar sites is a high priority for *P. harringtonii*.

To obtain information on the local climate at the *Penstemon harringtonii* sites, we referred to data collected between 1948 and 2004 and compiled by the Western Regional Climate Center (2003). The closest weather stations that approximate the elevation range of the populations of *P. harringtonii* are in Eagle and Vail, Eagle County, Colorado. The weather station at Eagle is at approximately 6,500 ft., and the station in Vail is at approximately 8,200 ft. There were no data available for a comparable site at the upper end of the elevational range of *P. harringtonii* (9,400 ft.). At the Eagle weather station the average annual precipitation is 11 inches, and the average annual snowfall is 48 inches. The Vail weather station receives twice as much rain as the Eagle station (22 inches annually on average) and nearly four times as much snowfall (186 inches annually on average). At both stations, in July, when *P. harringtonii* is probably most actively growing, the average maximum temperatures are at their highest (Vail: 78 ºF, Eagle: 85 ºF), average minimum temperatures are at their highest (Vail: 40 ºF, Eagle: 46 ºF), and monthly precipitation is relatively high at 1 to 2 inches.

Reproductive biology and autecology

Penstemon harringtonii is a perennial plant species that may persist as a rosette for one or more years before flowering. It is thought to be a long-lived species that relies more on long-term survival of reproductive adults than on annual reproductive capability (Scheck personal communication 2004, Buckner personal communication 2006, Grant personal communication 2006). Observations suggest that mature plants may persist underground for one or more years between flowering events (Scheck personal communication 2004, Buckner personal communication 2006). In most years less than 50 percent of the plants produce flowering stalks, and seedlings are hardly ever observed (Scheck personal communication 2004, Buckner personal communication 2006, Grant personal communication 2006, Lyon personal communication 2006). These factors suggest that *P. harringtonii* recruitment may be episodic, with seeds persisting in the seed bank, and mature plants persisting aboveground or underground.

Penstemon harringtonii reproduces sexually and primarily by insect pollination (Tepedino 1996). It is self-compatible (capable of self-fertilization, both autogamous and geitonogamous) but sets more fruit when cross-pollinated by insects (Tepedino 1996, Nielson 1998). Sexual reproduction is probably important for *P. harringtonii* in that it allows the plants to maintain the genetic diversity necessary to cope with changing environmental conditions (Tepedino 1996). It does not appear to reproduce asexually by clonal growth based on the widely spaced pattern of individual plants, as well as the root structure that is not likely to give rise to new individuals (Buckner and Bunin 1992).

Although *Penstemon harringtonii* is not usually found in disturbed sites, it does tolerate some disturbance; it has been found along roads, trails, fencerows, and power lines, on eroding slopes, and in areas that are grazed by deer, elk, cattle and sheep (Colorado Natural Heritage Program 2006). *Penstemon harringtonii* also occurs in burned areas and in areas where the sagebrush has been removed with a rotary chopper (Scheck personal communication 2004). In general, the disturbance that *P. harringtonii* appears to tolerate is light, involving some removal or trampling of vegetation, but not disrupting or removing the soil profile (Scheck personal communication 2004). However, while *P. harringtonii* has some affinity for disturbed areas, it also persists in climax vegetation, such as grassy meadows with little bare ground, old-age sagebrush parks with encroaching pinyon and juniper trees, and other areas with well-developed vegetation (Colorado Natural Heritage Program 2006). Although *P. harringtonii* has been documented in disturbed areas, more study is needed to determine how plants respond to disturbance.

Pollinators and pollination ecology

Penstemon harringtonii has several adaptations that promote outcrossing by insect pollination. The brightly colored, conspicuous flowers are effective for attracting pollinators, and the flowers are scented (Nielson 1998). At the base of two of the four stamen filaments, *Penstemon* flowers have nectary glands that also serve to attract insects (Thomson et al. 1998).

The genus *Penstemon* uses a variety of insect pollinators including dipterans, hymenopterans, and lepidopterans. Some *Penstemon* species are hummingbird-pollinated (Straw 1966). Many penstemons rely on a specific pollinator (Straw 1956), especially a group of small bees in the genus *Osmia* (Crosswhite and Crosswhite 1966). In pollination studies of *P. harringtonii* conducted at five sites in 1993 and 1994, Nielson (1998) observed 34 species of insects making contact with the flowers of *P. harringtonii*. The primary pollinators appeared to be bees in the family Megachilidae, including seven species of *Osmia*, and wasps in the family Masaridae (Nielson 1998). Tepedino (1996) also observed that the primary pollinators of *P. harringtonii* are bees. Based on relationships observed with other *Penstemon* species (Crosswhite and Crosswhite 1966, Tepedino et al. 1997), it is likely that one or more species in the genus Osmia (Megachilidae) are very important pollinators, and it is possible that they may have a mutualistic relationship with *P. harringtonii* (Nielson 1998). Nielson (1998) also found that the insect taxa and visitation rates varied from site to site and from year to year. Different pollinators may be utilized by *P. harringtonii* depending on the timing of flowering (Nielson 1998). Reliance on a broad suite of pollinators probably buffers plants from population swings of any one pollinator (Parenti et al. 1993). Nielson (1998) found that *P. harringtonii* plants are not pollen-limited, so although the relative importance of specific pollinators has not been determined, pollination does not appear to be a limiting factor for this species.

Although common wisdom holds that pollinators are attracted to denser floral resources, Nielson (1998) found that *Penstemon harringtonii* plants that were closely aggregated produced less fruit than widely spaced individuals. This may be because the aggregated plants suffer from inbreeding depression or resource competition (Nielson 1998).

Pollen presentation theory studies the way plants control pollen transfer based on their pollination mechanisms (Thomson et al. 1998). For example, plants may make only small amounts of pollen available for each visitor if visits are frequent, or they may make more pollen accessible if visits are infrequent. Flowers may also be shaped differently in order to accommodate different pollinators, such as birds or insects. Pollen presentation theory guides the study of how plants evolve the ways they control pollen transfer, and how they shift their systems (e.g., from bee to bird pollination) over time (Thomson et al. 1998). In an effort to test pollen presentation theory adequately, Thomson and his colleagues (1998) are reconstructing the phylogeny of the genus *Penstemon*. They have gathered leaf material from *P. harringtonii* and have leaves, seeds, and/or DNA extracted from at least 125 *Penstemon* species.

Phenology

In most years, *Penstemon harringtonii* begins flowering in early June at low elevation sites, and in late June at higher elevation sites (Buckner and Bunin 1992). The development of fruit proceeds through late August, at which time the capsules dehisce. Seeds are dispersed by September, but the capsules remain attached to the plant indefinitely (Buckner and Bunin 1992). Because *P. harringtonii* occurs in xeric sites, the periodicity of successful recruitment may coincide with wet or otherwise favorable years during which seedlings can become established (Buckner and Bunin 1992, Denver Botanic Gardens 2003).

Fertility and propagule viability

In general, *Penstemon* species of dry or harsh climates germinate less easily than species from more mesic areas, such as the eastern United States (Swayne 2000). Seeds often need to be exposed to long periods of dry conditions, moist cold stratification, or periods of temperature variation (Swayne 2000). These conditions are meant to mimic the natural conditions in which germination occurs for each species. For many *Penstemon* species, germination is irregular and occurs over a long period of time (Swayne 2000). Germination may not occur until the second or third year after the seeds are set (Swayne 2000). For *P. harringtonii*, Swayne (2000) recommends that the seed be sown, barely covered for 8 weeks at 40 ºF (4 ºC), and that germination occur at 40 ºF, under light.

Dispersal mechanisms

Little is known about how *Penstemon harringtonii* becomes established in new sites. Nothing is known about seed production, dispersal, dormancy, or germination requirements, seedling vigor, age of

plants, or interaction with predators (Buckner and Bunin 1992). There are no known dispersal adaptations of the seeds or fruit of *P. harringtonii*. The seeds are probably too large to be carried by wind, and they lack wings or other appendages that would promote dispersal by wind or animals (Straw 1966). *Penstemon harringtonii* is probably dispersed by surface flow of water and granivorous rodents (Buckner and Bunin 1992). Lyon and Huggins (2003) observed that, in some cases, *P. harringtonii* appeared to follow cow trails across a hillside, suggesting that their seeds may be dispersed via the intestinal tracts or hooves of cattle. Alternatively, this could indicate only that these areas lacked competing vegetation. Although the longevity and dormancy of the seeds of *P. harringtonii* have not been studied, Heidel and Shelly (2001) found that seeds of *P. lemhiensis* (Lemhi penstemon) remain viable for at least six years.

Phenotypic plasticity

Penstemon harringtonii does not exhibit a great degree of phenotypic plasticity. Plants vary in size, stature, and reproductive effort, probably due to year-to-year variations in climate (Dawson personal communication 2004, Lyon personal communication 2004). There is some variation in the purple to pinkish coloring of the corolla (Colorado Natural Heritage Program 2006); this may be due to the age of the flower.

Mycorrhizal relationships

Roots of *Penstemon harringtonii* have not been assayed for the presence of mycorrhizal symbionts. Arbuscular mycorrhizal (AM) fungi have been reported to form symbioses with at least one member of the genus *Penstemon* (Titus and Tsuyuzaki 2002). AM fungi belong to a group of nondescript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). While AM fungi are generally thought to have low host specificity, there is increasing evidence for a degree of specificity between some taxa (Rosendahl et al. 1992, Sanders et al. 1996). While this group has not previously been thought of as particularly diverse, recent studies suggest that there is unexpectedly high diversity at the genetic (Sanders et al. 1996, Varma 1999) and single plant root levels (Vandenkoornhuyse et al. 2002). As root endophytes, the hyphae of these fungi enter the cells of the plant roots where water and nutrients are exchanged in specialized structures.

Hybridization

Hybridization has not been documented in *Penstemon harringtonii* although there are congeners in the immediate vicinity with which it could exchange pollen. Its closest relatives are *P. osterhoutii* and *P. cyathophorus*, and gene flow between species is possible. No hybrid plants or hybrid characteristics of any herbarium specimens have been reported.

Demography

Maintaining genetic integrity and preventing inbreeding depression are important conservation considerations for *Penstemon harringtonii*. Since it is primarily an outcrossing species, small occurrences are vulnerable to inbreeding depression or limited pollinator activity. Given the moderate degree of disturbance and fragmentation of *P. harringtonii*'s habitat, it is possible that genetic diversity is being lost. Maintaining distinct genetic populations and natural levels of gene flow are also important for its conservation.

The lifespan of *Penstemon harringtonii* has not yet been determined through demographic studies or observations. There are no data regarding the proportion of individuals within an occurrence that reproduce in a given year. For a hypothetical life cycle graph for *P. harringtonii* please see **Figure 6**.

No Population Viability Analysis (PVA) has been performed for *Penstemon harringtonii*. Apparently there has never been a PVA of any member of the genus *Penstemon* from which inferences could be drawn for this report. Two species of *Penstemon* (*P. penlandii* and *P. haydenii*) are currently listed as endangered (U.S. Fish and Wildlife Service 2004), but PVAs of these species have not been conducted (U.S. Fish and Wildlife Service 1992a, 1992b).

Annual precipitation and competition with hydraulic lifting species such as sagebrush are hypothesized to be the main determinants for seedling establishment, survival, and seed production in *Penstemon harringtonii* (Denver Botanic Gardens 2003). Although relatively wet years appear to promote an increase in overall plant numbers, researchers at the Denver Botanic Gardens (2003) found that over an

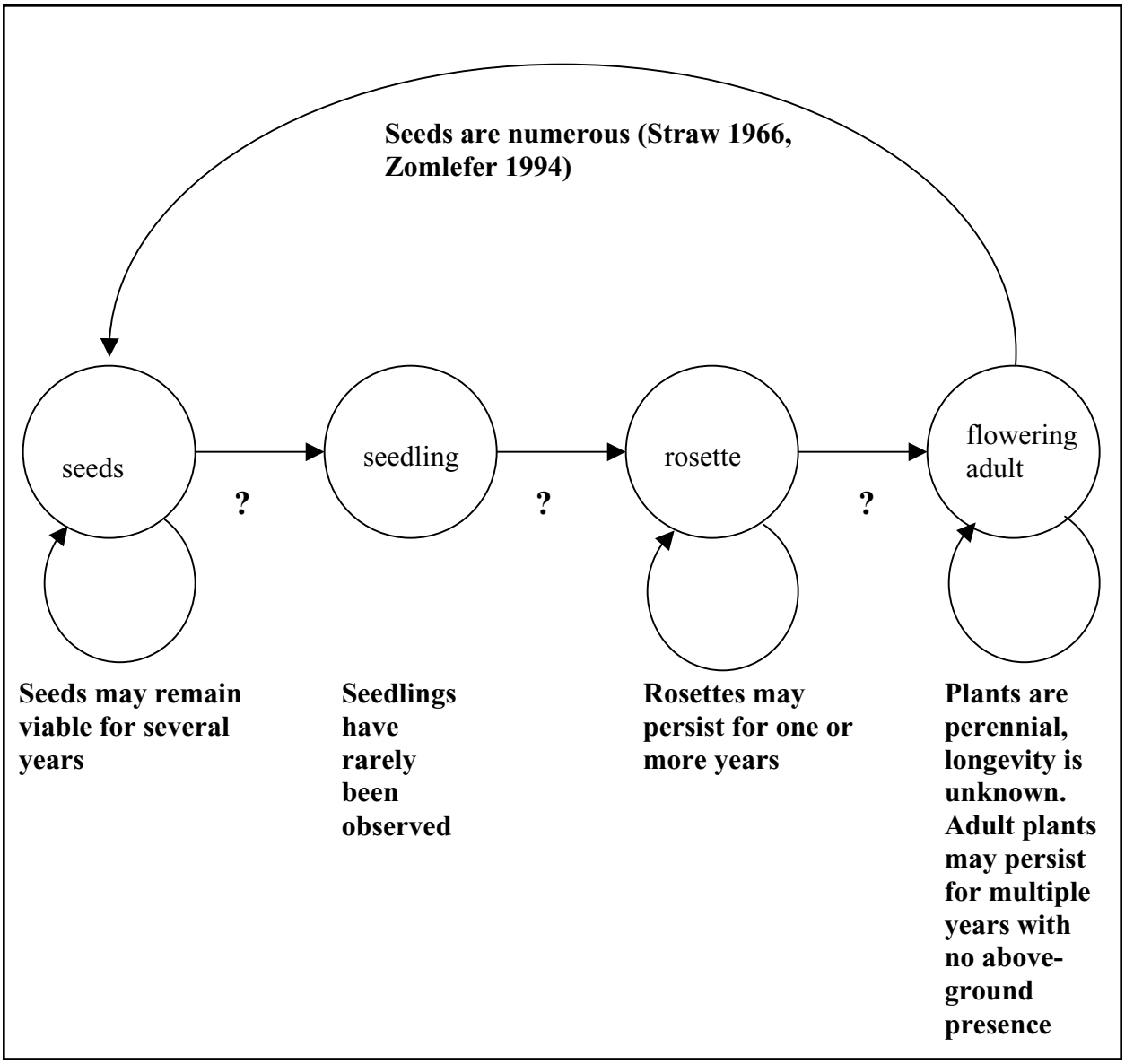

Figure 6. Hypothetical life cycle graph (after Caswell 2001) for *Penstemon harringtonii*, including the known life history stages gleaned from limited observations and from information on other species of *Penstemon*.

eight-year period at two sites, plants produced fewer flowers and less fruit in years with greater annual rainfall. Mortality is probably highest in hot, dry years.

As a habitat specialist of sagebrush shrublands, occurrences of *Penstemon harringtonii* are naturally limited by habitat availability. It is not known if *P. harringtonii* is seed-limited or what factors control seedling recruitment success. Plant fecundity does not appear to be holding back the distribution of *P. harringtonii*. Human impacts may be responsible for limiting population growth. Habitat destruction and fragmentation are occurring throughout the area occupied by *P. harringtonii*.

It is not known how long the seeds of *Penstemon harringtonii* survive. In their studies of *P. lemhiensis*, Heidel and Shelly (2001) found that the seed banks remain viable for at least six years. Increased germination and recruitment of *P. lemhiensis* tends to happen during years of high moisture and cool temperatures or after disturbance such as fire (Heidel and Shelly 2001).

Community ecology

Penstemon harringtonii is restricted to sagebrush habitats on the west slope of Colorado. This corresponds with the Inter-Mountain Basins Big

Sagebrush Shrubland ecological system as defined by NatureServe (2005). In the past, this habitat has been used primarily for grazing and, on a more limited basis, for crops, in which case the sagebrush is completely removed. Thus some of the natural vegetation and associated species for *P. harringtonii* may have been disrupted or removed. It is likely that the community type in this area was dominated by sagebrush with bunchgrasses such as *Pseudoroegneria spicata* (bluebunch wheatgrass). Overgrazing appears to modify the sagebrush community in two ways: 1) in mesic sites *Balsamorhiza sagittata* (arrowleaf balsamroot) and *Wyethia amplexicaulis* (mule ears) increase as does the overall forb cover; 2) in xeric sites the herbaceous cover decreases and the sagebrush cover increases, leaving sagebrush and bare ground. *Penstemon harringtonii* is rarely found in the first scenario but appears to tolerate the second (Fayette et al. 2000).

Table 2 is a list of all of the vascular plant species that have been documented in association with *Penstemon harringtonii*. *Penstemon harringtonii* is not described as dominant or co-dominant in any of the plant communities that it occupies. In some cases, the sagebrush stands in which *P. harringtonii* occurs are being invaded by pinyon and juniper trees. This encroachment could eventually out-compete or shade *P. harringtonii* (Scheck personal communication 2004).

Herbivores

Predation by insects or mammals may limit *Penstemon harringtonii* growth and reproduction. Research conducted by the Denver Botanic Gardens (2003) found that there was an inverse relationship between herbivore damage and the percentage of plants producing fruits. They did not differentiate between insect and mammal herbivory, only whether or not herbivory occurred.

Several researchers have noted that many *Penstemon harringtonii* plants have had the top half of the flower stems eaten off (Colorado Natural Heritage Program 2006, Lyon personal communication 2006). USFS biologist Keith Giezentanner found several piles of two to six such flower tops moved away from the parent plants, and not eaten. Giezentanner speculates that golden-mantled ground squirrels or chipmunks are the likely culprits (Giezentanner personal communication 2004). Rabbits (Scheck personal communication 2004) and cows (Lyon personal communication 2006) may also be responsible for this activity. Most of the areas where herbivory is documented are grazed by cattle, but cattle have not definitively been determined to be browsing *P. harringtonii*. Deer, elk, sheep, and small mammals are also present in areas supporting *P. harringtonii*. At least one researcher noted signs of deer nipping buds of *P. harringtonii* (Colorado Natural Heritage Program 2006).

Although grazing animals may eat the flowers and thereby limit reproductive potential, the basal rosette is compact and low to the ground. Buckner and Bunin (1992) suggest that the leathery leaves of *Penstemon harringtonii* are probably not palatable to cattle, deer, and elk, but they may be attractive to sheep and goats.

In 1990, *Penstemon harringtonii* plants in the vicinity of the Eagle River and the Colorado River exhibited signs of predation by a very small beetle (Buckner and Bunin 1992). The entire corolla, ovary, and much of the calyx were eaten. In some subpopulations, this insect predation appeared to eliminate the potential for reproduction (Buckner and Bunin 1992). Researchers who have observed *P. harringtonii* since 1991 have not mentioned this sort of predation (Colorado Natural Heritage Program 2006). Lyon and Huggins (2003) mention that there was no evidence of insect herbivory on *P. harringtonii* during extensive surveys in 2003. The specific responses of *P. harringtonii* to herbivore damage have not been investigated.

Competitors

There has been no formal study of the community ecology and interspecific relationships of *Penstemon harringtonii*. As a habitat specialist of open sagebrush shrublands, *P. harringtonii* may be a poor competitor (Buckner and Bunin 1992), which may leave it vulnerable to negative impacts from introduced species. Even when the sagebrush in *P. harringtonii* habitat becomes moderately dense, such as at the Dry Lake site north of Gypsum (Buckner and Bunin 1992, Denver Botanic Gardens 2003), the herbaceous layer is sparse (Buckner and Bunin 1992).

Sagebrush is thought to be a particularly effective competitor because it is able to draw water from deep in the soil column and make the water available to the upper layers by hydraulic lifting (Denver Botanic Gardens 2003). However, Nielson (1998) found that there was no difference in seed set between *Penstemon harringtonii* plants growing within sagebrush canopies versus those growing in the open. This suggests that sagebrush is not a significant competitor with *P. harringtonii*. Plants may have benefited from the shade provided by the sagebrush canopy even though some

water was lost (Nielson 1998). *Penstemon harringtonii* is often found in protected sites under sagebrush shrubs (Lyon personal communication 2004, Scheck personal communication 2004).

Grazing by wild or domestic ungulates may serve to benefit *Penstemon harringtonii* by reducing competition (Buckner and Bunin 1992). Additionally, *P. harringtonii* is found in coarse, calcareous, and excessively well-drained soils that are not favorable to many plants. These conditions may reduce overall levels of competition for *P. harringtonii* (Buckner and Bunin 1992).

CONSERVATION

Threats

Threats to the persistence of *Penstemon harringtonii* include habitat conversion to cropland and pasture, residential development, motorized recreation, exotic species invasions, grazing by domestic and wild ungulates, oil and gas development, and climate change. Each occurrence of *P. harringtonii* is not necessarily threatened by each of these factors. The specific threats vary from site to site, and more complete information on the biology and ecology of this species may reveal other threats. Assessment of threats to this species will be an important component of inventory and monitoring studies.

It is possible that in spite of the threats detailed below, the population of *Penstemon harringtonii* is large enough to survive (Lyon personal communication 2004, Scheck personal communication 2004). However, the cumulative effects of all threats must also be considered. Only about 11 of the 74 occurrences do not have significant management concerns (Colorado Natural Heritage Program 2006). Few protective measures are in place to assure the persistence of this species in the context of human population growth intensifying land use.

One potential threat that is not detailed below but could occur is spraying insecticides on rangeland to control grasshoppers. Tepedino (1996) warns that this could have serious implications for the pollinators of *Penstemon harringtonii*. Scheck (personal communication 2004) indicates that the BLM has not done any pesticide applications within the range of *P. harringtonii* in the past 12 years.

Habitat conversion to pasturelands

One of the greatest threats to sagebrush habitats and *Penstemon harringtonii* is conversion to pasture to increase grazing productivity for cattle, sheep, horses, deer, and elk. Sagebrush shrublands have been chained, burned, and sprayed with herbicides (Denver Botanic Gardens 2003, Colorado Natural Heritage Program 2006), diminishing their extent in the Intermountain West (Cronquist et al. 1986). It is not known how much sagebrush conversion has occurred or is planned in relation to specific occurrences of *P. harringtonii*. Further research is warranted to determine the extent of these activities and how they affect the distribution and abundance of *P. harringtonii*.

Residential development

At least 10 of the 74 occurrences of *Penstemon harringtonii* are affected by residential development and associated infrastructures, such as roads and power lines (Colorado Natural Heritage Program 2006). Thirty-three percent of the occupied habitat documented for *P. harringtonii* is on private lands (Colorado Natural Heritage Program 2006). Based on the distribution of this species in relation to areas that are rapidly being developed, it is likely that more occurrences have been or will be impacted by these activities. Eagle, Edwards, Gypsum, Avon, Beaver Creek, Rifle, Carbondale, Basalt, and Snowmass are the towns in closest proximity to occurrences of *P. harringtonii*. These areas have grown substantially in the past 25 years (Colorado Division of Wildlife 2004) and are developing rapidly as popular tourist destinations and sites for second homes. For example, the human population of Eagle County increased by 90 percent (from 21,928 to 41,659 people) from 1990 to 2000 (Colorado Division of Wildlife 2004).

Penstemon harringtonii has been documented in remnant sagebrush stands within housing developments (Colorado Natural Heritage Program 2006). Plants have been found under and along power lines, along roads, within landscaped yards of newly constructed homes, within native sagebrush shrublands surrounding houses that are not landscaped, and adjacent to several golf courses (Colorado Natural Heritage Program 2006). We take this as evidence that many individual plants have been lost, and that development has fragmented the sagebrush habitat of *P. harringtonii*.

A part of at least one occurrence has been extirpated by road construction (Buckner and Bunin 1992). In the Eagle River Valley, residential and commercial development likely destroyed undocumented occurrences, and parts of others were destroyed by construction activities in 1990 and 1991 (Buckner and Bunin 1992).

Motorized recreation

Motorized recreation (including all-terrain vehicles, dirt bikes, four-wheel drive vehicles, motorcycles, and snowmobiles) poses a significant threat to the quality and availability of habitat for *Penstemon harringtonii*. Individual plants are lost, and the sagebrush habitat is fragmented and degraded by motorized recreation. Motorized recreation has been observed at 11 occurrences (Colorado Natural Heritage Program 2006), and is increasing throughout the area (Lyon personal communication 2004, Scheck personal communication 2004). It is possible that motorized recreation is occurring at other occurrences. In some cases, the motorized vehicle trails through *P. harringtonii* habitat are described as abundant and having a heavy impact (Colorado Natural Heritage Program 2006). The White River National Forest Land and Resource Management Plan (USDA Forest Service 2002b) calls for limiting motor vehicles to established routes. However, it is extremely difficult for the USFS to enforce these regulations since vast areas of land are overseen by relatively few people (Johnston personal communication 2004).

Most of the areas where motorized recreation is occurring in *Penstemon harringtonii* habitat on BLM land are currently designated "open for travel on and off roads" in the 1984/1988 BLM resource management plan (Scheck personal communication 2004). BLM staff recognize that this represents a resource conflict where *P. harringtonii* is found, but the travel designations are not scheduled for amendment until revision of the resource management plan, which will begin in 2006 (Scheck personal communication 2004). At least two of the highest quality locations known for *P. harringtonii*, Hardscrabble and East of Blowout Hill, are threatened by motorized vehicle use (Colorado Natural Heritage Program 2006). Many of the occurrences in the East of Blowout Hill area are in a Special Recreation Management Area that is specifically being developed for recreational use (Scheck personal communication 2004).

While its primary impact on *Penstemon harringtonii* is reduction of habitat, motorized recreation also affects individuals and occurrences directly and indirectly. Disturbed sites may harbor fewer species of pollinators for *P. harringtonii* than natural sites. Motorized recreation in the range of *P. harringtonii* fragments natural habitat. Roads may act as barriers to pollinators and prevent gene flow by disrupting the movement of pollinators. In addition to damaging *P. harringtonii* directly, motorized recreation has destroyed cryptobiotic crusts and other vegetation, and it has encouraged the invasion of weeds such as cheatgrass (*Bromus tectorum*; Lyons and Huggins 2003).

Despite the increase in motorized recreation and the threats that this activity poses to *Penstemon harringtonii* and other native species, it is difficult for the USFS and BLM to close roads because of strong public interest in accessing these areas. The lack of specific information regarding impacts to *P. harringtonii* weakens arguments for road closure.

Although the Bull Gulch and Thompson Creek ACECs are closed to off-road vehicle use (Scheck personal communication 2004), only very small portions of *Penstemon harringtonii* occurrences are within these boundaries. Another occurrence of *P. harringtonii* that has some protection from motor vehicle use is an area east of Eagle that is "designated for travel on existing roads only" (Scheck personal communication 2004). BLM, the town of Eagle, and other cooperators have rallied to uphold this designation and to close and reclaim roads and trails that multiplied through the area during the time that the designation was in place but not enforced (Scheck personal communication 2004).

Exotic species invasions

A total of 11 exotic plant species have been documented with *Penstemon harringtonii*: cheatgrass (*Bromus tectorum*), crested wheatgrass (Agropyron cristatum), dandelion (*Taraxacum officinale*), field pennycress (*Thlaspi arvense*), Kentucky bluegrass (*Poa pratensis*), musk thistle (*Carduus nutans*), perennial sow-thistle (*Sonchus arvensis*), orchardgrass (*Dactylis glomerata*), smooth brome (*Bromopsis inermis*), white top (*Cardaria* spp.), and yellow sweet clover (*Melilotus officinale*) (Colorado Natural Heritage Program 2006). One or more of these non-native plants is found in at least 21 occurrences of *P. harringtonii*. Several are aggressive weeds that have invaded native sagebrush shrublands throughout Colorado and pose a serious potential threat to *P. harringtonii* and its habitat. Three are included on the state noxious weed list for Colorado: cheatgrass, musk thistle, and perennial sow

thistle. Weeds generally become established following disturbance, such as that created by roads; roaded areas that support *P. harringtonii* are more vulnerable to the spread of non-natives. Several researchers have noted that weeds are becoming a serious problem in *P. harringtonii* habitat (Colorado Natural Heritage Program 2006).

Cheatgrass is the most frequently documented non-native associated with *Penstemon harringtonii* habitat, and it is particularly problematic. In several cases, cheatgrass dominance appears to mark the boundary of *P. harringtonii* occurrences, even though potential habitat extends into the cheatgrass-dominated area (Scheck personal communication 2004, Colorado Natural Heritage Program 2006). Invasion of sagebrush shrublands by cheatgrass increases the likelihood of fire, after which sagebrush must resprout from seed. This can lead to dominance by cheatgrass and other non-natives, rather than sagebrush (Bunting et al. 1987 as cited in Johnston et al. 1999). Cheatgrass invasion is the primary concern in occurrences managed by the USFS (Doer personal communication 2006).

Researchers have also noted five other noxious weeds near *Penstemon harringtonii* occurrences: common mullein (*Verbascum thapsus*), Canada thistle (*Cirsium arvense*), houndstongue (*Cynoglossum officinale*), dame's rocket (*Hesperis matronalis*), and Dalmatian toadflax (*Linaria dalmatica*); two other non-natives that could pose a competitive threat to *P. harringtonii* include alfalfa (*Medicago* sp.), and shasta daisy (*Leucanthemum maximum*) (Colorado Natural Heritage Program 2006). To date, however, none of these have been documented in association with *P. harringtonii* (Colorado Natural Heritage Program 2006). The proximity of these invasive species to occurrences of *P. harringtonii* suggests that if the habitat is disturbed, they could expand into the disturbed areas and outcompete *P. harringtonii* or prevent establishment of the plant in potential habitat (Scheck personal communication 2004).

Grazing by domestic and wild ungulates

The predominant land use for *Penstemon harringtonii* habitat is domestic cattle grazing (Colorado Natural Heritage Program 2006). Researchers report that at least 20 occurrences of *P. harringtonii* have been, or are being used for cattle grazing (Colorado Natural Heritage Program 2006). At least one occurrence, and possibly more, is used for grazing domestic sheep (Colorado Natural Heritage Program 2006).

While conversion of sagebrush shrublands to pasture presents a significant threat because the habitat for *Penstemon harringtonii* is severely modified, livestock grazing itself does not necessarily have detrimental effects, as long as the grazing is not too heavy (Colorado Natural Heritage Program 2006). USFS biologist Keith Giezentanner (personal communication 2004) noticed that *P. harringtonii* was more common on the grazed side of a uniform hillside in the Taylor Creek area, one of the five locations known on National Forest System land. However, when cattle are present, researchers have noted that they are trampling many plants, compacting soil, and apparently eating flowers before seeds have matured and dispersed. Cattle grazing is known to reduce the availability of water in sagebrush systems (Johnston et al. 1999, Rondeau 2000). Range development projects (e.g., fences, stock ponds) may threaten occurrences of *P. harringtonii*. Although these generally affect small, localized areas, the cumulative effects may be significant for some occurrences (Scheck personal communication 2004).

Deer and elk also use *Penstemon harringtonii* habitat, and in some cases the use is described as heavy (Colorado Natural Heritage Program 2006). Further research is needed to determine the effects of cattle, sheep, deer, and elk grazing on occurrences of *P. harringtonii*.

Oil and gas development

At least four occurrences of *Penstemon harringtonii* have been impacted by oil and gas development (CNHP occurrence numbers 5, 35, 91, and 94 in **Table 1**; Colorado Natural Heritage Program 2006). As an example, eight to ten gas wells and two pipelines have been constructed or approved within *P. harringtonii* habitat, impacting a total of about 10 percent of one occurrence (Scheck personal communication 2004). Over time, these areas will undoubtedly be developed with additional wells to extract the maximum amount of gas (Scheck personal communication 2004). At least one other occurrence is potentially threatened by a proposed oil and gas pipeline (Klish personal communication 2004, Scheck personal communication 2004, Colorado Natural Heritage Program 2006). These occurrences are located on BLM and private lands. The occurrences on National Forest System land are not threatened by these activities.

Oil and gas wells within the known distribution of *Penstemon harringtonii* are concentrated in Garfield County. An oil and gas well location map for Colorado

(Colorado Oil and Gas Conservation Commission 2004) shows that most of the occurrences of *P. harringtonii* in Garfield County are near oil and gas development activities. There are a few wells located near occurrences in Eagle and Routt counties, but these do not appear to be close enough to affect the occurrences.

Most of the *Penstemon harringtonii* occurrences in Garfield County are on BLM lands, where they gain some protection from oil and gas development by standard stipulations that allow the BLM to require a move of development activities of up to 200 m to avoid sensitive species. So far, this has resulted in relocation of activities only far enough to avoid direct impacts to all or most of the actual plants. In the case of large occurrences, the compromise is to avoid at least 90 percent of the plants (Scheck personal communication 2004).

It is hard to predict the future of oil and gas activity since the industry changes so rapidly. There are areas in Eagle, Pitkin, and Garfield counties that support *Penstemon harringtonii* that while they may have potential resources, may not be currently economically viable for production. In these cases, exploratory wells may be drilled in the next couple of years. Depending on the outcome, the area could see increased activity in the future. The impacts from even small-scale oil and gas development could be severe, depending on the proximity to occurrences and/or potential habitat for *P. harringtonii*. Wells, associated roads, and pipelines could fragment, degrade, or destroy habitat, and potentially introduce competitive non-native plant species.

Global climate change

Global climate change is likely to have a wide-range of effects on *Penstemon harringtonii*. One projection based on current atmospheric CO_2 trends suggests that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables (U.S. Environmental Protection Agency 1997). Because the habitat for *P. harringtonii* is already xeric, lower soil moisture resulting from decreased precipitation could eliminate the species. Other models (e.g., Giorgi et al. 1998) predict increased winter snowfall, which could delay the onset of the growing season for *P. harringtonii* if persistent snow covers occurrences late into the spring.

Conservation Status of Penstemon harringtonii in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

The cumulative impacts of residential development, agriculture, motorized recreation, oil and gas development, exotic species invasions, and habitat fragmentation are causing a decline of *Penstemon harringtonii*. Botanists have observed impacts to *P. harringtonii* in a significant portion of its range, and they have noted declines of this species, resulting particularly from residential development, over the past 25 years (Buckner personal communication 2006, Coles personal communication 2006, Colorado Natural Heritage Program 2006, Grant personal communication 2006, Jennings personal communication 2006). Because the pre-settlement abundance of *P. harringtonii* is not known, it is difficult to assess the effects of grazing management on abundance. While prolonged or constant disturbance, such as sagebrush removal and heavy off-road vehicle use, is likely to extirpate occurrences, occasional light to moderate disturbance may be beneficial. With so many different landowners and land managers within the distribution of *P. harringtonii*, it is likely that management of some properties is not compatible with the persistence of *P. harringtonii* but that other properties are managed appropriately. Population trends on lands managed by the National Forest Service are not known. Additional inventories and monitoring (Denver Botanic Gardens 2003) will help to clarify the population trend of this species.

Do habitats vary in their capacity to support this species?

Habitats where *Penstemon harringtonii* is found appear to vary in their capacity to support it. However, many apparently suitable sites do not support *P. harringtonii*, which makes it difficult to assess the quality of these habitats. The nature of the disturbance regime of a given site may factor into its capacity to support *P. harringtonii*. However, much remains unknown about the types and intensities of disturbance to which *P. harringtonii* is adapted. Refinements of our understanding of the relationships between *P. harringtonii* and its habitat will be possible with more research.

Vulnerability due to life history and ecology

Penstemon harringtonii does not appear to be vulnerable because of its life history or ecology. However, the unfortunate position of *Penstemon harringtonii*'s narrow range within an area of rapid residential development, agricultural uses, oil and gas development, and popular recreation areas is the primary source of its vulnerability. As a narrowly restricted species, *P. harringtonii* may be somewhat vulnerable to environmental stochasticity, at least to factors operating on a regional scale. The degree to which it can survive bad years will depend largely on how long individual plants can persist, or remain dormant as seeds.

Evidence of populations in Region 2 at risk

Residential and agricultural development, motorized recreation, and oil and gas development have the potential to affect large parts *Penstemon harringtonii*'s global range, and current provisions to ensure the long-term viability of this species are inadequate. There are only three small protected areas, all on BLM-managed public land, that include *P. harringtonii*: Bull Gulch, Deep Creek and Thompson Creek ACECs. The White River National Forest has developed a forest management plan in which motorized recreation is limited to designated routes only in areas inhabited by *P. harringtonii*. However, enforcement of these limitations is difficult, if not impossible (Johnston personal communication 2004).

The total population of *Penstemon harringtonii* is an estimated 40,000 to 43,000 plants based on current documentation. While populations of this size are probably viable, the fragmentation of this species' habitat suggests that gene flow throughout the population may be obstructed, leading to smaller effective population sizes. Fragmentation also affects the movement of pollinators. While *P. harringtonii* may be capable of self-fertilization, it is likely that reliance on this means of reproduction will rapidly reduce the genetic diversity of the species.

Management of Penstemon harringtonii in Region 2

Implications and potential conservation elements

Current data suggest that *Penstemon harringtonii* is vulnerable due to its narrow endemism and threats to its habitat. Conservation easements on private lands and proactive management of public lands offer the best opportunities for the conservation of this species. Given its restricted range and threats to its habitat, management policies must be designed to ensure that this species persists. The authors of this report concur with the opinion of other Colorado botanists that designating *P. harringtonii* as a sensitive species in Region 2 and including it on the BLM Colorado State Sensitive Species List is needed to drive the development of appropriate management actions (Buckner personal communication 2006, Grant personal communication 2006, Handwerk personal communication 2006, Jennings personal communication 2006). Without efforts to conserve it, *P. harringtonii* may eventually warrant federal listing. Management policies will need to address motorized recreation, human and natural disturbance regimes, pollinator resources, and restoration of native plant communities. Given (1994) offers practical advice regarding restoration that will assist with the development of effective management and restoration policies.

Desired environmental conditions for *Penstemon harringtonii* include sufficiently large areas where the natural ecosystem processes on which it depends can occur, permitting it to persist unimpeded by human activities and their secondary effects. This includes a satisfactory degree of ecological connectivity between occurrences to provide corridors and other nectar resources for pollinators. Although *P. harringtonii* occurrences are apparently viable at present, the natural ecosystems and ecosystem processes have been altered, and the habitat is disturbed and fragmented. Further research on the ecology and distribution of *P. harringtonii* will help to develop effective approaches to management and conservation. Given the rarity and potential vulnerability of this species, conserving the highest quality known occurrences is a high priority for biodiversity conservation. A thoughtful assessment of current management practices on lands occupied by *Penstemon harringtonii* would likely identify opportunities for change that would be inexpensive and have minimal impacts on the livelihood and routines of local residents, managers, stewards, and recreationists while conferring substantial benefits to *P. harringtonii*.

Tools and practices

Species inventory

Species inventory is a high priority for *Penstemon harringtonii*. Much suitable habitat within its range remains to be searched. For example, Derby Mesa on the White River National Forest may have suitable habitat (Scheck personal communication 2004). Collecting

baseline information and developing a detailed map of the distribution and abundance will provide a starting point from which population trends can be assessed. During recent surveys for *P. harringtonii*, several new occurrences were identified (Colorado Natural Heritage Program 2006). This suggests that further searching could yield other new occurrences. Species inventories are simple, inexpensive, and effective, and they are necessary for developing an understanding of the target species sufficient for developing a monitoring program. Identifying occurrences in which the population, condition, and the landscape context are high quality will help managers to prioritize conservation efforts.

Penstemon harringtonii is a relatively conspicuous species; as long as it is flowering, it is not difficult to distinguish from other *Penstemon* species. It tends to grow in open habitats, which makes it easy to find, although it is inconspicuous in the vegetative stage. Field crews could be quickly taught to recognize this species. Searching for *P. harringtonii* is complicated by the need to obtain permission to enter private land throughout its known range, and can be difficult in dry years when fewer plants produce flowers.

Areas with the highest likelihood of new occurrences are open sagebrush stands within the range of the known occurrences. Many areas within the known range of *Penstemon harringtonii* remain to be searched because of the difficulties in accessing remote areas and private lands. There may be other occurrences in sagebrush habitats many miles away from the known range, particularly if it was once more widespread.

Habitat inventory

The Colorado Natural Heritage Program routinely uses aerial photographs, topographic maps, soil maps, and geology maps to refine searches when conducting inventories of large areas. This approach has been highly effective in Colorado and elsewhere. It is most effective for species for which we have a search image of its habitat from which distribution patterns and potential search areas can be derived.

Searches for *Penstemon harringtonii* could be aided by modeling habitat based on the physiognomy of known occurrences. The intersection of elevation, geologic substrates, and vegetation could be used to generate a map of a probabilistic surface showing the likelihood of the presence of *P. harringtonii*. This would be a valuable tool for guiding and focusing future searches. Techniques for predicting species occurrences are reviewed extensively by Scott and others (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003) and Colorado (Decker et al. 2005), and these methods would apply to *P. harringtonii* as well.

Kim Fayette and her colleagues (2000) developed a potential habitat map for *Penstemon harringtonii* within Eagle County. The map includes large areas of intact potential and occupied habitat, and it includes sagebrush habitat between 6,700 and 9,200 ft. based on 7.5" topographic maps, GAP vegetation maps, digital elevation models, and fieldwork. Some areas were not considered potential habitat because of their degraded condition, but they may be restorable. Housing developments within habitat that is known to include *P. harringtonii* were also excluded because they were not thought to support high quality occurrences.

Population monitoring

The best time for inventory and monitoring of *Penstemon harringtonii* is from early June through early July when the plants are in flower. A monitoring program for *P. harringtonii* would begin by targeting a subset of the known occurrences, and other occurrences could be added to the program as necessary. Monitoring sites under a variety of land management scenarios (e.g., grazing and fire regimes) will help to identify appropriate management practices for *P. harringtonii* and to understand its population dynamics and structure.

A demographic monitoring program that addresses recruitment, seed production, seed and plant longevity, population variability, and pollinators would generate data useful to managers and the scientific community. Population trend monitoring for *Penstemon harringtonii* is proposed by the Denver Botanic Gardens (2003). Monitoring interactions with pollinators could be done by expanding on the methods employed by Spackman Panjabi (2004). Suitable methods for monitoring pollinators are also discussed in Kearns and Inouye (1993). Measuring seed production will require a visit later in the summer after fruit set. It will be important to define *a priori* the changes the sampling regime intends to detect and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998).

Because of a high annual variability in reproductive effort, annual sampling of monitoring plots will be necessary to gain insight into the population dynamics of *Penstemon harringtonii*. A random design might be employed to establish the sampling units. Permanent

quadrats could be selected within a macroplot by randomly choosing X and Y UTM coordinates. Then, the quadrats could be located using a highly accurate Global Positioning System (GPS) unit. Once established and marked, a recreation-grade GPS could be used to relocate the quadrats. If subsequent power analysis indicates that the sample size is inadequate, it would be easy to add more quadrats within the macroplot. Researchers at the Denver Botanic Gardens (2003) are using similar methods for monitoring population trends in *P. harringtonii*.

Elzinga et al. (1998) recommend several methods of monumentation, depending on the site physiography and frequency of human visitation to the site. This is an important consideration that will reap long-term benefits if addressed properly at the outset of the monitoring program.

The highest priority is to gather data on distribution and abundance for *Penstemon harringtonii*. Gathering abundance data can be done rapidly and requires only a small amount of additional time and effort (Elzinga et al. 1998). Thus, presence/absence monitoring is not recommended for *P. harringtonii*.

Habitat monitoring

Habitat monitoring would be particularly beneficial to *Penstemon harringtonii* and should be conducted concurrently with population monitoring. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring studies will augment our understanding of *P. harringtonii*'s habitat requirements and management needs. Fields for these factors could be incorporated into the forms used for the population sampling regimen described above. Habitat monitoring of occurrences will alert managers of new impacts such as weed infestations and damage from human disturbance. Making special note of signs of degradation from recreational uses may help managers to prevent serious habitat damage by implementing changes in the management regime. Change in environmental variables might not cause observable demographic repercussions for several years, so re-sampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use practices and management are important to document while monitoring populations.

Estimating cover and/or abundance of associated species within the monitoring macroplots described above could permit the investigation of interspecific relationships through ordination or other multivariate techniques. In very sparsely vegetated plots this can be difficult, but it can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding the environmental constraints on *Penstemon harringtonii* would facilitate the management of this species. Gathering data on edaphic characteristics (e.g., moisture, texture, and soil chemistry, particularly pH, if possible) from the permanent plots described above would permit analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species.

Adding a photo point component to the monitoring protocol could facilitate the tracking of occurrences and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available that offers detailed instructions on establishing photo monitoring plots. Monitoring sites should be selected carefully, and a sufficient number of sites should be selected if the data are intended to detect population trends.

Observer bias can be a significant problem with habitat monitoring (Elzinga et al. 1998) unless field crews are carefully trained to be accurate and consistent in estimating plant cover. Habitat monitoring is usually better at identifying new impacts than at tracking changes in existing impacts. For example, estimating weed infestation sizes using broad size classes helps to reduce the effects of observer bias. To assess trampling impacts, using photographs of impacts to train field crews will help them to consistently rate the severity of the impact.

Habitat management

In 2003 and 2004, BLM used chainsaws, hydro-axes, and hydro-flailers to remove pinyon and juniper trees from sagebrush habitat that was known to be occupied by *Penstemon harringtonii* (Scheck personal communication 2004). These actions were taken to improve the habitat for sage grouse (*Centrocercus urophasianus*), and they are thought to have benefited *P. harringtonii*. Although *P. harringtonii* is still present in the management sites (Scheck personal communication 2006), there are no data or long-term observations to show how this species responded to this treatment. One of the treatment areas has been monitored by the Denver Botanic Gardens for the past 10 years (Grant personal communication 2006). To minimize disturbance at this research site, the BLM removed pinyon and juniper trees with chain saws (Scheck personal communication 2006). Researchers at the Denver Botanic Gardens may

be able to gain insight into how *P. harringtonii* responds to this treatment if they continue monitoring at this site (Grant personal communication 2006).

The BLM is mechanically removing the sagebrush with a rotary chopper in occupied *Penstemon harringtonii* habitat that has decadent sagebrush but few trees (Scheck personal communication 2004). This treatment is also thought to help maintain suitable habitat conditions for *P. harringtonii* by mimicking small, low-intensity fires. In general, for areas where the understory vegetation is diverse and in good condition, methods that reduce sagebrush density and remove encroaching trees are thought to benefit *P. harringtonii* (Scheck personal communication 2004).

Research is needed to determine if these activities are truly beneficial for *Penstemon harringtonii* (Buckner personal communication 2006, Grant personal communication 2006). Although *P. harringtonii* may indeed respond positively, it is also possible that the treatments described above may result in grasses and other herbaceous vegetation increasing and outcompeting *P. harringtonii* (Buckner personal communication 2006, Williamson personal communication 2006). These treatments could also introduce and spread exotic plant species.

Beneficial management actions

The establishment of areas managed for the benefit of *Penstemon harringtonii* is the best conservation strategy for this species. As the human population increases, additional occurrences of *P. harringtonii* are likely to be lost and its habitat is likely to become increasingly fragmented. Conservation easements, fee purchase, and other land trust activities are useful conservation tools to protect occurrences on private land and to connect occurrences on public lands. Although it appears that *P. harringtonii* does not occur on any existing conservation easements, there are many opportunities for counties or other entities to purchase lands that support occurrences of *P. harringtonii*. Land exchanges that bring sites on private land into federal ownership would also be a useful conservation tool. However, this can be an extremely difficult prospect in areas where there are so many private landowners.

USFS and BLM could contribute substantially to the conservation of *Penstemon harringtonii* by establishing areas that are specifically managed for the species. The BLM Resource Management Plan for the area occupied by *P. harringtonii* (Glenwood Springs office) will be revised beginning in 2006 (Scheck personal communication 2004). It is possible that certain areas could be identified in this plan where the management emphasis would be for *P. harringtonii*.

Management practices that reduce the impacts of recreation on occurrences of *Penstemon harringtonii* are likely to contribute to the conservation of this species. Research is needed to identify disturbance regimes that are compatible with *P. harringtonii*. Given our current limited knowledge based solely on observations, limiting motorized recreation to designated roads within known occurrences is most likely to be compatible with *P. harringtonii*.

Management strategies that control and prevent weed infestations in *Penstemon harringtonii* habitats are likely to confer benefits to the species. Avoiding the use of aggressive, non-native species, such as crested wheatgrass, for reclaiming disturbances in potential and occupied habitat will preserve the potential for *P. harringtonii* to colonize these areas. If aggressive non-natives are used, they tend to dominate the site and outcompete most native species (Scheck personal communication 2004). Weed control mechanisms also have the potential to affect *P. harringtonii* negatively. Avoiding the use of herbicides or using hand application to target weed species within *P. harringtonii* occurrences is likely to be beneficial. The Colorado Natural Heritage Program can provide accurate data on the distribution of this species to assist with avoiding impacts to occurrences. Clearances of areas in question by someone who is familiar with *P. harringtonii* may also be necessary in certain situations.

Penstemon harringtonii may benefit from the introduction of low-intensity fire (prescribed burns and/or naturally occurring fires) in sagebrush communities where the native understory is still intact. However, since sagebrush is killed by fire, removal of the shrub overstory may make *P. harringtonii* plants more vulnerable to trampling and herbivory (Scheck personal communication 2004). Burned areas tend to attract grazers due to the flush of new growth (Scheck personal communication 2004). Numerous small burns might reduce the chance of concentrating grazing use in a single area, allow sagebrush to re-colonize from seed sources at the perimeter of the fire, and thereby reduce detrimental effects to *P. harringtonii*. In areas where the understory is now composed mostly of exotic species, especially cheatgrass, the use of fire as a restoration tool may worsen the habitat condition, although a degree of restoration may be possible through carefully controlled burns (Naumann personal communication 2006). In their five-year study on the effects of fire

on *P. lemhiensis*, another rare *Penstemon* species that occupies sagebrush dominated ecosystems, Heidel and Shelly (2001) concluded that fire was an appropriate management tool for that species.

Appropriate management of natural vegetation in the vicinity of occurrences of *Penstemon harringtonii* is likely to benefit pollinators. Since *P. harringtonii* relies on a broad suite of pollinators, in order to assure reproduction in all years it is necessary to protect all pollinators (Tepedino et al. 1997).

Maintaining livestock stocking rates at suitable levels will prevent most grazing impacts to *Penstemon harringtonii*. Preventing the installation of range improvements (e.g., fences, stock ponds) within *P. harringtonii* occurrences is also likely to conserve the species.

Seed banking

No seeds or genetic material are currently in storage for *Penstemon harringtonii* at the National Center for Genetic Resource Preservation (Miller personal communication 2003). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002). Collection of seeds for long-term storage will be useful if restoration is necessary.

Information Needs

Distribution

Species inventory specifically targeting *Penstemon harringtonii* is a high research priority. Until there is a complete picture of its distribution and abundance, it will not be possible to assess the conservation needs and priorities for this species. Often, when a species thought to be rare is inventoried, it is found that it is not as rare as previously believed. Recent floristic inventory work has located a number of new occurrences, suggesting that other occurrences await discovery.

Life cycle, habitat, and population trend

Research is needed to understand the life history and population ecology of *Penstemon harringtonii*. Little is known about the species' seed production, seed dispersal, seed dormancy, germination requirements, seedling establishment and vigor, or lifespan of plants. The population trend of *P. harringtonii* is unknown and may be difficult to quantify because the species responds strongly to annual precipitation and is capable of remaining dormant for at least a year if conditions are unfavorable. Occurrences may have many aboveground plants in a wet year and few in a dry year.

The habitat for *Penstemon harringtonii* has been described, but the specific limiting factors of its habitat and natural disturbance regime are poorly understood. Specific information about how this species and its habitat respond to fire is needed. Sagebrush shrublands occur in many other parts of Colorado, but the particular environmental variables to which *P. harringtonii* responds are unknown. An explanation for the limited range of *P. harringtonii* is lacking. Hypotheses regarding the role of soil pH and texture, dispersal ability, disturbance, community ecology, and historic versus contemporary habitat availability as causes of rarity for *P. harringtonii* need to be tested. Understanding its habitat and being able to identify suitable habitat is particularly important for the conservation and management of *P. harringtonii*. Autecological research is needed to help refine our definition of appropriate habitat and to facilitate habitat monitoring and conservation stewardship of this species.

Response to change

Rates of reproduction and establishment and the effects of environmental variation on these parameters have not been investigated in *Penstemon harringtonii*. The potential effects of various management options therefore cannot be assessed during project planning.

Understanding the responses of *Penstemon harringtonii* to disturbance is important for determining appropriate management practices; these need research for clarification. It is not known if *P. harringtonii* is present in disturbed areas because of the conditions created by the disturbance or if it is persisting despite the disturbance. It would be helpful to know how long it takes *P. harringtonii* to re-colonize sites following disturbances such as the installation of pipelines, well pads, and road cuts, as well as how this species respond to brushbeating and burning (Scheck personal communication 2006).

Additional residential and agricultural developments and recreational use in the range of *Penstemon harringtonii* could decrease habitat as well as the availability and diversity of pollinators. In her studies of *Ipomopsis polyantha*, Collins (1995) noted that large-bodied insect species have greater nutrient reserves, enabling them to travel further. Thus we might expect a shift towards larger pollinators if the

area becomes more fragmented and occurrences of *P. harringtonii* become more insular. Pollinators capable of residing in disturbed habitats are also likely to be favored. Studies of the effects of disturbance on pollinator species richness will help to reduce the loss of genetic diversity of *P. harringtonii*.

Metapopulation dynamics

Research on the population ecology of *Penstemon harringtonii* has not been done to determine the importance of metapopulation structure and dynamics to its long-term persistence at local or regional scales. Migration, extinction, and colonization rates are unknown for *P. harringtonii*. Baseline population dynamics and viability must first be assessed.

Demography

Only the broadest generalizations can be made regarding the demography of *Penstemon harringtonii*. Occurrences of *P. harringtonii* have not been censused, and current estimates of abundance are coarse. Growth and survival rates are also unknown, and the rate of reproduction is poorly understood. Our knowledge of the distribution of the species is incomplete. Much work is needed in the field before local and range-wide persistence can be assessed with demographic modeling techniques. Short-term demographic studies often provide misleading data for conservation purposes, so complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002).

Population trend monitoring methods

The Denver Botanic Gardens is currently conducting a ten-year population monitoring study of two occurrences of *Penstemon harringtonii* (Denver Botanic Gardens 2003). Their methods could be expanded to include other occurrences. Selection of monitoring sites from a variety of land use scenarios would be most helpful for clarifying management priorities.

Restoration methods

There have been no known attempts to restore habitat or individuals of *Penstemon harringtonii*. Because of this, there is no applied research from which to develop a restoration protocol. Seeds could be gathered from established occurrences and sown in restoration sites. *Penstemon harringtonii* may also be propagated in a greenhouse, but it may be difficult to transfer plants successfully into a natural or restored environment.

Nielson (1998) suggests that restoration in lower-elevation sites may be more successful because of a longer growing season. Plants should be spaced at a density that results in the greatest seed production. Nielson (1998) found that single plants produced more fruit than those that grew in clumps of three plants. Since seeds probably do not disperse very far, it is likely that plants growing near each other are closely related. Frequent pollinations between closely related individuals could lead to reduced seed set and inbreeding depression (Nielson 1998). Planting individuals that are not closely related next to each other may increase the chances of cross pollination between individuals that are not as closely related (Nielson 1998) and therefore be more successful in a restored occurrence.

Research priorities for Region 2

Inventories are needed to identify all occurrences of *Penstemon harringtonii*. Delineating the boundaries of known occurrences, identifying new occurrences within the known range, and searching sagebrush stands outside of the known range is the best strategy to developing an understanding of this species' distribution. Targeted searches during peak anthesis (June) in suitable habitat will help to confirm the distribution and abundance of *P. harringtonii* and may identify opportunities for its conservation.

The identification of large, vigorous occurrences is needed so that conservation action on behalf of *P. harringtonii* can begin. Identifying robust occurrences in natural settings is important for setting conservation targets and priorities. Collecting detailed notes on associated species, habitat, geology, soil, and other natural history observations at all locations will be extremely useful. Documentation of any threats and visible impacts to *P. harringtonii* will help managers to develop conservation strategies and to mitigate these threats.

The USFS and the BLM could identify areas that are to be specifically managed for *Penstemon harringtonii*. Private landowners who are interested in establishing conservation easements could contribute to the conservation of this species.

Trend monitoring and demographic studies are needed for *Penstemon harringtonii*. Demographic data are far more useful for assessing status and developing recovery efforts than genetic information (Schemske et

al. 1994). Determining the critical life history stages of *P. harringtonii* will allow managers to focus efforts on implementing management protocols that benefit those stages. A monitoring program that determines effective population sizes and investigates the growth, survival, and reproduction of individuals within occurrences will have considerable practical value and will help determine the conservation status of *P. harringtonii*.

Reaching a better understanding of the influence of human activities on individuals and habitat of *Penstemon harringtonii* will aid land managers and planners. Identifying life history and phenological stages when *P. harringtonii* is less sensitive to recreational impacts would help to mitigate threats by providing a basis for management prescriptions that are compatible with *P. harringtonii*.

The role of disturbance in the autecology of *Penstemon harringtonii* remains poorly understood. An understanding of the specific tolerances of *P. harringtonii* to different human and natural disturbance regimes (e.g., fire) will assist with developing conservation strategies and management plans by determining the types of disturbance most likely to affect it negatively. Research that investigates how this species responds to various land management strategies (e.g., tree removal in sagebrush habitat) will be particularly valuable.

Information gleaned from studies of the physiological and community ecology of *Penstemon harringtonii* will be valuable in the event that an occurrence needs to be restored, and it will help to determine biotic and abiotic factors that contribute to its survival. Understanding the plant-environment relationship for *P. harringtonii* will provide insight on the coping strategies employed by this species and help to model its potential distribution.

Definitions

Abiotic – non-living, devoid of life (Allaby 1998).

Autecology – the ecology of individual organisms and populations (Allaby 1998).

Autogamy – self-fertilization involving just one flower.

Dehisce – burst or split open.

Dipterans – flies.

Edaphic – of the soil or influenced by the soil (Allaby 1998).

Exserted – protruding (Allaby 1998).

Geitonogamous – fertilization involving different flowers on the same plant.

Graminoid – grass.

Hydraulic lift – a process by which deep-rooted plants take in water from lower soil layers and exude that water in upper, drier soil layers (Denver Botanic Gardens 2003).

Hymenopterans – bees and wasps.

Lepidopterans – butterflies and moths.

Outcrossing – fertilization involving pollen and ovules from different flowers on genetically distinct plants; synonymous with Xenogamy (Allaby 1998).

Perfect – flowers that include both male and female structures; bisexual (Weber and Wittmann 2001).

Potential Conservation Area (PCA) – a best estimate of the primary area supporting the long-term survival of targeted species or natural communities. PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2001).

Quadrat – a basic sampling unit of vegetation surveys (Allaby 1998).

Ruderal – a plant that is associated with human dwellings or agriculture, or one that colonizes waste ground (Allaby 1998).

Taxon (plural taxa) – a group of organisms of any taxonomic rank, e.g., family, genus, or species (Allaby 1998).

Transect – a linear vegetation sampling method (Allaby 1998).

Imperilment Ranks used by natural heritage programs, natural heritage inventories, Natural Diversity Databases, and NatureServe.

Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be interpreted as legal designations.**

G/S1	Critically imperiled globally/state-province because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.
G/S2	Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).
G/S4	Apparently secure globally/state-province, though it might be quite rare in parts of its range, especially at the periphery.
G/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.
S#B	Refers to the breeding season imperilment of elements that are not permanent residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliable identified, mapped, and protected.
SA	Accidental in the state or province.
SR	Reported to occur in the state or province, but unverified.
S?	Unranked. Some evidence that the species may be imperiled, but awaiting formal rarity ranking.

Notes: Where two numbers appear in a G or S rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

References

Allaby, M. 1998. A Dictionary of Plant Sciences. Oxford University Press, New York, NY.

Bailey, R.G. 1995. Description of the Ecoregions of the United States. Second edition. Misc. Publ. No. 1391. USDA Forest Service, Washington, D.C.

Barbour, M.G. and W.D. Billings. 1988. North American Terrestrial Vegetation. Cambridge University Press, Cambridge, England.

Buckner, D.L. 2006. Personal communication with author of 1990/1991 Status report for *Penstemon harringtonii* regarding current status of this species.

Buckner, D.L. and J.E. Bunin. 1992. 1990/1991 Status report for *Penstemon harringtonii* Penland. Unpublished report prepared for the U.S. Fish and Wildlife Service.

Center for Plant Conservation. 2002. National Collection of Endangered Plants. Accessed via the World Wide Web at http://www.mobot.org/CPC/NC_Choice.html.

Coles, J. 2006. Personal communication with NatureServe ecologist regarding *Penstemon harringtonii*.

Collins, C. 1995. The Natural History and Reproductive Biology of the Pagosa Gilia, *Ipomopsis polyantha* (Rydberg) V. Grant var. *polyantha* (Polemoniaceae). M.A. Thesis. California State University, Fullerton, CA.

Colorado Department of Agriculture. 2003. Rules pertaining to the administration and enforcement of the Colorado Noxious Weed Act. 8 CCR 1203-19. Accessed via the World Wide Web at http://www.ag.state.co.us/csd/weeds/statutes/weedrules.pdf.

Colorado Division of Wildlife. 2004. Natural Diversity Information Source accessed via the Internet at http://ndis.nrel.colostate.edu.

Colorado Native Plant Society. 1997. Rare Plants of Colorado. Second edition. Falcon Press, Helena, MT.

Colorado Natural Heritage Program. 2003. 2003 Data Distribution. Provided in CD format to the USDA Forest Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Colorado Natural Heritage Program. 2006. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, CO.

Colorado Natural Heritage Program Site Committee. 2001. Recommendations for Development and Standardization of Potential Conservation Areas and Network of Conservation Areas. Colorado Natural Heritage Program, Fort Collins, CO.

Colorado Oil and Gas Conservation Commission. 2004. COGCC oil and gas well spatial data set. Accessed via the World Wide Web at http://oil-gas.state.co.us.

Cronquist, A., A.H. Holmgren, N.H. Holmgren, J.L. Reveal, and P.K. Holmgren. 1984. Intermountain Flora- Vascular Plants of the Intermountain West, U.S.A. Volume 4, Subclass Asteridae (except Asteraceae). The New York Botanical Garden, New York, NY.

Cronquist, A., A.H. Holmgren, N.H. Holmgren, and J.L. Reveal. 1986. Intermountain Flora- Vascular Plants of the Intermountain West, U.S.A. Volume 1. The New York Botanical Garden, New York, NY.

Crosswhite, F.S. and C.D. Crosswhite. 1966. Insect pollination of *Penstemon* series *Graciles* (Scrophulariaceae) with notes on *Osmia* and other Megachilidae. American Midland Naturalist 76(2):450-467.

Dawson, C. 2004. Personal communication with Bureau of Land Management Colorado State Botanist regarding *Penstemon harringtonii*.

Decker, K., A. Lavender, J. Handwerk, and D.G. Anderson. 2005. Modeling the potential distribution of *Phacelia scopulina* var. *submutica* (Debeque phacelia) and *Astragalus debequeus* (Debeque milkvetch) in Western Colorado. Unpublished report prepared for the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Denver Botanic Gardens. 2003. Population monitoring of *Penstemon harringtonii* (Scrophulariaceae), an endemic species of Colorado, USA. Unpublished report prepared by the Denver Botanic Gardens Research, Herbaria and Records Department for the Bureau of Land Management, Colorado State Office.

Doer, J. 2006. Personal communication with USDA Forest Service, White River National Forest, Botanist regarding *Penstemon harringtonii*.

Dworak, A. 2004. Personal communication with Biologist with Buys and Associates, Denver, CO, regarding *Penstemon harringtonii*.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1.

Fayette, K., M. Wunder, and S. Schneider. 2000. Biological Survey of Eagle County, Colorado. Unpublished report prepared for the Eagle Valley Land Trust by the Colorado Natural Heritage Program, Fort Collins, CO.

Fernando, A.A. and R.S. Currah. 1996. A comparative study of the effects of the root endophytes *Leptodontidium orchidicola* and *Phialocephala fortinii* (Fungi Imperfecti) on the growth of some subalpine plants in culture. Canadian Journal of Botany 74:1071-1078.

Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM sensitive and USFWS Threatened and Endangered Plant Species. Wyoming Natural Diversity Database, Laramie, WY.

Giezentanner, K. 2004. Personal communication with USDA Forest Service, White River National Forest, Biologist regarding *Penstemon harringtonii*.

Giorgi, F., L.O. Mearns, C. Shields, and L. McDaniel. 1998. Regional nested model simulations of present day and 2 x CO_2 climate over the central plains of the U.S. Climatic Change 40:457-493.

Given, D.R. 1994. Principles and Practice of Plant Conservation. Timber Press, Portland, OR.

Grant, T. 2006. Personal communication with Denver Botanic Gardens Botanist regarding *Penstemon harringtonii*.

Hall, F.C. 2002. Photo Point Monitoring Handbook- Parts A and B. General Technical Report PNW-GTR 526. USDA Forest Service Pacific Northwest Research Station, Portland, OR.

Handwerk, J. 2006. Personal communication with Colorado Native Plant Society President (2000-2004) regarding *Penstemon harringtonii*.

Harley, J.L. 1991. Introduction: The state of the art. Pages 1-24 *in* J.R. Norris, D.J. Read, and A.K. Varma, editors. Methods in Microbiology, Vol. 23. Academic Press, London, England.

Heidel, B. and J.S. Shelly. 2001. The effects of fire on Lemhi penstemon (*Penstemon lemhiensis*) - final monitoring report, 1995-2000. Report to the Beaverhead-Deerlodge National Forest and Dillon Field Office - Bureau of Land Management. Montana Natural Heritage Program, Helena, MT.

Jennings, B. 2006. Personal communication with Colorado Botanist regarding *Penstemon harringtonii*.

Johnson, D. 2002. Personal communication with Western Resource Development Biologist regarding methods for estimating population size of *Penstemon harringtonii*.

Johnston, B.C. 2001. Biological assessment and biological evaluation for *Penstemon harringtonii*. USDA Forest Service, White River National Forest, Glenwood Springs, CO.

Johnston, B.C. 2004. Personal communication with USDA Forest Service Botanist regarding populations of *Penstemon harringtonii* on the White River National Forest.

Johnston, B.C., L. Huckaby, T.J. Hughes, and J. Pecor. 1999. Ecological types of the Upper Gunnison Basin. Technical Report un-numbered. USDA Forest Service, Lakewood, CO. 874 pp.

Kartesz, J.T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. *In*: J.T. Kartesz and C.A. Meacham. Synthesis of the North American Flora [computer program]. Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Kearns, C.A. and D.W. Inouye. 1993. Techniques for Pollination Biologists. University Press of Colorado, Niwot, CO.

Klish, M. 2004. Personal communication with WestWater Engineering Environmental Scientist regarding *Penstemon harringtonii*.

Law, R. 1985. Evolution in a mutualistic environment. Pages 145-170 *in* D.H. Boucher, editor. The Biology of Mutualism, Ecology and Evolution. Oxford University Press, New York, NY.

Lindborg, R. and J. Ehrlén. 2002. Evaluating the extinction risk of a perennial herb: demographic data versus historical records. Conservation Biology 16:683-690.

Lyon, P. 2004. Personal communication with Colorado Natural Heritage Program Botanist regarding *Penstemon harringtonii*.

Lyon, P. 2006. Personal communication with Colorado Natural Heritage Program Botanist regarding *Penstemon harringtonii*.

Lyon, P. and J. Huggins. 2003. Survey of Hardscrabble/Tenderfoot area for *Penstemon harringtonii*. Unpublished report prepared for the BLM, Glenwood Springs Field Office, CO.

Lyon, P., J. Sovell, and J. Rocchio. 2001. Survey of critical biological resources of Garfield County, Colorado. Unpublished report prepared for Garfield County by the Colorado Natural Heritage Program, Fort Collins, CO.

Manabe, S. and R.T. Wetherald. 1986. Reduction in summer soil wetness induced by an increase in atmospheric carbon dioxide. Science 232:626-628.

Miller, A. 2003. Personal communication with National Center for Genetic Resource Preservation Seed Analyst regarding *Penstemon harringtonii*.

NatureServe. 2005. NatureServe Explorer: an online encyclopedia of life [web application]. Version 4.6. NatureServe, Arlington, Virginia. Available online at http://www.natureserve.org/explorer.

Naumann, T. S. 2006. Personal communication with the Dinosaur National Monument botanist regarding the use of fire to restore native grasses to sagebrush and grassland communities in northwestern Colorado.

New York Botanical Garden. 2003. Image of isotype specimen for *Penstemon harringtonii*. Accessed via the Internet at http://scisun.nybg.org:8890/searchdb/owa/wwwcatalog.detail_list?this_id=4412922.

Nielson, R.L. 1998. The reproductive biology and ecology of *Penstemon harringtonii* (Scrophulariaceae): implications for conservation. M.S. thesis, Utah State University, Logan, UT.

Nold, R. 1999. *Penstemons*. Timber Press, Portland, OR. 259 pp.

O'Kane, S.L. 1988. Colorado's rare flora. Great Basin Naturalist 48:434-484.

Parenti, R.L., Jr. A.F. Robinson, and J. Kagan. 1993. Bradshaw's Lomatium Recovery Plan. Portland, OR. Unpublished report prepared for the U.S. Fish and Wildlife Service.

Penland, C.W.T. 1958. Two new species of *Penstemon* in Colorado. Madroño 14:153-156.

Pianka, E.R. 1970. On *r*- and *K*-selection. American Naturalist 104:592-597.

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

Rondeau, R. 2000. Sagebrush Shrubland- Matrix. Community Characterization Abstract produced for the Colorado Natural Heritage Program and The Nature Conservancy.

Rosendahl, S., C.N. Rosendahl, and U. Sochting. 1992. Distribution of VA mycorrhizal endophytes amongst plants from a Danish grassland community. Agric Ecosystem and Environment 29:329-335.

Sanders, I.R., J.P. Clapp, and A. Wiemken. 1996. The genetic diversity of arbuscular mycorrhizal fungi in natural ecosystems - a key to understanding the ecology and functioning of the mycorrhizal symbiosis. New Phytologist 133:123-134.

Scheck, C. 2004. Personal communication with Bureau of Land Management Ecologist regarding *Penstemon harringtonii*.

Scheck, C. 2006. Personal communication with Bureau of Land Management Ecologist regarding *Penstemon harringtonii*.

Schemske, D.W., B.C. Husband, M.H. Ruckelshaus, C. Goodwillie, I.M. Parker, and J.G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75:584-606.

Scott, M.J., P.J. Heglund, M.L. Morrison, J.B. Haufler, M.G. Raphael, W.A. Wall, and F.B. Samson. 2002. Predicting Species Occurrences- Issues of Accuracy and Scale. Island Press, Washington, D.C.

Spackman, S., B. Jennings, J.C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997a. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, the U.S. Forest Service and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program, Fort Collins, CO.

Spackman, S., K. Fayette, D. Culver, K. Murrell, and M. Sherman. 1997b. Summit County Conservation Inventory Volume 1: A Natural Heritage Assessment. Unpublished report prepared for Summit County Open Space and Trails and Planning Departments by the Colorado Natural Heritage Program, Fort Collins, CO.

Spackman, S., K. Fayette, J. Siemers, K. Murrell, and M. Sherman. 1999. Roaring Fork Watershed Biological Inventory. Unpublished report prepared for Pitkin County, the Aspen Wilderness Workshop, and the Roaring Fork Valley Audubon Society by the Colorado Natural Heritage Program, Fort Collins, CO.

Spackman Panjabi, S.C. 2004. Visiting insect diversity and visitation rates for seven globally imperiled plant species in Colorado's middle Arkansas Valley. Unpublished report prepared for the Native Plant Conservation Alliance by the Colorado Natural Heritage Program, Fort Collins, CO.

Straw, R.M. 1956. Adaptive morphology of the *Penstemon* flower. Phytomorphology 6:112-119.

Straw, R.M. 1966. A redefinition of *Penstemon* (Scrophulariaceae). Brittonia 18:80-95.

Swayne, J. 2000. The *Penstemons*, seed germination methodology. Available online at http://tomclothier.hort.net/page08.html.

Tepedino, V.J. 1996. The reproductive biology of rare rangeland plants and their vulnerability to insecticides. Available online at http://www.sidney.ars.usda.gov/grasshopper/Handbook/III/iii_5.htm.

Tepedino, V.J., S.D. Sipes, J.L. Barnes, and L.L. Hickerson. 1997. The need for "extended care" in conservation: examples form studies of rare plants in the western United States. Acta Horticulturae 437:245-248.

Thomson, J.D., W.S. Armbruster, P. Wilson, and A.D. Wolfe. 1998. Floral function and phylogeny in *Penstemon*: tests of pollen presentation theory. Funded by NSF DEB-9708332. Available online at http://www.biosci.ohio-state.edu/~awolfe/Penstemon/collaboration/collaboration.html.

Titus, J.H. and S. Tsuyuzaki. 2002. Arbuscular mycorrhizal distribution in relation to microsites on recent volcanic substrates of Mt. Koma, Hokkaido, Japan. Mycorrhiza 12(6):271-275.

USDA Forest Service. 2002a. What is a Sensitive Species? USDA Forest Service, Rocky Mountain Region. Accessed via the Internet at: http://www.fs.fed.us/r2/nebraska/gpng/sensitive.html.

USDA Forest Service. 2002b. Rocky Mountain Region, White River National Forest, Final environmental impact statement to accompany the land and resource management plant-2002 revision. Provided in CD format by the USFS.

USDA Natural Resources Conservation Service. 2004. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA.

U.S. Department of Interior. 2002. Colorado BLM State Director's sensitive species list. Accessed via the World Wide Web at http://www.co.blm.gov/botany/sens_species.htm.

U.S. Environmental Protection Agency. 1997. Climate Change and Colorado. EPA 230-F-97-008f. Office of Policy, Planning, and Evaluation, Climate and Policy Assessment Division, Washington, D.C.

U.S. Fish and Wildlife Service. 1992a. Osterhout milkvetch and Penland beardtongue recovery plan. Denver, CO. 16 pp.

U.S. Fish and Wildlife Service. 1992b. Blowout penstemon (*Penstemon haydenii*) recovery plan. Denver, CO. 40 pp.

U.S. Fish and Wildlife Service. 2004. Species information: threatened and endangered animals and plants. Available online at http://endangered.fws.gov/wildlife.html.

Vandenkoornhuyse, P., S.L. Baldauf, C. Leyval, J. Straczek, and J.P.W. Young. 2002. Extensive fungal diversity in plant roots. Science 295:2051-2052.

Varma, A. 1999. Functions and application of arbuscular mycorrhizal fungi in arid and semi-arid soils. Pages 521-556 *in* A. Varma and B. Hock, editors. Mycorrhiza. Second edition. Springer-Verlag, Berlin, Germany.

Weber, W.A. and R.C. Wittmann. 1992. Catalog of the Colorado Flora. University Press of Colorado, Niwot, CO.

Weber, W.A. and R.C. Wittmann. 2001. Colorado Flora: Western Slope. University Press of Colorado, Niwot, CO.

Western Regional Climate Center. 2003. Monthly Climate Summary for Vail and Eagle, Colorado. Accessed via the Internet at http://www.wrcc.dri.edu.

Western Resource Development Corporation. 1982. Regional study on the distribution of *Penstemon harringtonii* Penland in Eagle, Grand, and Routt counties, Colorado. Unpublished report prepared for Tom Pitts and Associates, Consulting Engineers, Loveland, CO.

Western Resources Development. 1992. *Penstemon harringtonii* survey data Cordillera property and adjacent area 1992 field inventory, Eagle County. Unpublished report prepared for Cordillera, Edwards, CO.

Williamson, M. 2006. Personal communication with Colorado State University graduate student regarding vegetation responses to tree removal in sagebrush habitat.

Zomlefer, W. 1994. Guide to Flowering Plant Families. University of North Carolina Press, Chapel Hill, NC.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.