The Effects of Fire on Lemhi Penstemon (*Penstemon Lemhiensis*) – Final Monitoring Report 1995 - 2000

Prepared for:

Beaverhead-Deerlodge National Forest
and
Dillon Field Office - Bureau of Land Management

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June 2001

MONTANA Natural Heritage Program

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Agreement 00-CS-11010200-016
Agreement 1422E930A960015, Task Order No. 23

This document should be cited as follows:

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 the Dillon Field Office - Bureau of Land Management. Montana Natural Heritage Program, Helena. 22 pp. plus appendices.

Executive Summary

Lemhi penstemon (*Penstemon lemhiensis)* is a short-lived perennial that occupies early-to mid-successional habitats. In Beaverhead County it is found in settings that are dominated by mountain big sagebrush (*Artemisia tridentata ssp. vaseyana).* Previous monitoring indicated that the species was declining in major populations and that new plant recruitment was absent, so we evaluated prescribed burning as a management action for maintaining long-term species viability. The response of *Penstemon lemhiensis* to prescribed burn treatments was determined at 3 sites in Beaverhead County over 5-6 consecutive years, comparing pre- and post-burn trends.

Key indicators of species' viability, including population growth rates and recruitment-to- mortality ratios, increased drastically at one site following a prescribed burn where the species faced competition. Species viability showed little net change in a second site and declined in the third, where results were confounded by grazing effects and incomplete prescribed burn treatment, respectively. We conclude that fire is an appropriate tool in Artemisia tridentata – dominated habitats where the species faces competition. Carefully timed and managed prescribed fire treatments can be used to restore the habitat of Penstemon lemhiensis in cases where competition has increased. After the use of fire for habitat restoration, grazing in treated habitats needs to be managed to allow successful recruitment and reproduction of new individuals. Noxious weed control should be incorporated into any habitat management plans, as needed, to prevent the invasion or further spread of invasive plant species after fire treatments.

We have also demonstrated that population trends for *Penstemon lemhiensis* are well-buffered by the existence of seed banks. Monitoring results indicate that the seed banks can remain viable for at least six years, and support germination and recruitment episodes during years of higher moisture, cooler average temperatures, or taking advantage of disturbance events such as fire.

Illustration of *Penstemon lemhiensis*, by Jeanne R. Janish, from 'Vascular Plants of the Pacific Northwest'

Acknowledgements

The support and annual monitoring coordination provided by Dan Svoboda, John Joy and Brian Hockett are acknowledged with special gratitude. We thank each of the people who have assisted in the field over the six years of annual monitoring, including Kari Rogers, Dale McKnight, Katie Bump, Tobin Kelley, Katie Svoboda, Anne Dalton and Reyer Rens. We also acknowledge the help of people working in the permit review processes, burn treatment plans, and every related task.

Seed dormancy tests were conducted by Dr. Susan Meyer (Intermountain Research Station in Provo, Utah.) This work was benefited by early discussions with Caryl Elzinga and Linda Pietarinen. Current Idaho status information on *Penstemon lemhiensis* was provided by Michael Mancuso (Idaho Conservation Data Center.) Population projections were run by Dr. Christine Damiani (Duke University.) The report was edited by Joy Lewis (MTNHP) and formatted by Katrina Scheuerman (NRIS). It benefited by the review of Rob Sutter (Southeast Regional Office of The Nature Conservancy.) Our thanks go out to all these people.

The study was supported by a multi-year challenge cost-share agreement between the Montana Natural Heritage Program and the Beaverhead National Forest, and a separate series of annual challenge cost-shares agreements between the Montana Natural Heritage Program and the Montana State Office of the Bureau of Land Management.

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Introduction and Research Background

Lemhi penstemon (*Penstemon lemhiensis*) is a regional endemic plant species known from 4 counties in southwest Montana and from Lemhi County, Idaho. It is ranked G3 (globally vulnerable) and S2 (state imperiled) by the Montana Natural Heritage Program and the Idaho Data Conservation Center. It is recognized as sensitive by both Region 1 of the U.S. Forest Service (USDA 1999) and by the Montana State Office of the Bureau of Land Management (USDI BLM 1996), as well as Idaho agency counterparts. It was designated as a Category 2 candidate (C2) for federal listing by the U.S. Fish and Wildlife Service (USDI FWS 1990) and dropped as a candidate in 1996 with the alteration of the candidate species designation process.

This research into the effects of fire on *Penstemon lemhiensis* follows the original status survey work and later baseline monitoring work in which species' trends were evaluated (Shelly and Heidel 1995). These earlier studies and the rationale for this study are summarized in the following paragraphs.

Status surveys and subsequent fieldwork documented *Penstemon lemhiensis* from 89 occurrence records in Montana and 102 records in Idaho to date (191 total; Shelly 1987, 1990, Moseley et al. 1990, Montana Natural Heritage Program 2000, Idaho Data Conservation Center 2000). A recent compilation of rangewide data indicated that over 50% of the known populations were composed of fewer than 30 individuals, and only 3 populations were known to have over 300 individual plants at peak counts (Elzinga 1997).

The first study of the species' biology and habitat requirements indicated that it is a poor competitor under high vegetation densities (Ramstetter 1983). The author concluded:

> "…these data suggest that *Penstemon lemhiensis* may be out-competed in areas that have very high densities of vegetation (sagebrush and grasses in particular). The occurrence of the associated species does not seem to be as sensitive to high vegetation densities." (Ramstetter 1983).

If all populations were stable, then the long-term viability of *Penstemon lemhiensis* would not be an evaluation priority. The Idaho status report suggested that its many small populations are unstable, and further postulated that *Penstemon lemhiensis* is a fire-dependent seral species (Moseley et al. 1990):

> "We feel that many of the small populations have declined, or some have already gone extinct, due to unnatural vegetative succession resulting from wildfire suppression. Negative correlations between Lemhi penstemon density and such factors as grass cover, lack of fire, and tree canopy closure were noted… The species is probably adapted to localized declines resulting from lack of wildfire, and may be able to persist for long periods in small populations. But the unnaturally long fire intervals it currently experiences may be outside of its adaptive ability. For instance, seed dispersal distance is probably very short. It may, therefore, be very limited in its ability to colonize suitable habitat that is newly-created or currently unoccupied." (Moseley et al. 1990)

This is consistent with Idaho status survey observations as well as the fire history literature:

> "The most vigorous population that we observed, in terms of both individual plant growth and population numbers and density, occurred in the Long Tom Complex Fire, which burned in 1986 [four years prior to survey]." (Moseley 1992)

Later, a prescribed burn in the Big Hole National Battlefield in Beaverhead County, Montana was observed to have more *Penstemon lemhiensis* a decade after the burn than before treatment. The species disappeared from an adjoining untreated area at the same time (J. Pierce personal comm.).

Inventories and anecdotal observations can detect trends, but do not determine causality, predict viability, or identify management options (Palmer 1987). Botanists in Idaho and Montana initiated demographic monitoring studies in both states in order to document trend and life history bottlenecks among populations managed by the U.S. Forest Service and the Bureau of Land Management. This baseline demographic monitoring, a labor-intensive level 3 monitoring in the sense of Menges and Gordon (1996), set the stage for the current management response study.

The previous baseline monitoring was initiated at 4 study sites; 2 on the Beaverhead National Forest (Shelly 1990) and 2 on the Dillon Resource Area of the Bureau of Land Management (Achuff 1992). Results indicated that even some of the largest populations east of the Continental Divide, including Badger Pass North and Park Mine (a portion of the French Creek population), were in sharp decline, and that seed germination and recruitment are critical life history stages. One "small" monitored population was restricted to "unnatural" roadcut habitat and was similarly in decline (Shelly and Heidel 1995 and K. Bump pers. comm.). Continued declines were projected in the absence of seed germination and recruitment at part or all of the 3 other sites (Shelly and Heidel 1995).

Based on the baseline monitoring results, 2 research needs were identified to address management needs:

- Seed germination / seed bank research, and
- Research on species' response to prescribed burn management treatment

Elzinga (1997) also identified weed control research as a third critical conservation research need particularly west of the Continental Divide. Spotted knapweed (*Centaurea maculosa*) is a widespread invasive plant in *Penstemon lemhiensis* habitat west of the Divide in Lemhi County, Idaho and Ravalli County, Montana. It is not invading *Penstemon lemhiensis* habitat at present in Beaverhead and Silver Bow counties, though it has this potential, and there are a few cases where it has recently invaded in places that directly adjoin occupied habitat in these counties where it can still be controlled without direct impact to *Penstemon lemhiensis* (e.g., Badger Pass Microwave).

Our research focused on the effects of fire, to address the immediate decline of *Penstemon lemhiensis*. The previous baseline study was converted to an experimental manipulation study to determine species' management response to prescribed burn treatment, at the request of the managing agencies. Seed germination research was conducted by Dr. Susan Meyer, the expert in Penstemon seed biology, a tandem study that contributed information to this study and is reported in Appendix A.

Species Background

Penstemon lemhiensis (Lemhi penstemon) is an iteroparous short-lived perennial (i.e., reproducing more than once in a lifetime) with one to many basal rosettes of leaves arising from a branched caudex. All plants go through a single-rosette stage. The semi-evergreen basal rosettes overwinter and their number may remain stable, but over time the number of rosettes on each plant usually increases or less often decreases. Each rosette either develops a stout flowering stalk, 35-70 cm tall, or remains in vegetative condition.

The species reproduces strictly by seed. Flowers are protandrous (i.e., with staggered development of the male and female organs in each flower), pollinated mainly by a vespid wasp (*Pseudomasaris vespoides*), and the species is a near-obligate outcrosser

(Ramstetter 1983, Shelly 1987). There are no known dispersal adaptations of the seed or capsule, and it was surmised that most seeds fall within a meter of the parent plant (Ramstetter 1983, Elzinga 1997). The mature capsule dehisces in late summer, releasing seeds around the parent plant. No animals have been observed collecting or consuming seeds, but the seeds are relatively large, and longer-distance dispersal by insects, birds, or small mammals is possible.

Seedlings become established and form a rosette with the development of the stout, woody caudex. The caudex is the perennating organ of this geophyte, and is essential to moisture absorption and stress tolerance. Seedlings usually develop a caudex within their first year as seedlings, but occasionally survive for more than a year as stunted plants without developing a caudex or rosette.

The levels of flowering and seed germination are highly variable and influenced by climate from year to year. In general, both flowering and germination are highest in cool, wet springs and early summers, correlated with April-June mean maximum monthly temperatures and net precipitation in the same period (Elzinga 1997). The levels of mortality among established plants are highest in hot, dry years (Elzinga 1997). The key climate variables that indicate the levels of germination, flowering, and mortality include early summer mean monthly precipitation and the late summer mean maximum monthly temperatures (Elzinga 1997).

Basic information on seed biology was wanting, so a concurrent study of seed germination was conducted by Dr. Susan Meyer to help interpret fire response results. The introduction, methods and results of the seed germination study are described separately in Appendix A. Results indicated that seeds of *Penstemon lemhiensis* have 2 levels of dormancy. There is a chill-responsive fraction that germinates after prolonged freezing conditions, suggesting that they overwinter and germinate in spring. A large proportion of the seeds do not respond to chill treatment but remain dormant in a seed bank. In retrieval experiments with other Penstemon species that have a seed bank, some seeds remained dormant for at least 6 years (Meyer et al. 1995). The trigger(s) that eventually breaks dormancy is not known. The seed germination study helped us understand that the seed bank and chill-responsive fractions differ between populations but the seed bank fraction is consistently large. *Penstemon lemhiensis* seeds from 3 populations and settings were sampled and had germination rates ranging from 19.8-33.3% germination after a 20-week chill treatment. The balance of the seeds that were not chill-response represent the seed bank fraction (Appendix A).

Study Areas

This study was conducted at 3 high priority sites for *Penstemon lemhiensis* conservation rangewide, including Badger Pass North, Badger Pass Microwave and Canyon Creek, as indicated by peak population counts and habitat conditions (identified in Elzinga1997). The 3 study sites occupy foothill and montane settings, though they have similar elevations (Table 1). Each setting is

Table 1. Study area characteristics

Site	Elevation	Setting	Slope (%), Aspect	Habitat Category (reassigned from Elzinga 1997)
Badger Pass North	6980	Rolling foothills	18-34; southeast	Shallow-soil Rangeland
Badger Pass Microwave	7320	Foothills ridge	10 – 26; northeast	Shallow-soil Douglas-fir Opening
Canyon Creek	7200	Montane valley	50-51; south	Deep-soil Rangeland

locally dominated by mountain big sagebrush (*Artemisia tridentata* spp*. vaseyana*), as found in sagebrush steppe or Douglas-fir openings. Idaho fescue (*Festuca idahoensis*) is the dominant or co-dominant grass at all sites. Bluebunch wheatgrass (*Pseudoroegneria spicata*) is also co-dominant at Canyon Creek. The range of slope values that are listed below represent the pair of sample units at each site.

The sites fall within both shallow – and deep-soil sites as characterized in Elzinga (1997). The soils of deep-soil rangelands are "…usually sandy to clay loams, and often rocky or gravelly. Slopes are often steep, creating the bare soil microsite inhabited by Pentstemon lemhiensis through slope movement and erosion." The soils of shallow-soil rangelands are "…composed of large coarse fragments or outcrops with clay to sandy loam. Slopes are moderate to gentle, the bare soil microsite created by shallow harsh soils rather than the steepness of the slope."

Rooting depth is positively related with the canopy cover values of *Artemesia tridentata* (discussed in Knight 1994) and these habitat categories may indicate high- and low-competition conditions with sagebrush as well as basic environmental conditions.

We compiled information from the nearest weather monitoring stations at Dillon and Wise River to represent the climates at the study sites in each year of monitoring. The Dillon (Western Montana College) station is about 23 km east of the Badger Pass sites and 549-m lower in elevation (1594 m.) It has a high, intermontane valley climate, with a mean annual temperature of 14.4 C (57.9° F) and mean annual precipitation of 34.0 cm (13.39 in; 1895-2000 data; Western Regional Climate Center). The Wise River station is app. 13 km northwest of the Canyon Creek site and 396 m lower in elevation (1750 m). It has a montane climate, with a mean annual temperature of 13.0° C (55.4° F) and mean annual precipitation of 29.8 cm (11.74 inches; 1951-2000 data; Western Regional Climate Center). Two data tables from each station are presented and graphed, showing mean maximum monthly temperature and mean monthly precipitation for each year of the monitoring (Appendix B. Annual climate data for study areas, nearest stations at Dillon and Wise River, in keeping with the indicator values ascribed to these statistics [Elzinga 1997, pers. comm.]. Conversion values have been developed in the Gravelly Mountains of southwestern Montana for characterizing the montane climate using valley meteorological station data (Mueggler 1971).

The data from these weather stations is for general characterization rather than correlations. It has also been recommended that that multi-year climate data taken at the Dillon airport be substituted for that of Western Montana College in any further characterization or correlation effort, at the advice of Beaverhead – Deerlodge National Forest Service staff.

All 3 sites are part of federal grazing allotments. The Badger Pass sites are in primary range and Canyon Creek is in secondary range. The Badger Pass North study site lies within a large pasture that is not near water. The Badger Pass Microwave transects lie within an exclosure constructed by the Bureau of Land Management in 1980 to advance *Penstemon lemhiensis* conservation. It curtails livestock access but not big game movement.

Methods

Our goal was to determine the response of *Penstemon lemhiensis* to prescribed burn treatment at three sites by monitoring population sample-sets before and after treatment. A priority was placed on documenting seedlings and seed recruitment because they are critical in determining trend. To make projections and understand the nature of the response more fully, we followed all individuals by stage class and reproductive characteristics.

Field Methods

Monitoring was conducted at two existing belt transects used for baseline demographic monitoring at Badger Pass North and Badger Pass Microwave. The belt transect sampling methodology is described by Lesica (1987) and the transect establishment is documented in Shelly (1990) and Achuff (1991). It was not practical to include more plants by expanding the belt boundaries. We added separate 10 x 10 m quadrats at both belt transect sites to increase the sample size, minimize edge affects, study slightly different local microhabitats, and evaluate the quadrat as an alternate study design. We added a third site at Canyon Creek, where we put in 2 quadrats. The establishment report (Heidel and Shelly 1997) provides complete information on study site location and recording conventions.

The permanent monitoring transects and plots were subjectively placed in areas of high plant density for efficiency and to obtain meaningful demographic data (Lesica 1987). They do not statistically represent the respective populations and population trends, however they do include over 20% of the total estimated population numbers. Each transect or quadrat represents the statistical sample set for monitoring local trend, comparing change over time. We were not able to use a sampling design with paired treatments and control replicates because the number and distribution of individuals at all 3 sites were sparse, and the occupied microhabitats were small and variable.

Monitoring was conducted after flowering when fruits were mature. The monitoring times over the years ranged from July 28-August 20. All plants present in the belts or quadrats were mapped in the series of 1 x 1 m frames. The exception is that we did not precisely map seedlings in 1995 and 1996, though they were tallied within 1 m of all *Penstemon lemhiensis* plants in all other stages. Individual plants were assigned unique codes that included the plot frame and a letter that corresponded with the mapped location and coordinates within the frame. These unique codes remain assigned to the plant at that location for the duration of the study. If a new plant appeared in the frame, then it was assigned the next available letter. The stage of each individual was recorded using the following codes and tallies to represent stage class, reproduction, and damage (Table 2): Thus, a plant with 5 rosettes, 2 inflorescences (one of which is browsed), and 12 mature fruits was mapped and recorded as: R5-I2-F12-B1. Each plant recorded was sought in subsequent years. The complete monitoring spreadsheets have been printed and are on file at the Montana Natural Heritage Program. We followed 1,167 individually mapped plants between 1995-1999.

Table 2. Documentation of *Penstemon lemhiensis* stage class, reproduction and damage

Documentation	Code	Category
Stage	S	Seedling
Stage	C	An uncommon stage class representing prolonged juvenile plants of less than 2.5 cm diameter and less than five leaves, but no cotyledons
Stage	R	Rosette, including a tally of the number of rosettes per plant
Reproduction	I	Total number of Inflorescences per plant
Reproduction	F	Total number of fruits that set seed per plant
Reproduction	A	Total number of aborted fruits per plant
Damage	B	Total number of browsed or grazed inflorescences, noted separately from the sum of all inflorescences

Table 3.Prescribed burn conditions at study sites					
Site Name	**Date**	**Extent (acres)**	**Temperature (F) @ ignition**	**Humidity @ ignition**	**Comments**
Badger Pass North	9/11/1997	More than 10	63-65 Max 66-67; forecast	60-63% Min 55-60; forecast	All litter and most duff was burned off, and all sagebrush was killed.
Badger Pass Microwave	9/15/1998	Less than 5	Max 78-82; forecast	24-27 % forecast	Trees were felled in 1997. Burning the next year was very spotty. Logs and patches were spot-torched.
Canyon Creek West	9/25/1995	Less than 1	52-60; actual reading	41-52; wet bulb-dry bulb actual reading	Most litter was burned off, and all sagebrush was killed.

Each of the study sites was subjected to a prescribed burn treatment in September under the direction of the Beaverhead-Deerlodge National Forest (Table 3). Burning took place in different years as the environmental review processes, weather, and workforce allowed. Fire treatments were delayed at the Badger Pass sites and we extended monitoring through 2000 at Badger Pass North in particular, to confirm establishment and survival of new plants.

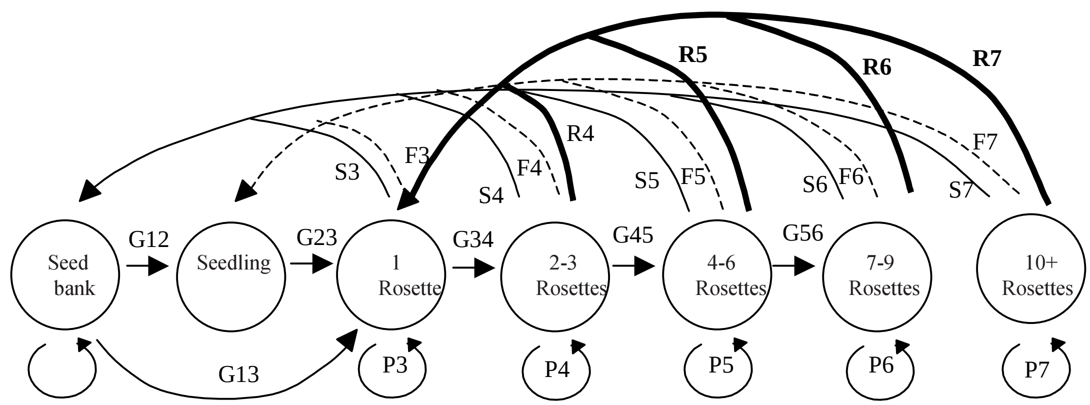
To help characterize the effects of fire on the rest of the sample plot vegetation, baseline vegetation data and ecological data were collected in each quadrat using ecodata sampling methods for environmental attributes and vegetation canopy cover estimates as documented by the U.S. Forest Service – Region 1. Vegetation data were recollected in the summer following prescribed burn treatment except at Canyon Creek West. There, intense grazing took place in the summer after fire, complicating identification and changing cover values. We delayed recording vegetation data at Canyon Creek West until 2 years after fire. In addition, pre-burn and post-burn photographic records were taken of transect landscapes and of quadrats from the lower lefthand corner of the quadrat at the time of establishment in 1995, and retaken at the time that vegetation data was recollected after burn treatment.

Data Analysis

Monitoring data analysis took 2 forms. First, we developed an overview of gross changes in numbers. Tallies were calculated and graphed on the number of plants in each sample set that were seedlings, vegetative plants, or flowering plants. Thus, a plant with 5 rosettes, 2 inflorescences (one of which is browsed), and 12 mature fruits would simply be tallied as one flowering plant.
The recruitment level was calculated as the sum of all new, established plants, i.e., those reaching the rosette stage. Seedlings were tallied and mapped but not counted as established plants until they survived their second year to become rosettes. Recruitment tallies also included fully established first-year plants that grew to 1-rosette stage in less than a year. We similarly tallied mortality among the seedlings and the established plants. Then net mortality and recruitment were tallied separately for each site, pooling data from pre-burn years, the year immediately following fire, and from subsequent post-burn years. Finally, we calculated the ratio of recruitment to mortality for established plants under each the 3 conditions (pre-burn, year immediately following burn, and successive post-burn years.)

Second, we developed stage-structured transition matrix projection models to determine population growth rates (Lefkovitch 1965, Caswell 1989, Morris et al. 1999). These models assume fixed transition probabilities over time, and the only way to evaluate monitoring data for a species in a fluctuating environment is to pool multiple years of data. We used the stage classes proposed by Elzinga (1997) to construct state to fate tables and transition matrices for each sample set and pair of years. The stage classes are schematically represented below. Note: All rosette classes are connected by two-way arrows to all other rosette classes. Thus, a plant with 5 rosettes, 2 inflorescences (one of which is browsed), and 12 mature fruits would simply be tallied as one plant in the class of plants with 4-6 rosettes. *Penstemon lemhiensis* survival, growth, and fecundity are size- and stage-related as they are for many species (see Menges 1990). This assumes that the shift in stages in any 2 years is independent of earlier stages and transitions. The equilibrium growth rate (lambda) is the dominant eigenvalue of the transition matrix; integrating all vital life history rates (Lefkovitch 1965, Caswell 1989). A lambda value greater than one indicates a population increase, while a value less than one indicates population decrease. The growth rates were calculated using the Ecolab students' version of RAMAS PVA software.

Figure 1. Life history of Penstemon lemhiensis



Elasticity measures the relative change in the value of lambda in response to changes in the value of a transition matrix element. The relative importance of different life history transitions can be compared in comparing their elasticity values.

We used the stage-specific monitoring results to develop models for the analyses. We note that critical pieces of life history information are missing to make accurate projections in this study, including pre- and post-burn data on fecundity, pre- and post-burn germination rates, data on seed bank longevity, viability over time, and dormancy release mechanisms. For the sake of projections, we made very simple assumptions that the seed germination in every year is constant and comprised of 50:50 contributions from the seed bank and from flowering plants. We used the single value of 23.5% (mean value, determined by Ramstetter 1983) to represent the proportion of seeds that are chill-responsive under pre- and post-burn conditions at the 3 sites. We also assumed that seed viability does not change in the seed bank over time.

Results

<u>Census Results</u>

An overview of census trends before and after the prescribed burns is presented in 5 monitoring datasets (Figures 2-6). The asterisked year marks the year of fall fire treatment and the culmination of pre-burn monitoring. In comparing established plant numbers (nonflowering + flowering) in the pair of years immediately before and after the prescribed burns, all 3 possible outcomes were observed:

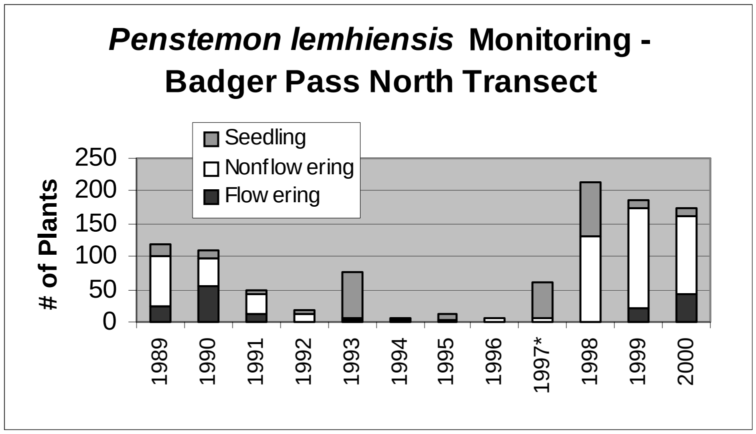


Figure 2

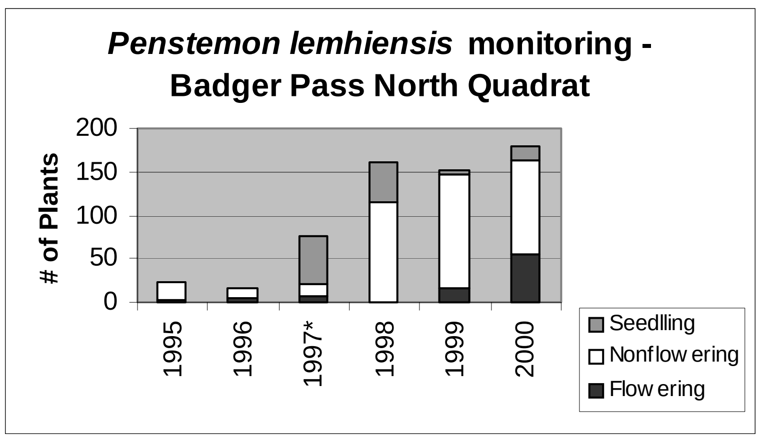


Figure 3

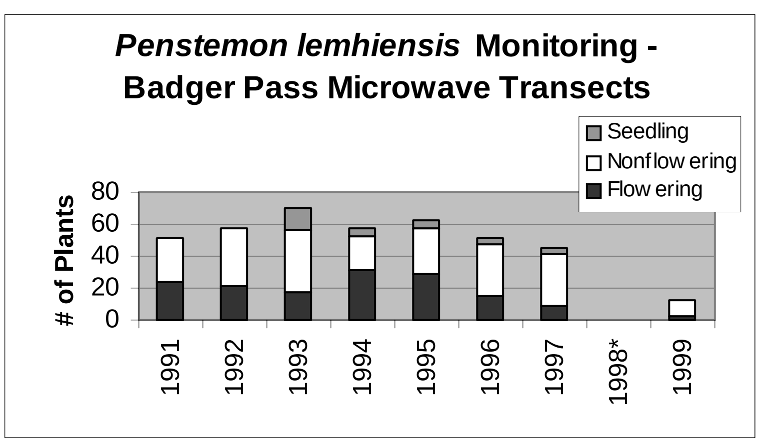


Figure 4

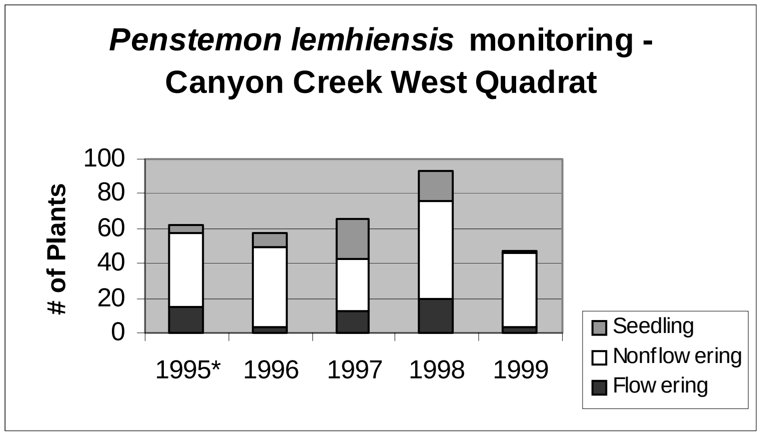


Figure 5

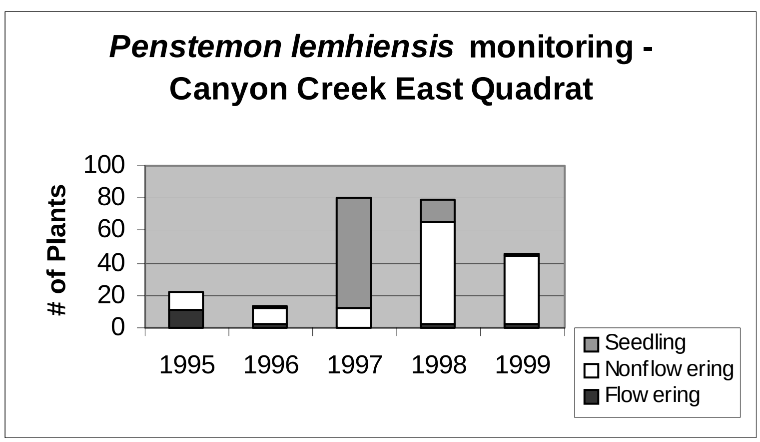


Figure 6

1. Net increases among established plants of 430% and 233% at Badger Pass North transect and quadrat, respectively;
2. Net decrease among established plants of 66% at Badger Pass Microwave transect (using 1997 for pre-burn data in the absence of 1998 data), and;
3. No appreciable change among established plants (8% decline) at Canyon Creek West.

The net number of established plants at the unburned Canyon Creek East plot also increased appreciably (525%). The purpose of showing all of the pre-burn data, including data from the baseline demographic monitoring, is to show overall trends, the sporadic nature of germination in the absence of any disturbance, and the low levels of recruitment in all pre-burn pairs of years.

Perhaps one of the most dramatic depictions of results is represented in a photograph. There was greater establishment in one portion of a 1m x 1m frame the year after the fire at Badger Pass North, than there was in all 50 1m x 1m frames in all previous 9 years combined (Figure 7). Moreover, there was low mortality in this flush of new plants compared to all pre-burn new plants. The study produced the first documented case in which *Penstemon lemhiensis* was observed to survive from the seedling stage to the flowering stage. A small proportion of the plants flowered within 3 seasons after fire and a greater-than-average proportion of plants flowered by the fourth year.

Figure 7. New *Penstemon lemhiensis* rosettes at Badger Pass North in the year following fire. Note: This photo represents a portion of a 1m x 1-m frame along the Badger Pass North Transect. The total number of new rosettes in this single photo exceeds the total number of new rosettes in all previous 9 years across the entire 1m x 50m transect sample area combined.

The immediate effects of fire were plant mortality levels ranging from 25-75% of the established plants in the year immediately following fall fire treatment (Table 4). But fire raised recruitment levels from 4600-6400% above average annual recruitment levels in Badger Pass North sample sets (Table 4.) The pre-burn average of 2.8 new plants/year/50 m^2 rose to 129 new plants in the post-burn years at Badger Pass North Transect. The pre-burn average of 1.7 new plants/year/100 m^2 rose to 109 new plants/year in the post-burn years at Badger Pass North Quadrat. The net effects at Badger Pass North are elevated post-burn ratios of recruitment to mortality. While recruitment declined at Badger Pass North during the second and third post-burn years, these sample populations remained relatively stable in the total number of individuals present, and retained levels of recruitment exceeding mortality. This is a primary line of evidence indicating positive response to fire treatment.

The Badger Pass Microwave transect had positive recruitment-to-mortality ratios in pre-burn years that dropped to zero recruitment in the year following burn treatment (Table 4). The response is not attributed to fire treatment because fire treatment covered only 17% of the sample populations in the transects and the rest remained unburned (see discussion).

We did not get pre-burn data from Canyon Creek to make a comparison between pre- and post-burn recruitment and mortality levels but note that there was a post-burn ratio of recruitment-to-mortality close to 1 in Canyon Creek West (Table 4). This was lower than the ratio of recruitment-to-mortality in the unburned Canyon Creek East Quadrat (Table 4), but results were greatly confounded by grazing (see discussion).

Projection Results

Transition matrix sets were compiled to calculate equilibrium growth rates under pre- and post-burn conditions for the 5 plots at the 3 sites, along with elasticitys and sensitivities (Appendix D). The

Table 4. *Penstemon lemhiensis* recruitment and mortality results

Site	Condition	Monitoring Year	Mortality of Seedlings		Mortality of Established Plants		Recruitment of Established Plants	Ratio of Recruitment: Mortality
			Net	Relative	Net	Relative	Net	(established plants)
Badger Pass North Transect	Pre-burn	1989-1997	80	90%	119	40%	25	0.21
	Burn	1998	41	79%	6	75%	129	21.5
	Post-burn	1999-2000	62	73%	53	19%	72	1.36
Badger Pass North Quadrat	Pre-burn	1995-1997	0 seedlings		8	22%	5	0.62
	Burn	1998	26	56%	7	41%	109	15.57
	Post-burn	1999-2000	23	50%	58	21%	88	1.52
Badger Pass North Microwave Transects	Pre-burn	1991-1997 (gap in1998)	18	56%	20	9%	25	1.25
	Burn	1999	3	100	15	58%	0	
Canyon Creek West Quadrat	Pre-burn	1995					4	
	Burn	1996	3	75%	14	25%	8	0.57
	Post-burn	1997-1999	20	50%	65	46%	62	0.95
Canyon Creek East Quadrat	Pre-burn	1995-1999	32	44%	61	48%	75	1.23

growth rate calculations show that of all sample sets with adequate data for projection, the Badger Pass Microwave transect pre-burn sample had the highest growth rate (Table 5). It and the Badger Pass North post-burn sample were the only ones appreciably above equilibrium. While our models are rudimentary, they serve in evaluating management response when one considers both the growth rates (Table 5) in combination with the variability in time (Elzinga et al. 1998; Appendix D.) We added one hypothetical case at Badger Pass North, evaluating the projected growth rate if livestock had not consumed all of the *Penstemon lemhiensis* infloresences that appeared in the third year after fire. This hypothetical case had the highest growth rate and reflects the importance of fecundity to recruitment following fire.

Other Life History Results

New life history information came out of the monitoring study that was used to refine the life history model. We confirmed the occurrence of uncommon "prolonged juvenile" plants (more than a year old) that fail to produce rosettes of leaves. They had not formed a stout caudex. These were put in a special "C" class as multi-year plants that have yet to become established, and subsequently were merged with 1-Rosette plants in the data analysis. We also confirmed that it is possible for newly-established plants to make their first-time appearance in the plots as fully established rosettes within one year of germination, as found at Badger Pass North. These plants did not skip the seedling stage as the life history diagram would indicate, but just germinated and developed from seedlings to rosettes in less than the one-year monitoring interval.

Table 5. *Penstemon lemhiensis* sample population growth rates

Site	Condition	Time Interval	Growth Rate (lambda)
Badger Pass North Transect	Pre-burn, no grazing	1989-1997	0.7918
Badger Pass North Transect	Post-burn, lt grazing	1998-2000	1.1212
Badger Pass North Transect	Post-burn, no grazing	1998-2000	2.0294
Badger Pass Microwave Transect	Pre-burn, no grazing	1995-1998	1.4087
Canyon Creek West	Post-burn, hvy grazing	1996-1999	0.7941
Canyon Creek East	Pre-burn, mod grazing	1995-1999	1.0917

Penstemon lemhiensis plants are short-lived. We did not determine the median age or life expectancy because the age of individual plants could not be determined on inspection past the seedling stage. We had hoped to determine life expectancy by following seedlings through their entire life cycle. However, no seedlings survived even to the flowering stage over the years of baseline monitoring. Inferences can be drawn from a review of plant survivorship over the duration of monitoring indicates. Only 1% of the individuals (one plant) survived through 8 years of demographic monitoring at Badger Pass North, while at the other extreme, 76% (13 plants) survived through the 6 years at Badger Pass Microwave nearby. In this study we determined that mortality levels differed between monitoring sites, but without knowing original population age structure, we cannot calculate absolute values. All that we conclude is that the species is a relatively short-lived perennial.

Associated Vegetation Change

The associated vegetation changes are represented by the paired photographic views of the pre- and post-burn study areas in Appendix C. The decline in woody cover after fire is evident in all three. The changes in herbaceous cover are not readily discerned. The changes between pre- and post-fire conditions within the 3 quadrats are graphed in Figures 8-10, and show just the 14 species that had greater than 1% canopy cover under either pre- or post-burn conditions at one or more sites (Table 6). At Badger Pass North, a complete post-burn herbaceous canopy cover conversion took place, unlike Canyon Creek West where the drop in the cover of mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) was the only major vegetation change between pre- and post-burn conditions. At Badger Pass North, the cover values of 3 grass species and four forb species also changed by at least an order of magnitude in comparing pre- and post-burn values. We note that the Badger Pass Microwave quadrat had so uneven a burn and low cover of *Artemisia tridentata* ssp. *vaseyana* to begin with that the cover data has limited value in characterizing the vegetation change in response to fire. While these are imprecise methods for evaluating canopy cover, they serve to document that significant vegetation composition changes took place at Badger Pass North compared to Canyon Creek West.

Table 6. Major canopy cover species in pre- or post-burn *Penstemon lemhiensis* quadrats

No.	Species
1	*Artemisia tridentata* ssp. *vaseyana*
2	*Agropyron spicatum*
3	*Carex rossii*
4	*Festuca idahoensis*
5	*Stipa viridula*
6	*Arenaria congesta*
7	*Castillega pallescens*
8	*Collomea linearis*
9	*Collinsia parviflora*
10	*Eriogonum umbellatum*
11	*Hieracium albiflorum*
12	*Lupinus spp.*
13	*Phacelia hastata*
14	*Solidago spp.*

Species List corresponds to Figure's 8-10

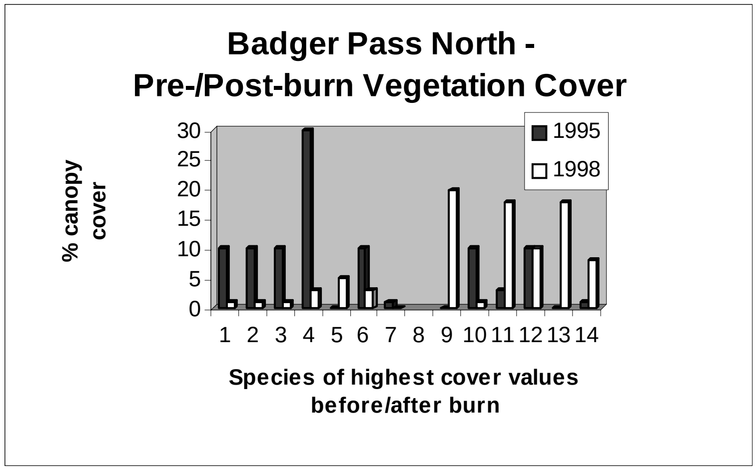


Figure 8

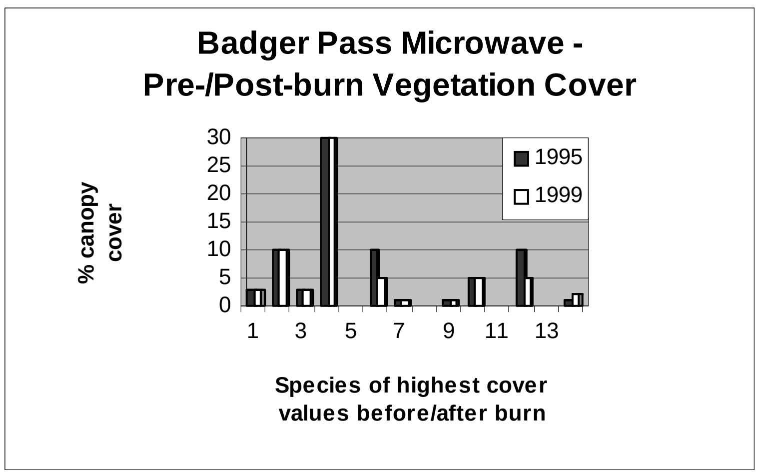


Figure 9

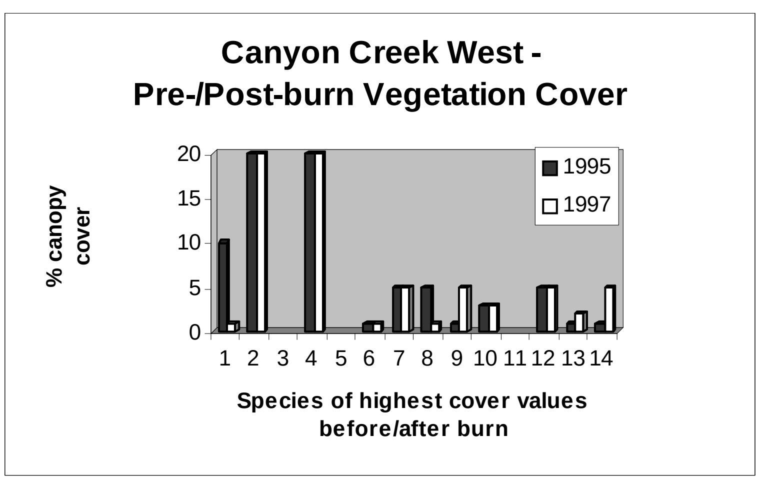


Figure 10

Discussion and Recommendations

Fire as a Management Tool

The results of the monitoring study at Badger Pass North provide the basis for recommending prescribed burning as a habitat restoration management tool for *Penstemon lemhiensis*, at least in deep-soil rangeland settings as defined by Elzinga (1997). Deep-soil rangeland settings occur mainly east of the Continental Divide, i.e., in the eastern part of the species' range. From the available information and observations, these sites are prone to increases in *Artemisia tridentata* in the absence of fire. *Penstemon lemhiensis* recruitment rose dramatically after fire treatment, consistent with the pattern of fire-adapted species for which fire generally promotes recruitment from seed banks through removal of accumulated litter and elimination or reduction of plant competition (Keddy et al. 1989).

There are 13 high priority areas for conservation of the species east of the Continental Divide on federal lands that were identified by Elzinga (1998) as top ("A") conservation priority sites, and/or which have population numbers documented at or above 100 plants. The 3 study sites are among the 13 high priority areas for species' conservation. We recommend reviewing each of the locales to identify if there is high cover of *Artemisia tridentata* in or adjoining species' habitat, and if so, to evaluate prescribed burn as a management option. Development of a long-term fire management plan is recommended for them. The distinction between "shallow-soil rangeland" settings for the species and "deep-soil rangeland habitat" may not be important if neighboring deep-soil habitats adjoin shallow-soils settings and represent suitable potential habitat for future population expansion.

The management recommendations are supported by both census and projection results. Projection matrices and the recruitment-to-mortality ratio calculations support the interpretation that prescribed fall burning at Badger Pass North turned a sharply declining trend into an increasing trend. The calculations of recruitment-to-mortality ratios document the burst of recruitment in the year after fire, and the ensuing successful net increases. The growth rate analysis results should not be considered rigorous quantitative analyses in the absence of site-specific pre- and post-burn data on fecundity, and data on seed bank longevity, seed viability over time, and dormancy release mechanisms. Despite these limitations, however, the growth rate analyses still have merit in assessing relative risks and benefits of management alternatives (Beissinger and Westphal 1998), and provide insights regarding the potential trends under burned and unburned conditions.

At the 3 monitoring sites, we recommend census revisits at intervals of between 5-10 years. This work might be linked to annual *Penstemon lemhiensis* census monitoring studies by the U.S. Forest Service in the Highland Mountains. For any future burns, we recommend demographic census data in permanent plots such as belt transects or the density transect presented by Elzinga (1997), monitored a minimum of 3 years prior to burn treatment and a minimum of 3 years afterward. The seedling stage class, while interesting to note, is not critical to monitor if newly established plants are meticulously recorded.

We propose the addition of a fire management clause to the list of recommended actions for conservation priority populations that have high cover of *Artemisia tridentata* ssp. *vaseyana* (20% or greater), including a prescribed burn objective and a customized wildfire policy, and all appropriate terms for grazing management and noxious weed control. Any prescribed burns or wildfires warrant at least census-level monitoring in permanent plots, also idled from grazing and treated for any noxious weeds at the same time. For a minimum of 2 years (2001-2002), the grazing of inflorescences needs to be curtailed at

Badger Pass North and Canyon Creek, by electric fencing or a rotation that eliminates grazing through the summer.

We reiterate that these results address the use of fire as an appropriate habitat restoration tool in *Artemisia tridentata*-dominated habitats where *Penstemon lemhiensis* faces competition due to past fire suppression. Other habitat management approaches may be more appropriate in occupied habitats west of the Continental Divide. The response of additional populations of *Penstemon lemhiensis* to the 2000 wildfires, and to prescribed burn treatment, is under separate consideration on the Bitterroot National Forest. The potential for noxious weeds to expand after fires is very high in occupied habitats on much of the Bitterroot National Forest, and such expansion may adversely affect the viability of many populations west of the Continental Divide. As such, fire response and noxious weed monitoring are critical needs in this area. Conditions on the Bitterroot National Forest also warrant ongoing noxious weed monitoring at all currently uninfested sites. Fire treatments should incorporate noxious weed control needs in all cases where post-treatment weed expansion or invasion is possible.

Challenges in Data Interpretation

Data analysis was confounded by facets of study design, burn treatment, and grazing affects:

1. We did not have the minimum 2 years of data to calculate pre-burn mortality at Canyon Creek or post-burn mortality at Badger Pass Microwave, or to make the accompanying population projections.

2. Burn treatment, though extensive across the Badger Pass Microwave exclosure, did not burn most of the transect areas with *Penstemon lemhiensis*. Of the 26 1 m x 1m frames along the three transect segments, 16 of the frames (60%) did not burn. The area that did burn burned with high intensity but contained only 17 % (7 plants) of the total number of plants that were present in 1997. In preparation for prescribed burns at this same site, the scattered Douglas-fir trees inside were felled, cut into sections, and left lying. The transect segments could not be read in 1998 because of the slash and logs, and it is possible that some plants were killed in burial. This was a difficult place to burn evenly because of woody debris.

3. The original intent was to set up controlled experimental conditions in which prescribed burning was the only disturbance variable. However, there was intense livestock grazing at the Canyon Creek sites in July of 1996 and 1999. This area is not ordinarily grazed. From July 5-25, 1996, there were 100 cow/calf pairs in the pasture, and they were drawn to the burn area of less than 1 acre. As a result, *Penstemon lemhiensis* plants were intensely grazed on the burned plot (all infloresences and much of the basal rosettes) and surface erosion escalated. It is a highly palatable plant. Not only were the tall flowering stalks grazed, but also most leaves on most rosettes were grazed, some quite severely with only the petiole left. We noted that the nearby unburned Canyon Creek East plot was also grazed, but the grazing was light, and grazing of *Penstemon lemhiensis* was mainly limited to the infloresences.

There was also grazing of *Penstemon lemhiensis* plants by livestock at the Badger Pass North site after burn treatment in 1998 and each of the following years, though the burn treatment area was a magnitude larger than the Canyon Creek burn, and the gentle slopes did not show surface erosion. The grazing on *Penstemon lemhiensis* at Badger Pass North was more dispersed and much lighter (all infloresences and occasional leaf rosettes) than at Canyon Creek. There were almost no dead plant remnants to indicate that there was mortality caused by grazing. There was no grazing by livestock at the Badger Pass Microwave site because it lies within an

exclosure. Intense grazing in the wake of prescribed burning comprises the fire response results if not survival and establishement of Pentstemon lemhiensis.
The full range of possible explanations for fire responses at Badger Pass Microwave and Canyon Creek include the following:

1. The neutral burn response at Canyon Creek West was tempered by heavy grazing.
2. The negative burn response at Badger Pass Microwave cannot be determined from a fragmentary burn that reached only 17% of the plants in the transects, and the results represent a response to conditions other than fire, possibly prolonged drought.
3. The burn responses at Canyon Creek West and Badger Pass Microwave reflect genetic differences.
4. The burn responses at Canyon Creek West and Badger Pass Microwave reflect differences in the burn treatments or in the ensuing environmental conditions that tempered the outcome, eg., belowground conditions or interactions.
5. Combinations of the above.

The only study site with adequate data for making robust pre- and post-burn comparisons of recruitment and for making projections is at Badger Pass North. The Badger Pass Microwave data are difficult to interpret because of the uneven and incomplete burn across the sample sites, and Canyon Creek West results do not include more than one year of pre-burn data, which are needed to determine mortality and recruitment under pre-burn conditions.

Two of the driest summers on record at Dillon (Appendix B; 1996 and 1999) also correspond with relatively high mortality at Badger Pass Microwave, a striking contrast to the survival and flush of new recruits at Badger Pass North in 1999. In addition, the growing conditions of 1999 and 2000 were not conducive to germination and recruitment of *Penstemon lemhiensis*. Thus, the post-burn response at Badger Pass North is all the more significant in conditions that were adverse to germination and recruitment.

Fire History

Fire regimes have been greatly altered throughout the species' range. The fire frequencies in one of this species' primary habitats of southwestern Montana, in the *Pseudotsuga menziesii* forest-grassland ecotone, was at 35-40 year intervals, and presumed to be shorter in grasslands and steppe in this region (Arno and Gruell 1983). Early journalists in the area noted that fire enhanced grasses and inhibited growth of woody plants (Gruell 1985). In the years since settlement, mountain big sagebrush cover increased dramatically over a 110-year interval about 10 miles southwest of Dillon (Plate 50, Gruell 1983). These bodies of information and repeated patterns have been interpreted to indicate that the high valleys and foothills of southwestern Montana were converted from a grassland landscape to a shrub-steppe landscape with the advent of fire suppression. Previously, mountain big sagebrush dominance was restricted to sites with soil texture extremes (e.g., sands, gravels, clays), whereas mountain big sagebrush (primarily Artemisia tridentata ssp. vaseyana) has become prevalent across broader areas of the landscape in the absence of fire (Arno and Gruell 1983).

Trial studies to control mountain big sagebrush for increased range production were conducted nearby, (3 km northeast of Bannack), and documented that the mountain big sagebrush canopy and mountain big sagebrush competition are most effectively reduced over the long-term by burning as compared to plowing, spraying, and rotocut treatment. Mountain big sagebrush cover that was originally at 15% canopy cover dropped to 0% with fall fire treatment and returned to only 1.8% over a 16-year period (1965-1981) after fire (Wamboldt and Payne 1986). Burn treatment also resulted in the highest biomass production for the dominant grass species, bluebunch wheatgrass (*Pseudoroegneria spicata*), compared to the other treatments. Though the Bannack study site is only about 600 feet lower in elevation than Badger Pass North, the mountain big sagebrush taxon was identified as *Artemisia tridentata* ssp. *wyomingensis*, a taxon of the Great Basin that is unlike *Artemisia tridentata* ssp. *vaseyana*, the montane subspecies identified at the 3 monitoring sites. We do not have information to compare the fire responses of the 2 subspecies and the applicability of these data from the Bannack setting to those in this study. But this earlier study provides a preliminary indication that prescribed burning may offer a relatively long-term management tool that could be used to enhance habitat conditions for *Penstemon lemhiensis* in this area.

<u>Seed Germination</u>

In the course of this study, we revisited the original hypothesis that recruitment was too low to maintain viable populations without prescribed burn intervention. The French Creek transects, in a shallow-soil rangeland setting, were revisited during the "good germination year" of 1997. The numbers of established plants had increased over 50% between 1993-1997. This represented the first time that significant recruitment had ever been quantitatively documented for *Penstemon lemhiensis*, and it occurred without management intervention (Appendix E. *Penstemon lemhiensis* monitoring at French Creek). These major recruitment episodes have not occurred in deep-soil rangeland habitat where the species faces competition over the duration of monitoring in the absence of fire.

In 1998 at the unburned Canyon Creek East quadrat, there was also a germination episode that led to significant recruitment. The unprecedented burst of recruitment in this case may have been driven by the same climate cycles as at French Creek. Alternatively, the montane setting at Canyon Creek is different enough that the conditions for seedling survival are less stringent (cooler and moister on average). Genetic differences may also partially account for different recruitment patterns. There is one more possible explanation. The nearby burn treatment drew livestock into this unburned area for an episode of grazing that increased the exposure of bare soil, and this may have offered a surrogate disturbance that favored germination and recruitment of *Penstemon lemhiensis* in the absence of fire

Generalizations about recruitment need to be tempered by site conditions and climate cycles. The Badger Pass Microwave site numbers were exceptionally stable throughout pre-burn monitoring. It appears that recruitment at the more mesic sites such as Badger Pass Microwave is sustained even during a dry cycle, that the more xeric sites like French Creek and Canyon Creek do well during wet seasons, and the high-competition sites do poorly, regardless of climate, in the absence of disturbance. We do not have sufficient data on site characteristics and on-site climate conditions to draw correlations, so these observations strictly represent refinements in our original hypothesis, and would require further study for verification.

These results, in combination with the seed chilling experiment of Meyer (Appendix A), meet the immediate research needs for germination studies as identified in Elzinga (1997). It is possible that the different seed germination responses reflect genetic (ecotypic) differences in seed dormancy. In any case, the differences in response to fire treatment between sites suggest that life history traits may be locally adapted, and possibly represent genetic variation between populations.

The seed germination experiment results were interpreted to indicate that seeds normally germinate beneath the snow followed by spring emergence. Typically, the "new" plants making their first appearance in monitoring plots were seedlings produced that spring, i.e., they still retained vestiges of the cotyledon when monitoring took place in late summer.

At Badger Pass North, this changed after prescribed burning took place, in which the majority of the “new” plants were well-established rosettes that had gone from seedling to rosette stage in less than one year’s time. The new plants making their first-time appearance as rosettes may have had longer to grow if they broke dormancy in the fall, or if fire accelerated spring thaw and lengthened the growing season. Reduced competition or the post-fire flush of nutrients may have also increased the rate of growth and development.

At least as important, we documented that population fluctuations are greatly buffered by the seed bank. Despite an almost complete absence of flowering plants at Badger Pass North from 1992-1997, there were two flushes of germination in the wet years of 1993 and 1997, and an even larger flush of germination in 1998 following the prescribed fire treatment. Only a substantial seed bank that can remain viable for at least 6 years could have supported these germination episodes. In general, seed banks have adaptive value in unstable environments, and the “benefits” that come from having seed banks are influenced by seedling establishment success, adult fecundity, and longevity (Fenner 1985, Rees 1994). Modeling results indicated that when both seedling establishment success and adult fecundity are variable, the likelihood of successful reproduction from new recruits is reduced (Rees 1994). This was evident in the pre-burn years at Badger Pass North. The effect is ameliorated when plants are long-lived, i.e. mortality is low, as demonstrated in the pre-burn data from the Badger Pass Microwave site.

Herbivory and Rangeland Management

Herbivory is natural for a palatable forb. Prior to burn treatment, the highest levels of browsing were documented in the Badger Pass Microwave exclosure, a structure that prevented entry by livestock but did not restrict mule deer and elk. During some years there was no browsing in the exclosure, while in other years it was as high as 72% of infloresences (Shelly and Heidel 1995; reported in Elzinga 1997), representing chance entry by big game. In post-burn years, 100% of flowering stalks were removed at both Badger Pass North and Canyon Creek West, and cattle use was evident. We did not quantitatively compare the intensity of grazing at Badger Pass North vs. Canyon Creek West, but the comparative steepness of the Canyon Creek West site and the small area of the burn, exacerbated the effects of grazing, as seen in the direct mortality at this site. Grazing can eliminate the benefits of prescribed burning and compromise the survival and establishment of *Penstemon lemhiensis*.

Projection matrices make it possible to assess the influence that the vital rates of particular classes have on the population as a whole (Morris et al. 1999). This in turn adds predictive ability when there is a change in vital rates, or management alternatives are to be tested for their potential effects on vital rates. The significance of fecundity in comparing the projection analyses between sites is reflected when we re-ran the Badger Pass North post-burn data using hypothetical site data. We re-calculated reproductive values based on the number of inflorescences that were produced, ignoring the fact that all inflorescences were grazed by livestock. The growth rate under this hypothetical ungrazed condition almost doubled. Thus, the effects of livestock grazing strictly on the infloresences without side effects of trampling and erosion can impede the positive effects of fire.

Any recommendations for habitat restoration or management that involve prescribed burns or wildfires needs to include grazing management provisions if the treated habitat is part of a grazing allotment or is otherwise regularly used by stock. Treated habitats are best idled for at least two years following fire if the habitat has a high erosion hazard, or if the burn is small and grazing is likely to be highly concentrated. In at least the third and fourth year, grazing rotation to avoid summer months when the inflorescence is palatable is also essential.

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Appendix A.

Penstemon lemhiensis germination experiment

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Introduction

Regulation of seed germination is critical to short-lived perennial plants that inhabit highly variable climates. Seed germination response of Lemhi penstemon (*Penstemon lemhiensis*), a short-lived perennial of the Section Habroanthus, was determined for seed samples collected at three sites under variable-length chilling, with or without warm treatment interruption. Seeds were tested to determine the proportion of seeds that are chill-responsive and non-responsive, and the effects of warm treatment interruption on the chill treatment response.

Methods

Seeds were collected from three Montana populations of *Penstemon lemhiensis* in late August-early September, 1995. The sites are presented in Table 1. They represent one Montana site west of the Continental Divide at Robbins Gulch, and two Montana sites east of the Continental Divide. The Badger Pass (Microwave) collection site is at a similar elevation as Canyon Creek, but is in a foothills setting rather than a montane setting, and an area of snow accumulation that is not directly exposed to the sun, in contrast to the steep, south-facing Canyon Creek site.

First, seeds were moist-chilled at 2C in the dark and then incubated for four weeks at 10/20C (12h:12h) with cool-white fluorescent light during the high temperature part of the cycle. They were removed from treatment at four-week intervals from 0-24 weeks and the percentages of germination were determined for each interval. The percentage of seeds germinating under each treatment represents the chill-responsive fraction, and the remainder did not respond to treatment.

Second, seeds were treated to a chilling period totaling 20 weeks, preceded or interrupted by warm treatment (incubation at 10/20C) for 4 weeks. These treatments were generated by returning petri dishes from chilling treatments 0-16 weeks (above) to chilling after their 4-week incubation at 10/20C, for a period sufficient to give them a total of twenty weeks of chilling.

Results and Discussion

Penstemon lemhiensis seeds from three sample sets required at least 16 weeks of chilling for any seeds to become germinable. Chilling beyond 16 weeks caused no further increase in germinable seed percentages for the Robbins Gulch and Canyon Creek collections, while the Badger Pass collection showed an increase with up to 20 weeks of chilling (Table 2). These results indicate that the species usually germinates in the spring after over-wintering, a response to chilling that probably relates to growing season conditions at the collection sites, as is the case for most other montane penstemons.

For most samples after chilling, only 20-25% of the seeds were chill-responsive; the remaining 75-80% did not lose dormancy in chilling regardless of chilling duration. They have an additional

Table 1. *Penstemon lemhiensis* seed collection sites

SITE	AGENCY	ELEV. (m)	Location	EO No.
Robbins Gulch	Bitterroot NF	1585	T.2S R.20W Sec. 10	056
Badger Pass Microwave	BLM	2216	T.7S R.11W Sec. 22	005
Canyon Creek	Beavernead NF	2195	T.2S R.10W Sec. 8	038

Table 2. Final post-incubation germination percentages of *Penstemon lemhiensis* following chilling periods of 0 to 24 weeks, expressed as percentage of viable seeds[1].							
Site	**Chilling Duration (Weeks)**						
	0	**4**	**8**	**12**	**16**	**20**	**24**
Robbins Gulch	0b	0b	1.1b	1.1b	21.7a	19.8a	22.6a
Badger Pass Microwave	0c	0c	1.0c	3.1c	11.7b	23.2a	25.8a
Canyon Creek	0b	0b	0b	4.0b	28.9a	26.5a	21.6a

dormancy carryover mechanism and they represent the seed bank. Results are consistent with the environmental conditions at the three sites and the germination timing patterns previously documented among Intermountain *Penstemon* in which the chill-responsive fraction germinates following periods likely to be encountered, and the other fraction resists chilling treatment (Meyer et al. 1995).

Prewarming and chill interruption tests with this species indicate that the effects of chilling are generally not "remembered" across the warm treatment interruption, even though the seeds remain imbibed. These results simulate the effect of warm episodes preceding or interrupting the freezing conditions of winter. Robbins Gulch seeds showed an increased germination percentage with an initial warm treatment in comparison to with the 20-week control, while the Badger Pass collection showed no significant effect, and the Canyon Creek collection showed a significant decrease (Table 3).

The wide range of habitats for *Penstemon lemhiensis* is reflected in a range of germination patterns. This is an indication of genetic differentiation (ecotypic adaptation.) We do not have information on the mechanism for breaking dormancy in the seed bank, but the environmental cues are received only by imbibed seeds. Moisture may be a limiting factor for any seed germination and account for the cyclic spikes in seed germination with cool, wet growing seasons.

Literature Cited

Meyer, S. E., S. G. Kitchen and S. L. Carlson. 1995. Seed germination timing patterns in Intermountain *Penstemon* (Scrophulariaceae). Am. J. Bot. 82(3):37-389.

Citation for this study:

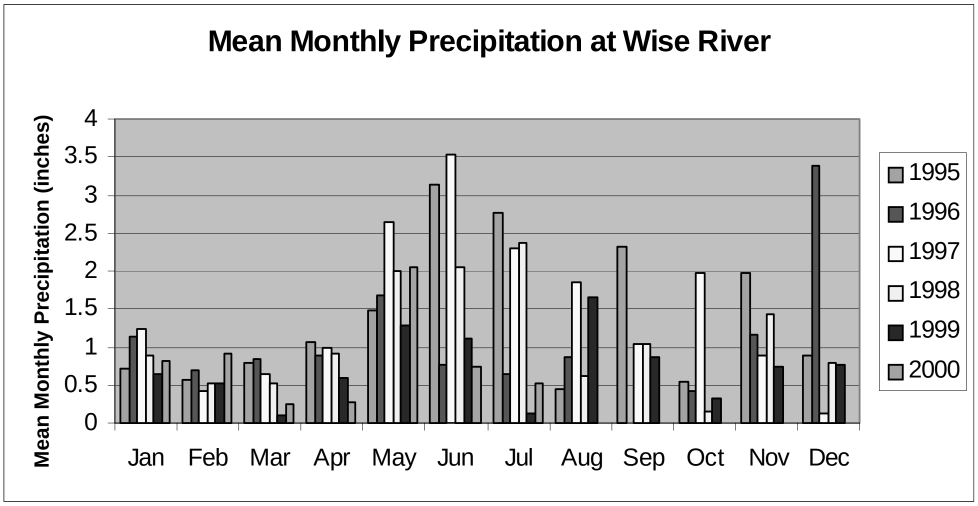
Meyer, S. E. 1996. Appendix A. *Penstemon lemhiensis* chilling experiment.Unpublished report.*In*: Heidel, B. and J.S. Shelly 2001. The effects of fire on Lemhi penstemon (*Penstemon lemhiensis*) – final monitoring report, 1995-2001. USDA Forest Service Shrub Sciences Laboratory. Provo, UT.

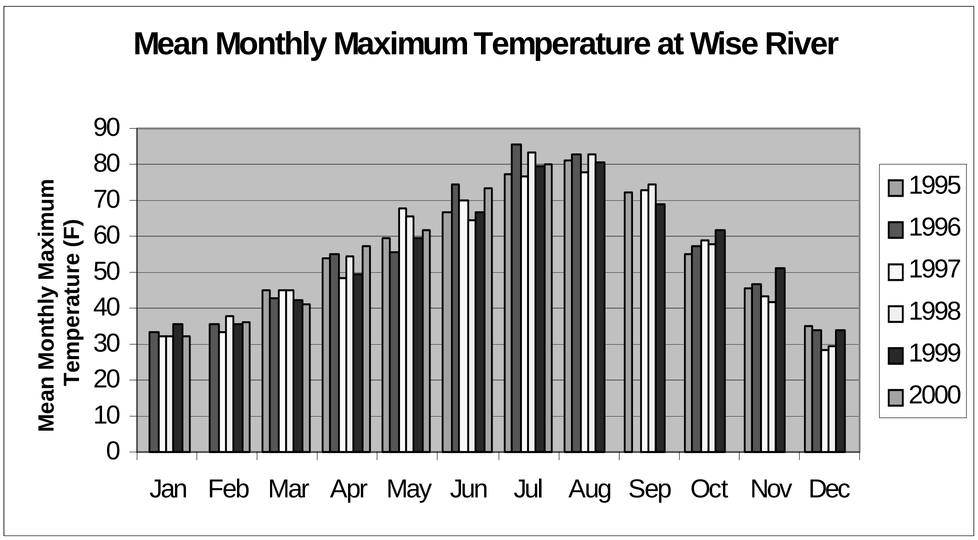
[1] Within each set from the same site, means followed by the same letter are not significantly different at the P<0.05 level according to an LSD test.

Table 3. Final post-incubation germination percentages of *Penstemon lemhiensis* following a chilling period totalling 20 weeks, preceded or interrupted by 4-week incubation[1]						
Site	**Chilling Duration (Weeks Chilling=Ch; Weeks 10/20=Wm)**					
	4WM+ 20Ch	4Ch+4Wm +16Ch	8Ch+4W m+12Ch	12Ch+4W m+8Ch	16Ch+4W m+4Ch	20Ch
Robbins Gulch	27.6a	11.5c	4.3d	1.1d	21.7ab	19.8b
Badger Pass Microwave	17.2a	1.0b	1.0b	3.2b	11.7a	23.2a
Canyon Creek	6.4b	3.8b	9.3b	4.0b	33.3a	26.5a

Appendix B

Annual climate data for study areas, nearest stations at Dillon and Wise River



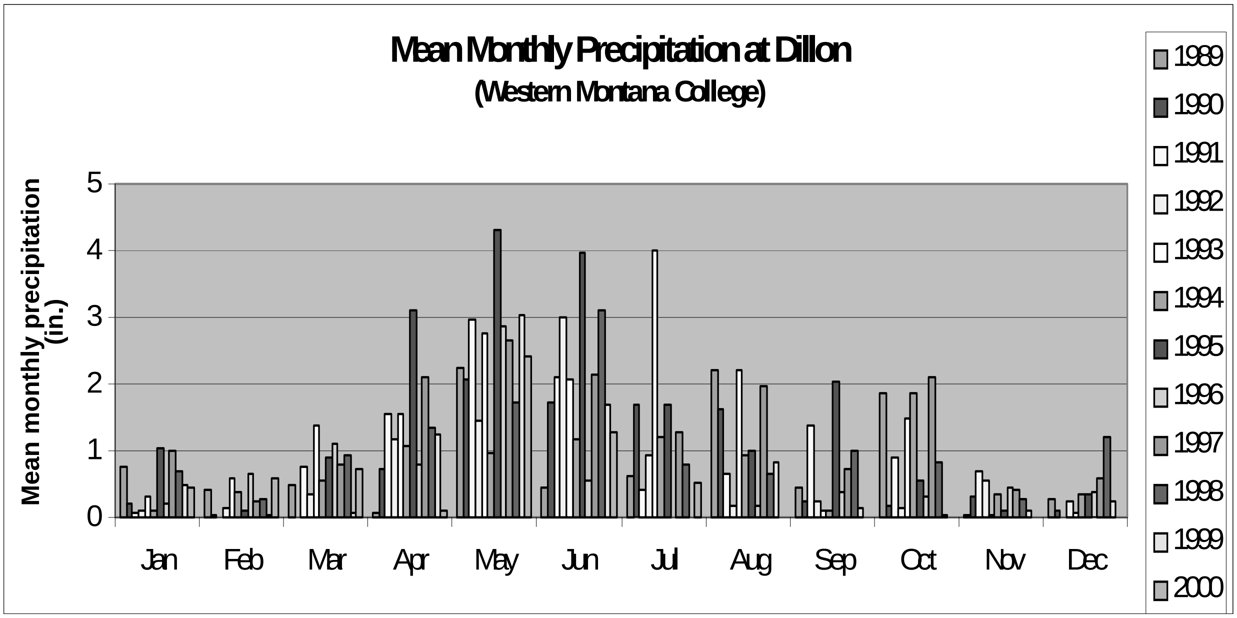


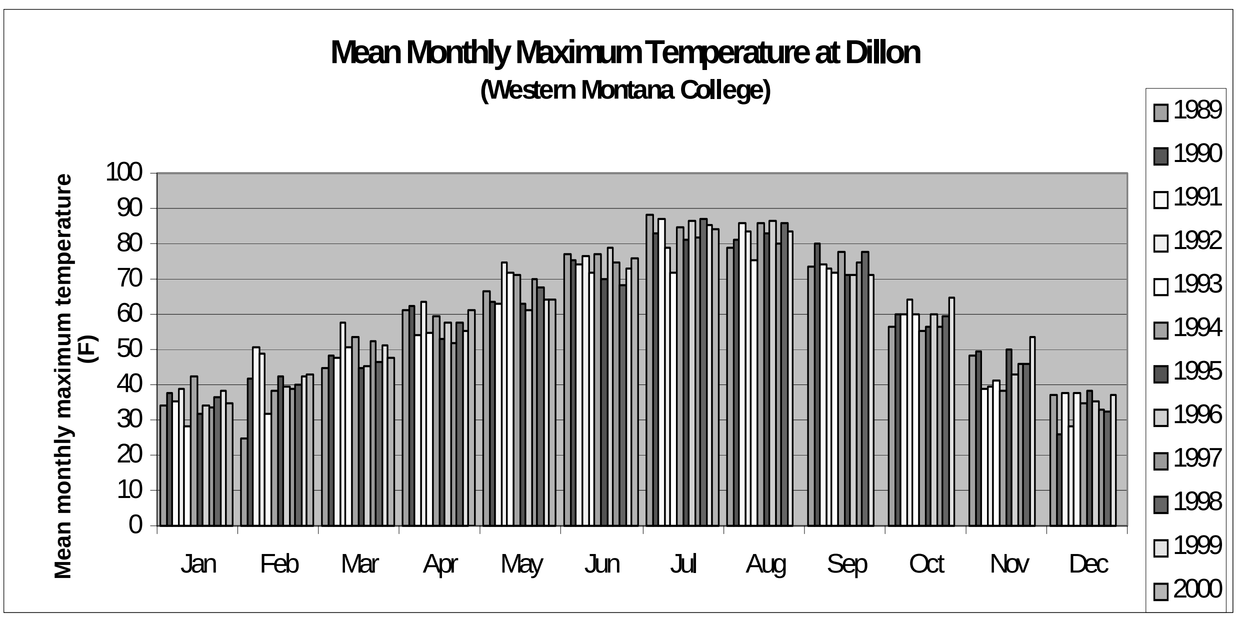
Wise River - mean monthly precipitation (inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	sum
1995	0.71	0.57	0.79	1.06	1.49	3.14	2.76	0.45	2.32	0.55	1.98	0.89	16.71
1996	1.13	0.69	0.83	0.9	1.67	0.76	0.65	0.87		0.41	1.16	3.38	12.45
1997	1.24	0.41	0.63	0.98	2.64	3.52	2.29	1.86	1.04	1.97	0.9	0.12	17.6
1998	0.9	0.52	0.51	0.92	2	2.04	2.38	0.62	1.03	0.14	1.44	0.79	13.29
1999	0.63	0.51	0.1	0.6	1.28	1.11	0.13	1.66	0.87	0.32	0.74	0.77	8.72
2000	0.82	0.92	0.25	0.28	2.05	0.74	0.51						

Wise River - mean monthly maximum temperature (F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mean
1995	-----	-----	44.9	54.1	59.29	66.5	77.29	81	72.17	54.81	45.33	34.77	59.02
1996	33.35	35.55	42.81	55.2	55.52	74.67	85.35	82.94	-----	57.16	46.9	33.97	54.86
1997	32.03	33.07	45.23	48.1	67.55	70.2	76.94	77.94	72.57	58.65	43.47	28.26	54.5
1998	32.26	37.96	45.23	54.5	65.35	64.37	83.23	82.52	74.43	58.03	41.7	29.71	55.77
1999	35.42	35.29	42.16	49.23	59.45	66.77	79.39	80.74	69.13	61.71	51.07	33.87	55.35
2000	32.06	36.28	41	57.2	61.65	73.07	80.1						54.48


Mean Monthly Precipitation at Dillon
(Western Montana College)
Mean monthly precipitation (in.)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000


Mean Monthly Maximum Temperature at Dillon
(Western Montana College)
Mean monthly maximum temperature (F)
0
10
20
30
40
50
60
70
80
90
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Dillon - WMC mean monthly ppt													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**sum**
1989	0.76	0.42	0.48	0.07	2.25	0.46	0.62	2.19	0.44	1.87	0.02	0.27	9.85
1990	0.22	0.03	0	0.74	2.06	1.71	1.68	1.62	0.23	0.16	0.31	0.11	8.87
1991	0.06	0	0.75	1.56	2.97	2.12	0.4	0.64	1.38	0.89	0.7	0	11.5
1992	0.12	0.14	0.36	1.18	1.46	2.99	0.93	0.17	0.25	0.14	0.54	0.24	8.52
1993	0.31	0.58	1.38	1.56	2.75	2.07	4.01	2.21	0.09	1.47	0.04	0.08	16.6
1994	0.12	0.39	0.54	1.06	0.98	1.16	1.22	0.93	0.09	1.86	0.33	0.35	9.03
1995	1.03	0.1	0.9	3.09	4.32	3.96	1.68	1.01	2.05	0.56	0.1	0.36	19.2
1996	0.19	0.66	1.1	0.79	2.87	0.54	0	0.17	0.37	0.32	0.44	0.38	7.83
1997	1.01	0.25	0.8	2.1	2.65	2.14	1.28	1.97	0.71	2.11	0.41	0.6	16
1998	0.69	0.29	0.92	1.33	1.72	3.1	0.79	0.66	1.01	0.84	0.29	1.19	12.8
1999	0.49	0.02	0.07	1.25	3.02	1.68	0	0.84	0.13	0.05	0.1	0.25	7.9
2000	0.45	0.6	0.71	0.09	2.42	1.26	0.52						6.05

Dillon - WMC mean monthly T													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**sum**
1989	34.1	24.8	44.7	61.1	66.4	77	88	78.7	73.5	56.5	48.4	37.3	57.5
1990	37.7	42	48.5	62.4	63.8	75.2	83.2	81.3	79.8	59.8	49.6	25.9	59.1
1991	35.2	50.9	47.7	54.1	63.2	74.1	86.9	86.2	74.4	59.9	39.1	37.7	59.1
1992	38.6	49	57.7	63.4	74.9	76.2	79	83.4	73.2	64.4	39.5	28	60.6
1993	28.4	32	50.6	54.9	71.7	71.8	71.6	75	71.8	60	41.3	37.6	55.6
1994	42.5	38.4	53.8	59.7	71.1	77.3	84.9	85.6	77.7	55.2	38.2	34.9	59.9
1995	32	42.6	44.9	53.2	62.8	70	81.2	82.9	71.1	56.7	50.1	38.2	57.2
1996	34.1	39.2	45.2	57.7	61.5	79	86.6	86.3	71.1	60.1	43.1	35.2	58.3
1997	33.3	39.1	52.2	51.6	70.3	74.5	81.8	80.1	74.9	56.5	46	33	57.8
1998	36.3	39.8	46.5	57.5	67.8	68.4	86.8	85.7	77.8	59.3	46.1	32.3	58.7
1999	38	42.3	51.5	55.1	64.2	73.2	85.5	83.7	71	64.9	53.5	36.8	60
2000	35	43.1	47.7	61.4	63.9	75.7	84.2						58.7

Appendix C

Pre- and post-burn plot photographs

Badger Pass North Transect, pre-burn (28 July 1989)

Badger Pass North Transect, post-burn (2 August 2000)

Badger Pass Mircowave Exclosure, pre-burn (18 August 1995)

Badger Pass Mircowave Exclosure, post-burn (20 August 1999)

Canyon Creek West Quadrat, pre-burn (17 August 1995)

Canyon Creek West Quadrat, post-burn and post-grazing (23 July 1997)

Canyon Creek West Quadrat, later post-burn (29 July 1998)

Appendix D

Stage matrices, elasticities, and sensitivities

WARNING: This analysis ignores the following feature(s) of this model, and therefore may be misleading or irrelevant. Interpret with caution!
* Initial distribution to Stages (different from stable distribution)
* Small number of individuals (sampling variation)

Badger Pass North Transect Pre-burn (1989-1997)
Stage matrix (default):

	1	2	3	4	5	6	7
1:	0.6800	0.0000	12.2800	43.2660	171.00	251.70	350.00
2:	0.0004	0.0000	0.0020	0.0100	0.0350	0.0390	0.0300
3:	0.0005	0.1010	0.2940	0.1600	0.1070	0.0830	0.1240
4:	0.0000	0.0000	0.1330	0.2270	0.2280	0.2260	0.0000
5:	0.0000	0.0000	0.0270	0.1710	0.2030	0.2260	0.0870
6:	0.0000	0.0000	0.0130	0.0230	0.0630	0.1940	0.2170
7:	0.0000	0.0000	0.0000	0.0000	0.0630	0.0650	0.3480

Growth rate (lambda)= 0.7918 (approximate)

Stage	Init. distr.	Stable distr.	Reprod. Value	Avg. residence
1	0.000	0.998	1.000	3.13
2	0.000	5.00E-04	25.877	1.00
3	0.000	0.001	202.863	1.42
4	0.000	4.00E-04	408.391	1.29
5	0.000	2.00E-04	762.183	1.25
6	0.000	1.00E-04	1058.078	1.24
7	0.000	0.000	1513.904	1.53

Elasticities: (approximate)

	1	2	3	4	5	6	7
1:	0.5052	0.0000	0.0119	0.0129	0.0255	0.0187	0.0000
2:	0.0077	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000
3:	0.0754	0.0076	0.0577	0.0097	0.0032	0.0013	0.0000
4:	0.0000	0.0000	0.0526	0.0276	0.0139	0.0069	0.0000
5:	0.0000	0.0000	0.0199	0.0388	0.0230	0.0128	0.0000
6:	0.0000	0.0000	0.0133	0.0072	0.0099	0.0153	0.0000
7:	0.0000	0.0000	0.0000	0.0000	0.0142	0.0073	0.0000

Sensitivities: (approximate)

	1	2	3	4	5	6	7
1:	0.5882	0.0003	0.0008	0.0002	0.0001	0.0001	0.0000
2:	15.2218	0.0076	0.0198	0.0061	0.0031	0.0015	0.0000
3:	119.3304	0.0598	0.1555	0.0479	0.0239	0.0120	0.0000
4:	240.2283	0.1204	0.3131	0.0963	0.0482	0.0241	0.0000
5:	448.3399	0.2247	0.5843	0.1798	0.0899	0.0449	0.0000
6:	622.3945	0.3120	0.8111	0.2496	0.1248	0.0624	0.0000
7:	890.5259	0.4464	1.1606	0.3571	0.1786	0.0893	0.0000

Badger Pass North Transect Post-burn (1998-2000)
Stage matrix (default):

	1	2	3	4	5	6	7
1:	0.6800	0.0000	0.0000	0.2120	5.7370	2.8280	0.0000
2:	0.0103	0.0000	0.0000	0.0000	0.2240	0.0000	0.0000
3:	0.0238	0.2120	0.2580	0.0240	0.5000	0.0000	0.0000
4:	0.0000	0.0590	0.3110	0.2930	0.2070	0.2000	0.0000
5:	0.0000	0.0000	0.1790	0.4150	0.4140	0.2000	0.2860
6:	0.0000	0.0000	0.0160	0.0000	0.3450	0.2000	0.1430
7:	0.0000	0.0000	0.0210	0.0490	0.0000	0.4000	0.2860

Growth rate (lambda)= 1.1212 (approximate)

Stage	Init. distr.	Stable distr.	Reprod. Value	Avg. residence
1	0.000	0.802	1.000	3.13
2	0.000	0.017	4.280	1.00
3	0.000	0.056	16.685	1.35
4	0.000	0.040	21.382	1.41
5	0.000	0.049	39.133	1.71
6	0.000	0.022	23.796	1.25
7	0.000	0.014	17.475	1.40

Elasticities: (approximate)

	1	2	3	4	5	6	7
1:	0.0906	0.0000	0.0000	0.0014	0.0472	0.0102	0.0000
2:	0.0059	0.0000	0.0000	0.0000	0.0079	0.0000	0.0000
3:	0.0529	0.0101	0.0402	0.0027	0.0687	0.0000	0.0000
4:	0.0000	0.0036	0.0620	0.0416	0.0364	0.0154	0.0000
5:	0.0000	0.0000	0.0653	0.1077	0.1333	0.0282	0.0262
6:	0.0000	0.0000	0.0036	0.0000	0.0676	0.0172	0.0080
7:	0.0000	0.0000	0.0034	0.0057	0.0000	0.0252	0.0117

Sensitivities: (approximate)

	1	2	3	4	5	6	7
1:	0.1494	0.0032	0.0105	0.0074	0.0092	0.0040	0.0026
2:	0.6395	0.0137	0.0448	0.0318	0.0395	0.0173	0.0113
3:	2.4930	0.0535	0.1745	0.1241	0.1540	0.0675	0.0439
4:	3.1949	0.0686	0.2236	0.1590	0.1973	0.0865	0.0562
5:	5.8471	0.1255	0.4093	0.2911	0.3611	0.1583	0.1029
6:	3.5556	0.0763	0.2489	0.1770	0.2196	0.0963	0.0626
7:	2.6111	0.0560	0.1828	0.1300	0.1613	0.0707	0.0459

Badger Pass North Transect Post-burn (1998-2000) with hypothetical electric fence (use pre-burn fecundity parameters)
Stage matrix (default):

	1	2	3	4	5	6	7
1:	0.6800	0.0000	12.280	43.266	171.00	251.70	350.00
2:	0.0103	0.0000	0.0020	0.0100	0.0350	0.0390	0.0300
3:	0.0238	0.2120	0.2590	0.0360	2.3700	0.0180	0.0370
4:	0.0000	0.0590	0.3110	0.2930	0.2070	0.2000	0.0000
5:	0.0000	0.0000	0.1790	0.4150	0.4140	0.2000	0.2860
6:	0.0000	0.0000	0.0160	0.0000	0.3450	0.2000	0.1430
7:	0.0000	0.0000	0.0210	0.0490	0.0000	0.4000	0.2860

Growth rate (lambda)= 2.0294 (approximate)

Stage	Init. distr.	Stable distr.	Reprod. Value	Avg. residence
1	0.000	0.969	1.000	3.13
2	0.000	0.005	8.228	1.00
3	0.000	0.018	53.136	1.35
4	0.000	0.004	92.095	1.41
5	0.000	0.003	245.412	1.71
6	0.000	8.00E-04	232.326	1.25
7	0.000	5.00E-04	261.343	1.40

Elasticities: (approximate)

	1	2	3	4	5	6	7
1:	0.0947	0.0000	0.0318	0.0243	0.0787	0.0290	0.0252
2:	0.0118	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
3:	0.1761	0.0081	0.0356	0.0011	0.0579	0.0001	0.0001
4:	0.0000	0.0039	0.0741	0.0151	0.0088	0.0021	0.0000
5:	0.0000	0.0000	0.1137	0.0571	0.0467	0.0056	0.0050
6:	0.0000	0.0000	0.0096	0.0000	0.0369	0.0053	0.0024
7:	0.0000	0.0000	0.0142	0.0072	0.0000	0.0120	0.0054

Sensitivities: (approximate)

	1	2	3	4	5	6	7
1:	0.2826	0.0015	0.0053	0.0011	0.0009	0.0002	0.0001
2:	2.3255	0.0120	0.0432	0.0094	0.0077	0.0019	0.0012
3:	15.0174	0.0775	0.2791	0.0605	0.0496	0.0124	0.0078
4:	26.0279	0.1344	0.4837	0.1048	0.0860	0.0215	0.0134
5:	69.3584	0.3580	1.2889	0.2793	0.2291	0.0573	0.0358
6:	65.6600	0.3389	1.2202	0.2644	0.2169	0.0542	0.0339
7:	73.8607	0.3813	1.3726	0.2974	0.2440	0.0610	0.0381

Badger Pass Microwave Transect Pre-burn (1995-1998)
Stage matrix (default):

	1	2	3	4	5	6	7
1:	0.6800	0.0000	5.4110	58.831	67.480	216.30	241.40
2:	0.0329	0.0000	0.0070	0.0520	0.0370	0.0030	0.0000
3:	0.0094	0.2110	0.6090	0.2190	0.0700	0.0500	0.1560
4:	0.0000	0.0000	0.1970	0.4800	0.2350	0.1740	0.0000
5:	0.0000	0.0000	0.0610	0.2130	0.4710	0.2610	0.4000
6:	0.0000	0.0000	0.0000	0.0130	0.1180	0.4350	0.4000
7:	0.0000	0.0000	0.0000	0.0000	0.0780	0.1300	0.2000

Growth rate (lambda)= 1.4087 (approximate)

Stage	Init. distr.	Stable distr.	Reprod. Value	Avg. residence
1	0.000	0.951	1.000	3.13
2	0.000	0.023	7.618	1.00
3	0.000	0.019	50.859	2.56
4	0.000	0.005	122.360	1.92
5	0.000	0.002	182.009	1.89
6	0.000	5.00E-04	346.315	1.77
7	0.000	2.00E-04	381.124	1.25

Elasticities: (approximate)

	1	2	3	4	5	6	7
1:	0.1369	0.0000	0.0214	0.0585	0.0357	0.0229	0.0102
2:	0.0505	0.0000	0.0002	0.0004	0.0001	0.0000	0.0000
3:	0.0962	0.0511	0.1226	0.0111	0.0019	0.0003	0.0003
4:	0.0000	0.0000	0.0954	0.0584	0.0152	0.0023	0.0000
5:	0.0000	0.0000	0.0440	0.0386	0.0454	0.0050	0.0031
6:	0.0000	0.0000	0.0000	0.0045	0.0216	0.0159	0.0059
7:	0.0000	0.0000	0.0000	0.0000	0.0157	0.0052	0.0032

Sensitivities: (approximate)

	1	2	3	4	5	6	7
1:	0.2836	0.0067	0.0056	0.0014	0.0007	0.0001	0.0001
2:	2.1605	0.0511	0.0425	0.0107	0.0057	0.0011	0.0005
3:	14.4240	0.3413	0.2837	0.0713	0.0379	0.0076	0.0030
4:	34.7023	0.8211	0.6824	0.1715	0.0912	0.0182	0.0073
5:	51.6193	1.2214	1.0151	0.2551	0.1357	0.0271	0.0109
6:	98.2182	2.3240	1.9315	0.4855	0.2582	0.0516	0.0207
7:	108.0901	2.5576	2.1257	0.5343	0.2842	0.0568	0.0227

Canyon Creek West Post-burn (1996-1999)

Stage matrix (default):

	1	2	3	4	5	6
1:	0.6830	0.0000	0.5990	17.06	55.770	184.30
2:	0.0001	0.0000	0.0000	0.0120	0.0330	0.0630
3:	0.0012	0.2170	0.3070	0.1690	0.1620	0.4130
4:	0.0000	0.2390	0.1100	0.3730	0.2000	0.0000
5:	0.0000	0.0220	0.0610	0.1360	0.1330	0.2000
6:	0.0000	0.0000	0.0000	0.0850	0.1000	0.1000

Growth rate (lambda)= 0.7941 (approximate)

Stage	Init. distr.	Stable distr.	Reprod. Value	Avg. residence
1	0.000	0.994	1.000	3.15
2	0.000	2.00E-04	100.225	1.00
3	0.000	0.003	84.268	1.44
4	0.000	0.001	234.374	1.59
5	0.000	7.00E-04	240.503	1.15
6	0.000	3.00E-04	394.036	1.11

Elasticities: (approximate)

	1	2	3	4	5	6
1:	0.4519	0.0000	0.0014	0.0148	0.0260	0.0368
2:	0.0066	0.0000	0.0000	0.0010	0.0015	0.0013
3:	0.0669	0.0024	0.0585	0.0123	0.0064	0.0069
4:	0.0000	0.0075	0.0583	0.0756	0.0218	0.0000
5:	0.0000	0.0007	0.0332	0.0283	0.0149	0.0096
6:	0.0000	0.0000	0.0000	0.0290	0.0184	0.0079

Sensitivities: (approximate)

	1	2	3	4	5	6
1:	0.5254	0.0001	0.0018	0.0007	0.0004	0.0002
2:	52.6629	0.0106	0.1801	0.0689	0.0371	0.0159
3:	44.2787	0.0089	0.1514	0.0579	0.0312	0.0134
4:	123.1517	0.0248	0.4212	0.1610	0.0867	0.0372
5:	126.3720	0.0254	0.4322	0.1653	0.0890	0.0381
6:	207.0454	0.0417	0.7081	0.2708	0.1458	0.0625

Canyon Creek East Pre-burn (1995-1999)
Stage matrix (default):

	1	2	3	4	5
1:	0.6830	0.0000	5.2370	95.125	350.00
2:	0.0112	0.0000	0.0240	1.0660	3.2260
3:	0.0030	0.5560	0.4530	0.4090	0.5970
4:	0.0000	0.0000	0.0800	0.2500	0.1430
5:	0.0000	0.0000	0.0100	0.1500	0.0000

Growth rate (lambda)= 1.0917 (approximate)

Stage	Init. distr.	Stable distr.	Reprod. Value	Avg. residence
1	0.000	0.967	1.000	3.15
2	0.000	0.013	23.916	1.00
3	0.000	0.018	46.961	1.83
4	0.000	0.002	246.161	1.33
5	0.000	4.00E-04	449.181	1.00

Elasticities: (approximate)

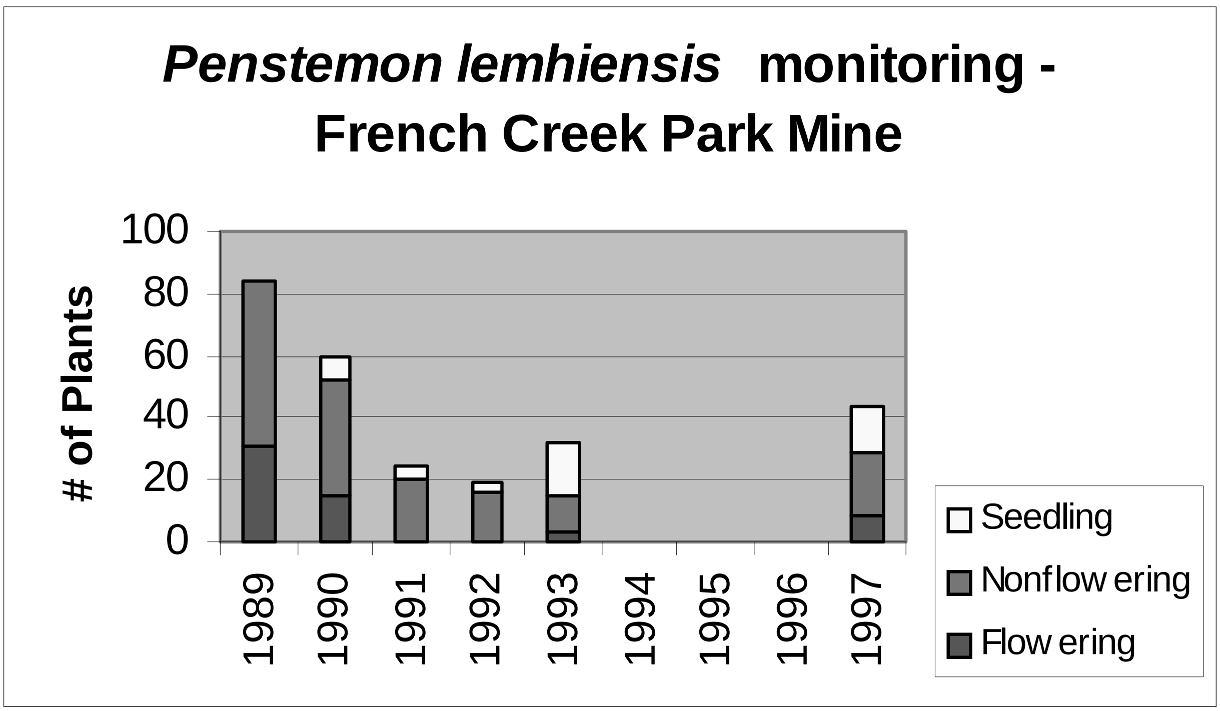
	1	2	3	4	5
1:	0.2239	0.0000	0.0311	0.0548	0.0474
2:	0.0878	0.0000	0.0034	0.0147	0.0105
3:	0.0462	0.1168	0.1262	0.0111	0.0038
4:	0.0000	0.0000	0.1168	0.0355	0.0048
5:	0.0000	0.0000	0.0266	0.0388	0.0000

Sensitivities: (approximate)

	1	2	3	4	5
1:	0.3578	0.0049	0.0065	0.0006	0.0001
2:	8.5582	0.1168	0.1548	0.0150	0.0035
3:	16.8046	0.2293	0.3041	0.0295	0.0069
4:	88.0873	1.2022	1.5938	0.1548	0.0364
5:	160.7372	2.1937	2.9083	0.2825	0.0665

Appendix E

***Penstemon lemhiensis* monitoring at French Creek**



APPENDIX F

Global and State Rank Guidelines

The term "species of special concern" includes taxa that are rare, endemic, disjunct, threatened or endangered throughout their range or in Montana, vulnerable to extirpation from Montana, or in need of further research. The term also encompasses species that have a special designation by organizations or land management agencies in Montana, including: Bureau of Land Management Special Status and Watch species; U.S. Forest Service Sensitive and Watch species; U.S. Fish and Wildlife Service Threatened, Endangered and Candidate species.

Taxa are evaluated and ranked by the Heritage Program on the basis of their global (range-wide) status, and their statewide status according to a standardized procedure used by all Natural Heritage Programs. These ranks are used to determine protection and data collection priorities, and are revised as new information becomes available.

For each level of distribution—global and state—species are assigned a numeric rank ranging from 1 (critically imperiled) to 5 (demonstrably secure). This reflects the species' relative endangerment and is based primarily on the number of occurrences of that species globally or within the state. However, other information such as date of collection, degree of habitat threat, geographic distribution patterns and population size and trends is considered when assigning a rank, and the number of occurrences listed below are suggestions, not absolute criteria.

For example, Clustered lady's slipper (Cypripedium fasciculatum) is ranked G4 S2. That is, globally the species is apparently secure, while in Montana it is imperiled because of rarity, or because of other factors making it demonstrably vulnerable to extirpation.

For ranks, substitute S (State) or G (Global) in these definitions

Rank	Definition
1	Critically Imperiled—Critically imperiled because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).
2	Imperiled—Imperiled because of rarity or because of some factor(s) making it very vulnerable to extirpation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
3	Vulnerable—Vulnerable either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
4	Apparently Secure—Uncommon but not rare, and usually widespread. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals.
5	Secure—Common, widespread, and abundant. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

Qualifiers and Rank Ranges

Qualifier	Definition
##	**Range Rank**—A numeric range rank (e.g., S2S3) is used to indicate the range of uncertainty about the exact status of the element. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4).
?	**Unranked**—rank not yet assessed.
#	A modifier to X or H; the species has been reintroduced but the population is not yet established.
*	G or S rank has been assigned and is under review. Contact the individual state Natural Heritage program for assigned rank.
HYB	**Hybrid**—Element not ranked because it represents an interspecific hybrid, not a species.
U	**Unrankable**—Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
E	**Exotic**—An established exotic; may be native in nearby regions (e.g., house finch or catalpa in eastern U.S.).
E#	**Exotic Numeric**—An established exotic that has been assigned a numeric rank to indicate its status, as defined for G1 or S1 through G5 or S5.
A	**Accidental**—Accidental or casual, in other words, infrequent and outside usual range. Includes species (usually birds or butterflies) recorded once or only a few times at a location. A few of these species may have bred on the one or two occasions they were recorded. Examples include European strays or western birds on the East Coast and vice-versa.
B	**Breeding**—Basic rank refers to the breeding population of the element.
C	**Captive or Cultivated**—Native element presently extant only in captivity or cultivation.
H	**Possibly Extirpated** (Historical)—Element occurred historically, and there is some expectation that it may be rediscovered. Its presence may not have been verified in the past 20 years. An element would become GH or SH without such a 20-year delay if the only known occurrences were destroyed or if it had been extensively and unsuccessfully looked for. Upon verification of an extant occurrence, GH or SH-ranked elements would typically receive a G1 or S1 rank. The GH or SH rank should be reserved for elements for which some effort has been made to relocate occurrences, rather than simply using this rank for all elements not known from verified extant occurrences.
N	**Nonbreeding**—Basic rank refers to the non-breeding population of the element.
P	**Potential**—Potential that element occurs but no extant or historic occurrences are accepted.
R	**Reported**—Element reported but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program hasn't yet received first-hand information; others are old, obscure reports.
T	Rank for subspecific taxon (subspecies, variety, or population); appended to the global rank for the full species, e.g. G4T3
X	**Presumed Extirpated**—Element is believed to be extirpated. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.

CRITERIA USED FOR RANKING

The criteria for ranking are based on a set of quantitative and qualitative factors. These factors are listed below in order of their general importance:

a. Number of Element Occurrences (EOs):
   the estimated number of EOs throughout the Element's global range;

b. Abundance:
   the estimated global abundance of the Element (measured by number of individuals, or area, or stream length covered);

c. Size of Range:
   the estimated size of the Element's global range;

d. Distribution trend:
   the trend in the Element's distribution over its global range;

e. Number of protected EOs:
   the estimated number of adequately protected EOs throughout the Element's global range;

f. Degree of threat:
   the degree to which the Element is threatened globally;

g. Fragility:
   the fragility or susceptibility of the Element to intrusion;

h. Other global considerations:
   for example, the quality or condition of EOs that affect or may affect endangerment status; unexplained population fluctuations; reproductive strategies that are dependent on specific habitat; etc.