Extensive Monitoring of *Penstemon haydenii* (Blowout Penstemon) – - 2015 Baseline

Carbon County, Wyoming

Prepared for
Bureau of Land Management – Rawlins Field Office and State Office

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ABSTRACT

This report represents the first year of a new phase of extensive *Penstemon haydenii* (blowout penstemon) monitoring in Wyoming, intended to run a minimum of three years. The objective is to document population numbers and trends for the species in all of the blowouts that have ever had high numbers (i.e., more than 300 established plants). There was one previous short-term extensive monitoring phase (2004-2006) as basis for comparison. In addition, there has been scaled-back monitoring in most of the intervening years so that at the end of the current extensive phase, we would have a long-term perspective. The 2015 monitoring provided an inkling of long-term results:

1) There were sharp declines in *P. haydenii* numbers at most blowouts. At least six of the nine had record lows.
2) However, six of the nine blowouts had seedlings, and the number of seedlings totaled several magnitudes more than the total number of seedlings in all of the past years combined.
3) The seedlings were located in the blowout bowls, which have generally been devoid of established plants in the past.
4) Adding to the significant discovery of the seedlings was finding two separate size classes of seedlings or seedling-like plants that appear to represent two separate cohorts.

Therefore, demographic monitoring was added to the census techniques to determine survival/mortality of the seedling plants. Three new lines of information on *P. haydenii* life history and movement of its dune habitat became available since the most recent status report and are reviewed as they have bearing on interpreting the 2015 monitoring data. They complicate analysis of monitoring data on one hand but reflect species' resilience on the other. This report represents a baseline for ensuing monitoring, an addendum to the most recent status report, an extension of strategic monitoring work to date, and a springboard for discussing the status and recovery of the species.

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Cover photo: *Penstemon haydenii* (Blowout penstemon) at Bear Mountain East, 22 June 2015

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INTRODUCTION

Penstemon haydenii Wats. (Blowout penstemon) was listed as an Endangered species in 1987 under the Endangered Species Act (ESA; USDI Fish and Wildlife Service 1987) when it was regarded as endemic to the Nebraska Sandhills. A recovery plan was prepared (Fritz et al. 1992) that is based on a minimum population numbers (300 plants) at a minimum number of sites where it is naturally reproducing and self-sustaining over time. Long-term monitoring has been conducted in Nebraska to gauge progress in meeting recovery goals (e.g., Stubbendieck and Kottas 2004).

In 1996, *Penstemon haydenii* was discovered at Bradley Peak in Carbon County of south-central Wyoming by Frank Blomquist, and specimen vouchers were collected from the site by Blomquist (Bureau of Land Management; BLM) and botanist colleagues in 1999 (Roderick et al. 1999, Taylor 2000, Fertig 2000, 2001). Hence there was an immediate need for *Penstemon haydenii* distribution and trend information in Wyoming to understand status and to address species' recovery. This was the motivation for an extensive monitoring study from 2004-2006 (Heidel 2007). It followed the monitoring conventions used in Nebraska and documented that Wyoming contributes significantly to species' numbers, with seven blowouts in Wyoming that had at least 300 plants as determined by at least two census counts. It also documented a 2005 peak in Wyoming census numbers at 19,343[1] plants.

Recently, the *Penstemon haydenii* recovery status was addressed in a 5-year review (USDI Fish & Wildlife Service 2012). The review called for a recovery plan update incorporating new status information, refining recovery criteria and identified research needs:

> "The revised recovery plan should include objective, measurable criteria which address all listing factors and which, when met, will result in a determination that the species be downlisted and eventually removed from the Federal List of Endangered and Threatened Plants. Recovery criteria should include population growth rates over time and documentation of populations dispersing to unoccupied habitat" (USDI Fish & Wildlife Service 2012).

The central purpose of this project is to replicate extensive monitoring of *Penstemon haydenii* plants (2015 through at least 2017) at the blowouts with high numbers, as needed, to determine population growth rate. Monitoring has been sporadic since 2006 and the current project represents a ramped up phase of monitoring. This report on 2015 monitoring is a baseline for extensive monitoring in 2016 and 2017, and provides an inkling of long-term population growth rates.

Concurrent surveys and censuses took place for the first time in 2015 on private lands. The full results of this separate work are presented in a report to U.S. Fish and Wildlife Service (FWS). They are not monitoring results because there was no prior data, but they are part of the census numbers that are presented in this report.

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[1] This number represents actual counts in 2005 at the seven largest blowouts and seven others, with earlier numbers used for two blowouts not censused in 2005. The total from the two small uncensused blowouts totaled 76 plants.

Monitoring designs ideally reflect species biology information to date. Previous information on the biology and habitat of *Penstemon haydenii* in Wyoming informed the 2004-2006 monitoring study and report, including Fertig (2000, 2001) and Heidel (2005); species' information from Nebraska including Fritz et al. (1992) and Stubbendieck et al. (1997), and concurrent pollination research (Tepedino et al. 2006). Since that time, a status report of all distribution data was produced (Heidel 2012) and three new lines of Wyoming information became available that have bearing on interpreting monitoring results including a master thesis on *P. haydenii* seed ecology (Tilini 2013), a reconstruction of *P. haydenii* dune movement based on aerial photointerpretation going back to the 1930's and 1940's (Heidel et al. 2014), and systematic excavation around *P. haydenii* plants to re-evaluate the ongoing census conventions (Heidel 2013). These three developments are added to a Background Information section that follows the Study Area section.[2]

STUDY AREA

Penstemon haydenii occurs in the Ferris Dunes of northwestern Carbon County, Wyoming. The three known populations are comprised of one to many dune blowouts that are named in this report by local land features, and numbered in the order in which they were discovered. The Bradley Peak population occupies a single large continuous area with three contiguous blowouts at three different levels and a steep slope. The Bear Mountain – Junk Hill population is comprised of fifteen discrete, mostly discontinuous blowouts, though all are on the same wind currents and close to one another for pollinator and seed dispersal connectivity. The Pathfinder population is likewise comprised of three discrete blowouts. In total, the populations are scattered between 19 blowouts and have been mapped from aerial photos and Global Positioning System (GPS) coordinates superimposed using ArcMap, so that their area can be calculated and distribution changes over time recorded.

Throughout this report, the discrete areas of *Penstemon haydenii* occupancy are referred to as blowouts. Blowouts are parabolic dune features comprised of an upwind blowout bowl and side arms, with a downwind rim and lee slopes. The side arms, rim and lee slopes wrap around the bowl in the shape of a horseshoe. The blowout zones have active sand movement, and the fringes of blowouts often includes loose sand in the process of stabilizing or destabilizing (Heidel et al. 2014). Blowouts may be completely isolated from one another or connected by loose sands between them. Blowouts occupied by *P. haydenii* are grouped by their proximity to one another and their position on the same wind stream. The species' distribution associated with these blowout groups is hypothesized to represent a population complex, because *P. haydenii* is an insect-pollinated species (Tepedino et al. 2006) and a wind-distributed species. By this interpretation, there are three populations or population complexes in Wyoming (Heidel 2012).

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[2] There is a recent report on the taxonomic status of Wyoming material in comparison with Nebraska material. The final report (Freeman 2015) indicates that there are basic differences. The implications of this when it comes to the ESA status of Wyoming material remain to be determined.

Documentation of local distribution was not completed on public lands until 2011, so it is helpful to highlight the progression of discovering blowouts occupied by the species, in order to separate species' trends from the progression of species' surveys. The Bradley Peak population was the first Ferris Dunes site to be discovered, photographed by Frank Blomquist (BLM) in 1996 and documented in 1999 by Walter Fertig (Wyoming Natural Diversity Database; WYNDD) and Frank Blomquist (Fertig 2000). Systematic survey of the Ferris Dunes was pursued by Walter Fertig in 2000, documenting four occupied blowouts making up an additional Carbon County population in the Bear Mountain – Junk Hill area, surveyed by Walter Fertig and Frank Blomquist (Fertig 2001). Later in 2000, Michael Evans reported an additional blowout. In 2002-2005, eight more blowouts were added to the Bear Mountain – Junk Hill set and a third Carbon County population of two blowouts was added near the Pathfinder Reservoir (Heidel 2005a). The total number of occupied blowouts was 16 as of 2005 (Heidel 2005) and the total of 19,XX plants is based on these 16 blowouts. Finally, in 2011, all Ferris Dune blowouts that had not been surveyed to date were surveyed, including ones on isolated public tracts requiring access permission. As a results, two more blowouts were added to the Bear Mountain – Junk Hill set and one blowout was added to the Pathfinder set, for a grand total of 19 blowouts (Heiel 2012).

Table 1 represents 2015 monitoring priorities, including each occupied blowout, the population number, the date of discovery, and whether it has ever been found to support 300 or more *P. haydenii* plants. The 2000 and 2001 surveys of *Penstemon haydenii* provided good estimates of population numbers. In 2002, the first census and collection of GPS coordinates took place at the two largest blowouts, by Frank Blomquist and Bonnie Heidel (WYNDD). Demographic monitoring transects were also installed at one of the blowouts (Blomquist and Heidel 2002). In 2003, the transects were reread in late July with the help of a crew to re-census the two largest blowouts (Blomquist and Heidel 2003). The crew did not have the benefit of field maps, and first two census years are considered trial years and pilot monitoring in the sense of Elzinga et al. (1998), providing the basis for planning a systematic extensive monitoring project. The study area for monitoring work during 2004-2006 originally focused on the four largest blowout numbers as of 2003. Four more blowouts with high numbers were located in 2004, but their numbers were not censused until 2005, for a total of seven that met the high population numbers criterion. An eighth blowout (Pathfinder Reservoir) with high plant numbers was documented in 2011 for inclusion in 2015 monitoring. In addition, concurrent surveys and census were conducted for the U.S. Fish and Wildlife Service on private lands in 2015, and in the course of these surveys, a ninth blowout was found to have high plant numbers. These nine blowouts are the study area for the 2015-2017 project.

All of the monitoring that took place after 2006 was "spot monitoring", scaled-back monitoring with limited time and support. The demographic and census results produced during 2004-2006 monitoring indicated that the numbers of plants in different blowouts and in different blowout zones do not change in synchrony, though it seemed as though there was analogous change among the blowouts with highest numbers so that those with high numbers remained relatively high among blowouts collectively. This was the basis for scaling back to monitoring of one blowout in most of the ensuing years. Resulting monitoring data were added and stored in the WYNDD central database. They were also reported to U.S. Fish and Wildlife Service (FWS), and incorporated by FWS into the 5-year review (USDI Fish and Wildlife Service 2012).

Almost all of the occupied blowouts fall within the Ferris Dunes Area of Critical Environmental Concern (USDI Bureau of Land Management 2008) established in the BLM Rawlins Resources Management Plan (2008, 2012a). No matter if inside or outside ACEC boundaries, *Penstemon haydenii* management is addressed in a statewide programmatic Biological Assessment (USDI BLM 2012b) and Biological Opinion (USDI Fish and Wildlife Service 2013).

Table 1. Monitoring priorities among blowouts occupied by *Penstemon haydenii* in Wyoming

Blowout Name	**Population No.**	**Population Name**	**Priority? (>300 plants, past or present)**	**First Discovery**	**Slope of Primary Occupied Habitat[3]**
Bradley Peak	001	Bradley Peak	Y	1996	Steep
Junk Hill Main	002	Bear Mtn-Junk Hill	Y	2000	Gentle
Junk Hill West 1	002	Bear Mtn-Junk Hill	Y	2004	Gentle
Junk Hill West 2	002	Bear Mtn-Junk Hill	Y	2004	Gentle
Junk Hill West 3	002	Bear Mtn-Junk Hill	Y	2004	Gentle
Junk Hill West 4	002	Bear Mtn-Junk Hill		2004	Gentle
Junk Hill West 5	002	Bear Mtn-Junk Hill	Y	2011	~Gentle
Bear Mt Valley	002	Bear Mtn-Junk Hill		2000	Steep
Junk Hill Upper Outlier	002	Bear Mtn-Junk Hill		2000	Steep
Bear Mt East	002	Bear Mtn-Junk Hill	Y	2000	Steep
Bear Mt West	002	Bear Mtn-Junk Hill	Y	2000	Steep
Bear Mt East Outlier	002	Bear Mtn-Junk Hill		2002	Gentle
Ferris 1	002	Bear Mtn-Junk Hill		2005	Gentle
Ferris 2	002	Bear Mtn-Junk Hill		2005	Gentle
Ferris 3	002	Bear Mtn-Junk Hill		2005	Gentle
Ferris 4	002	Bear Mtn-Junk Hill		2011	Gentle
Pathfinder Reservoir	003	Pathfinder	Y	2011	Gentle
Pathfinder South	003	Pathfinder		2004	Gentle
Pathfinder North	003	Pathfinder		2004	Gentle
TOTAL	3		9	-	5 steep; 14 gentle

BACKGROUND INFORMATION

The following information on the biology and ecology of *Penstemon haydenii* represents updates to the most recent status report (Heidel 2012). It was not part of the monitoring project, but reviewing this information is needed as context for interpreting monitoring results.

[3] From Heidel (2014). Prevailing gentle slopes are 0-5°; steep are usually much greater than 10°.

Biology of *Penstemon haydenii*

Plant population monitoring poses special challenges for biologists even though plants are stationary. In the case of *Penstemon haydenii*, census data at most major blowouts showed a dramatic rise in numbers (2004-2005) and a major fall right afterward (2005-2006; Heidel 2007). This spike is perplexing because there was no concurrent evidence of recruitment and mortality in demographic monitoring or observed in the course of census work. Furthermore, the spike happened in the midst of drought, as did the entire three-year monitoring period.

Two vital pieces of *Penstemon haydenii* life history recently became available that put past and present monitoring results into context. First, seed germination ecology research was conducted (Tilini 2013) that suggest *P. haydenii* seed germination responds positively to moist chilling and dry after-ripening. While analogous to over-wintering conditions, a chill period of only four weeks ensured complete germination, without extension to 8, 12, or 16 weeks. Field trials were also conducted, and seedling emergence decreased with increasing burial depth, suggesting that deep burial ensures dormancy and that the species is capable of forming a seedbank. The question of whether the seedbank of *P. haydenii* is "ecologically significant" was addressed in field trials with seeds in petri dishes buried just below the sand surface in which heavy post-dispersal insect predation was found to greatly impact viability. This third conclusion is tempered by whether a uniformly shallow burial simulates the range of burial conditions experienced by *P. haydenii* and thus, whether the seedbank is truly insignificant. If the species does form a sizeable seedbank at depths that deter insect predation, then there could be multiyear stockpiles of seed resources awaiting favorable climate conditions, a key cryptic stage in life history. Previously, the 2005 spike in *P. haydenii* numbers was inferred to be the result of recruitment (Heidel 2007).

Second, we re-examined how we have been counting *Penstemon haydenii* plants, prompted by a publication (Tepedino 2012) about the risks of over-counting plants with clonal reproduction. This was done in 2013 by carefully excavating sand around ten pairs of stems, all of which were somewhere between 15-100 cm of one another. The excavations were done on lee slopes of three different blowouts. Results were written up in a memo (Heidel 2013) and the results, with photos, are highlighted here.

We found that the subterranean axis was vertical in all cases and none of the plants were connected underground, even those that were 15 cm apart. We dug until reaching true roots, with root hairs for water and nutrient adsorption. Some stems had a series of successively buried rootcrowns, including one with three successively buried rootcrowns below the surface (Figure 3). Adventitious roots were produced above the rootcrown along buried stem segments to anchor the plants but they did not have root hairs. One of the most surprising results was made in digging between two stems almost 100 cm apart and finding buried individual *P. haydenii* plants having no aboveground growth. They were buried 15 cm or deeper below the sand. The discovery of underground plants at the time of flowering indicates that individuals can survive belowground for part if not all of the growing season, and that parts of the population may not be possible to count. The discovery of live, underground plants and plants with multiple rootcrowns indicated that the species is not necessarily short-lived as generally stated (Stubbendieck et al. 2001) but has adaptations for longevity including survival and persistence belowground with burial. In other words, we found no evidence for clonal reproduction and over-counting.

Instead, we found evidence that we may be under-counting. We do not know if this phenomenon could explain earlier spikes and plummets (Heidel 2007) but this cryptic phenomenon tempers census results. The phenomenon of plants surviving one or more growing seasons below ground has been called "seasonal dormancy" (Lesica 1994). While it remains to be seen whether *P. haydenii* can survive belowground for all of a growing season, its survival belowground for at least part of a growing season offers a possible explanation for major swings in numbers without evidence of recruitment or mortality. This excavation exercise represented a limited sample size and it remains to be determined whether the unprecedented high numbers (19,343 in 2005) in 2015 as compared with the previous and subsequent years can be attributed to emergence from burial and whether the species can otherwise respond to adverse climate by remaining belowground. Monitoring conventions have been developed to address seasonal dormancy but they require determining the mean length of dormancy and monitoring longer than that length (Lesica 1994). If it took a day to get excavation at ten pairs in three blowouts, and if burial patterns are local, then it would be difficult to collect enough data to determine the mean length of dormancy. The demographic monitoring of mapped seedling cohorts may offer a better dataset for pursuing this matter.

Figure 1. *Penstemon haydenii* rootcrowns

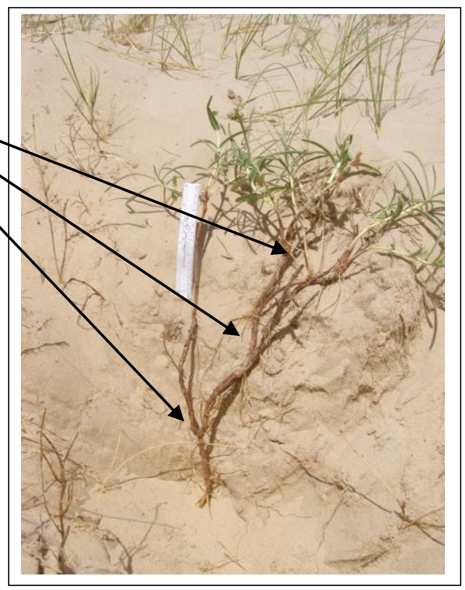
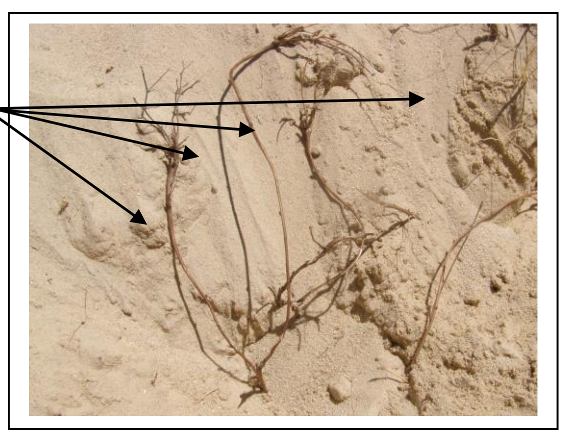
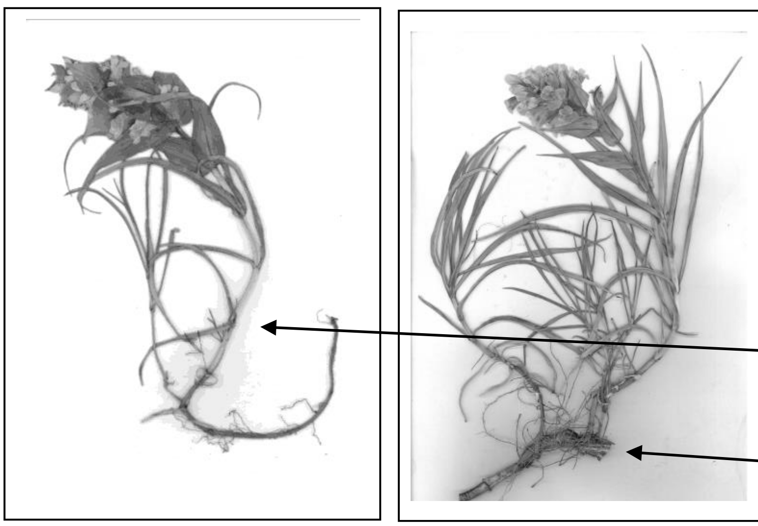


Figure 2. 4 separate *Penstemon haydenii* plants, originally buried over 15 cm belowground in late June 2013



Penstemon haydenii has been reported to have rhizomes (Stubbendieck et al. 2001), and buried horizontal stems have been observed in particularly wind-exposed settings. Field observations of *P. haydenii* in eroded Wyoming settings and in excavation indicate that although stems bowed over by the wind are technically buried stems, they do not appear to elongate or spread as such. It appears that stems maintain verticality in the absence of wind. They do produce shoots at buried nodes. They do apparently grow stouter over time. Two flowering specimens were collected in 2015 to document the Pathfinder population for the first time, and they demonstrate a buried vertical stem, and the shoots emerging from a horizontal segment of buried stem (Figures 3 and 4, respectively). This further lends support to the interpretation that *P. haydenii* does not have clonal reproduction.



Figures 3. and 4. *Penstemon haydenii* duplicate specimens (*Heidel 4162*)

Originally a vertical buried stem

Originally a horizontal buried stem

Ecology of *Penstemon haydenii*

Penstemon haydenii is an early-succession species that was originally listed as Endangered under the ESA based on its habitat loss, attributed in large part to human efforts at stabilizing dunes in Nebraska (USDI Fish and Wildlife Service 1987). There was no basis for addressing habitat trends in Wyoming because confirmed discovery here goes back no earlier than 1996.

The *Penstemon haydenii* recovery status was addressed in a 5-year review (USDI Fish & Wildlife Service 2012). The review called for a recovery plan update incorporating new status information, refining recovery criteria and identifying two research needs:

> "The revised recovery plan should include objective, measurable criteria which address all listing factors and which, when met, will result in a determination that the species be downlisted and eventually removed from the Federal List of Endangered and Threatened

Plants. Recovery criteria should include population growth rates over time and documentation of populations dispersing to unoccupied habitat".

"The revised recovery plan should determine mechanisms of habitat persistence, i.e., how long blowouts persist and the factors causing their healing and mechanisms for migration of plants to new habitat".

The preceding statements signify recognition that dune trends (creation of new habitat, healing of old habitat, and general persistence, migration, expansion or contraction) exert influence over population trends, so that both need to be considered at some level in future *P. haydenii* recovery planning. To address habitat trend in Wyoming, an analysis was conducted of historical imagery of the dunes over time. Aerial imagery was georectified and compared against the most recent available digital imagery (NAIP 2012). Areas of active blowout feature (active sand) were digitized, and the downwind segment was split out as potential habitat. This was needed to determine whether *P. haydenii* habitats in Nebraska and Wyoming are analogous for recovery purposes, to integrate habitat trend information with population trend information.

However, the short three-year period of monitoring from 2004-2006 was entirely within extreme drought conditions. It was hypothesized that the drought period trends set the course for inter-drought trends of *Penstemon haydenii.* Two main conclusions were drawn (Heidel et al. 2014):

1. *Penstemon haydenii* potential habitat in Wyoming has actively shifted over time but as a persisting, continguous blowout feature rather than healing over or starting anew in more recent times. In other words, the active sand features remain contiguous while different zones making up each blowout may move or shift from active to stable sand.

2. The approximate area of potential habitat of *Penstemon haydenii* has had limited decline (up to 13.5%) as determined from comparing the surface area of potential habitat of blowouts on the earliest imagery (mainly 1940's) and the most recent imagery (2012). These two conclusions provide a conceptual model for downwind migration over time.

In the example of just one blowout, Bradley Peak, the shift has been so great that much of the downwind active dune habitat of *Penstemon haydenii* in 1946 has little overlap with that in 2012 (Figure 5). The downwind arm of sand that is so apparent on recent imagery did not begin to form until 2006. This same time also marked desiccation of wetlands below the occupied habitat, and corresponded with blowout rims breaching at other occupied blowouts. There is an excellent dissertation on the geological history of the Ferris Dunes (Gaylord 1982) with later publications (Gaylord 1984, 1987) covering an area overlapping with part of *P. haydenii* distribution, and quantifying dune trends over geological time for context. From this study and field observations, and making inferences from the dissertation, it appears that while the blowouts are subject to zone changes and recontouring, the blowout rims do not migrate with the rest of the dune, and large-scale burial and erosion events may be episodic rather than a function of dune movement rates.

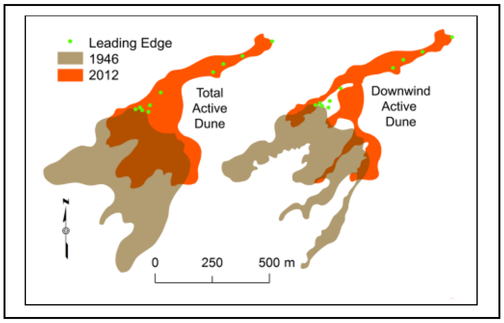


Figure 5. Blowout shifts at Bradley Peak, 1946-2012, including total area of active sand (left) and downwind area of active sand (right); from Heidel et al. (2014)

METHODS

Census Methods

The 2015 monitoring work was conducted by teams of one to four people, between 22-30 June. Censuses were conducted during flowering for ease of locating plants and consistency with past monitoring. Phenology was close to peak or slightly past peak flowering during this time. The following census methods follow 2004-2006 conventions unless otherwise stated. Every effort then and now was made to replicate *Penstemon haydenii* census techniques used in Nebraska for direct comparison of results.

Monitoring was conducted with use of annotated aerial photos for orientation. It involved systematically traversing the habitat. The sand substrate does not leave a distinct trace of footprints as visual record of survey unless there has been recent rain. Census was conducted across broad areas of habitat by one or two people walking parallel lines in series across discrete segments of the subpopulations. The distance between the parallel lines varied depending on the vegetation cover in the habitat, the density of the *Penstemon haydenii* plants, and the conspicuousness of the individuals, as influenced by flowering and browse levels.

During monitoring, separate tallies were kept for flowering (reproductive) vs. nonflowering (vegetative) plants. A single plant may produce 1-many stems that are all flowering, all nonflowering, or mixed states. Usually most plants in flower also have nonflowering stalks (see cover photo). For purposes of this census, plants with any flowering stalks were recorded as flowering plants. A third tally was kept of browsed plants (except for 2004 tallies). This was originally intended to evaluate the effects of herbivory on flower production, but in many cases, it was not possible to differentiate browse on a flowering stem from browse on a nonflowering stem from short vestiges of stems. For purposes of this census, plants with any stalks browsed were recorded as browsed plants. In general, the early herbivory occurs under the influence of antelope and elk in the early part of summer before livestock are brought to the surrounding pastures, as observed from tracks and wildlife behavior. This approach is a gauge of reproductive activity levels and herbivory levels. In 2015 census, data was further sorted by blowout zone, (bowl, rim, N and S side arms, and lee slopes; plus a couple other distinctions for steep slope settings).

Census requires consistency in distinguishing individuals. In census of *Penstemon haydenii*, any stems (ramets) that are within about 15 cm apart were inferred to be part of the same individual (genet). This threshold was adjusted slightly if they were further apart but buried and converging, or else eroded out stems but still separate below ground (Heidel 2007).

The first day of monitoring in 2015 targeted one of the largest, steepest blowouts, at Bear Mountain East. Seedlings were encountered in one area of steep slope that were small plants less than 3 cm tall, retaining their cotyledons (Figures 6, 7). In two of the past twelve years, seedlings had only been encountered at three places and in low numbers. The seedlings encountered on that first day were estimated to exceed 100 (Figure 8), and exceeded the rough estimates of all seedlings of all prior years and all places combined. The difficulty of reliably detecting and counting an additional category of 3 cm tall plants across steep terrain (Figure 9) and the other circumstances surrounding that first day lead to a decision to maintain existing census conventions to the exclusion of seedling tallies.

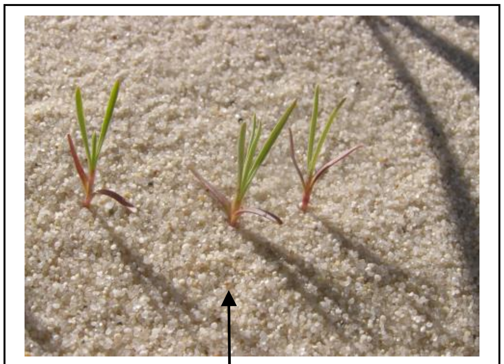


Figure 6. *Penstemon haydenii* small seedlings, the first time that seedlings still holding cotyledons have been found in Wyoming, 22 June 2015

Figure 7. The three *Penstemon haydenii* seedlings (above) beside an established plant, 22 June 2015

Figure 8. High *Penstemon haydenii* seedling density (35 seedlings in a view of about 0.5 m^2), 22 June 2015

Figure 9. Setting of *Penstemon haydenii* seedlings, localized in one area of steep slope, 22 June 2015

The decision to exclude seedlings was reevaluated when a new seedling category of *Penstemon haydenii* plants was found. The new seedling category was not distinguished from the nonflowering plant category at the first blowout where they were encountered, at Pathfinder Reservoir, where they were biggest. They had isolated shoots with slender stems, but no cotyledons and were mainly 10+ cm tall (Figure 10) Exploratory digging around them found a limited root system that may or may not be established, without any connectivity or remnants from previous years, thus supporting the interpretation that they had a were still in the process of becoming established. They are seedling-like if not true seedlings. They are referred to as seedlings in this report, albeit big ones, and correspond with what were called seedlings in the past. Except for Bear Mountain East seedlings, all other seedlings were restricted to blowout bowl settings, a zone typically devoid of established plants. Bear Mountain had only small seedlings, Pathfinder Reservoir had only big seedlings, and three of the four Junk Hill West series blowouts monitored in 2015 had both big and small seedlings, found to overlap in places (Figure 11). The settings of highest density are represented in Figures 12-13.

Figures 10 (left). *Penstemon haydenii* big seedling, 27 June 2015

Figure 11 (right). Mixture of *Penstemon haydenii* big and small seedlings (over 60 seedlings total in a view of about 1 m²); 29 July 2015

Figure 12. Blowout with sand deposition in wave-like pattern

Figure 13. Blowout with sand deposition in wave-like pattern (close-up of Figure 12)

Figure 14. *Penstemon haydenii* seedlings in windrow-like pattern, perpendicular to wave-like pattern (in the blowout of Figures 12 and 13, above)

For want of a seedling census at Bear Mountain, numbers were conservatively bracketed between 100-1000. For want of a seedling distinction at Pathfinder Reservoir, we estimated that numbers were 500-1000. We attempted to count all seedlings in the Junk Hill West settings (Figures 12-14) where numbers were in the 100's and to get robust estimates where numbers were in the 1000's.

Demographic Methods

Demographic monitoring of established *Penstemon haydenii* plants was pursued in 2004-2006, but it had limited value because there was no recruitment and we didn't know the age of the plants at the onset of monitoring. It was not part of original 2015 monitoring plans. However, when we discovered seedlings in high numbers in 2015, this represented a first-time opportunity to carry out the task flagged in the prior monitoring report, i.e., to initiate demographic monitoring with seedling establishment events in order to determine mean and maximum longevity, and produce robust transition matrices (Heidel 2007). A large set of photographs were taken during monitoring, including transect photos. They are labelled and presented in Appendix B.

The two seedling categories are likely to represent two cohorts of seedlings, or at least a true seedling and a bigger, seedling-like plant. It is reasonable to think that we know their ages relative to one another if not absolute ages. The places where they grew in highest density were in semi-continuous bands that appeared as though they were stripes or windrows in the blowout bowl. The simplest permanent plot design for demographic plant monitoring is in belt transects (Lesica 1986), so four demographic monitoring belt plots were set up in two blowouts a month after census work, from 28-29 July. Belt plots were subjectively placed to line up with the high density bands of seedlings. One of the two blowouts and one of the four sampling area settings are represented in Figures 12-14.

Four belt plots were marked by rebar stake endpoints to encompass areas of high density spanning 25 m, 15 m, and two belts of 10 m. The GPS coordinates of endpoints for the four transects were also recorded. At the time of monitoring, a measuring tape was placed taut between rebar endpoints. A ½ m^2 monitoring frame constructed of PVC piping (3/8 in with fitted joints) was marked in 10 cm increments and used to delimit continuous plots that were read above and below the tapeline for a total of 60 m^2. One person read the plot and the x, y (5 x 5) coordinates for each plant, and another person recorded results on graph paper. The primary product is a map of plants by category throughout the permanent belt transect. They are also tallied by 0.5 m^2 monitoring area and used to calculate mean seedling density per plot.

A set of transect images were taken at the endpoints. These transect photos and other images of seedlings and their habitat are presented in Appendix B. The blowout bowls with high seedling numbers appeared to have high rates of sand burial. It remains to be seen whether demographic monitoring is effective, i.e., whether any of the seedlings mapped in 2015 will remain aboveground in 2016. At least one of the two blowouts had seedlings eroded out by the wind exposing upper root systems, particularly the big seedlings but a small fraction of small seedlings were also eroded out.

RESULTS

Census Results

In 2015, the total number of *Penstemon haydenii* plants counted in the nine blowouts having high numbers was 5845 plants (5043 on public land; 802 on private land; Heidel 2015). Trends are presented by blowout for the nine (Figures 15-23). Record lows were documented for established plant numbers at six of the nine blowouts. This is despite the fact that some of those blowouts did not have complete counts in past years when only that portion of the blowout on public land was targeted. Apparent increases in numbers are either due to the inclusion of private land tallies (Junk Hill West 5) or not having the distinction pinned down between established plants and seedlings when conducting census (Pathfinder Reservoir). The survey results for all blowouts on private land are reported separately to U.S. Fish and Wildlife Service (Heidel 2015). The master table of census results is presented in Table 2.

Figures 15-23. *Penstemon haydenii* trends at the nine blowouts with highest numbers

Table 1. Monitoring priorities among blowouts occupied by *Penstemon haydenii* in Wyoming

Blowout Name	Population No.	Population Name	2015 Census Total[4]
Bradley Peak	001	Bradley Peak	170
Junk Hill Main	002	Bear Mtn-Junk Hill	810
Junk Hill West 1	002	Bear Mtn-Junk Hill	52*
Junk Hill West 2	002	Bear Mtn-Junk Hill	216*
Junk Hill West 3	002	Bear Mtn-Junk Hill	544*
Junk Hill West 4	002	Bear Mtn-Junk Hill	
Junk Hill West 5	002	Bear Mtn-Junk Hill	739*
Bear Mt Valley	002	Bear Mtn-Junk Hill	
Junk Hill Upper Outlier	002	Bear Mtn-Junk Hill	
Bear Mt East	002	Bear Mtn-Junk Hill	1915*
Bear Mt West	002	Bear Mtn-Junk Hill	341
Bear Mt East Outlier	002	Bear Mtn-Junk Hill	
Ferris 1	002	Bear Mtn-Junk Hill	
Ferris 2	002	Bear Mtn-Junk Hill	
Ferris 3	002	Bear Mtn-Junk Hill	
Ferris 4	002	Bear Mtn-Junk Hill	
Pathfinder Reservoir	003	Pathfinder	1080*
Pathfinder South	003	Pathfinder	
Pathfinder North	003	Pathfinder	
TOTAL	3		5845

Demographic Results

Despite the downward trends of established *Penstemon haydenii* plants in most blowouts, six of the nine blowouts had seedlings, and the number of seedlings totaled several magnitudes more than the total of all past years combined. Adding to the significant discovery of the seedlings was finding two separate size classes of seedlings that appear to represent two separate cohorts. Big seedlings were the focus of census, even at blowouts with mixed big and small seedling categories. Seedling census numbers are very rough estimates and the most important matter is survivorship of the two cohorts rather than initial recruitment numbers of either one. Demographic monitoring was initiated to get better quantitative seedling data and evaluate survivorship. The seedlings were located almost entirely in the blowout bowls, which have harbored all of the seedlings seen in the past but rarely supported established plants. It is not known whether the species can survive in blowout bowls, underground if not aboveground.

In demographic monitoring, we mapped 1536 seedlings along continuous 0.5 m bands spanning 60 m (30 m^2) of permanent belt transect for an average density of 51.2 seedlings per m^2. Densities in the four belts ranged from 16.6 - 82.1 seedlings per m^2 (Table 2). The results of demographic monitoring represent just a small fraction of occupied habitat in blowout bowls and suggest that seedling number estimates are low for big seedlings, and that small seedlings greatly

[4] Those blowouts that had seedlings have asterisks after the tallies for established plants.

outnumber big ones. Density values in themselves have limited meaning. If the seedlings can survive blowout bowl conditions, then we will have robust survival rates from three years of monitoring, and a window into the recruitment stage of life history.

Table 2. *Penstemon haydenii* seedling density

Belt (length)	Big seedling density (plants per m²)	Small seedling density (plants per m²)	Total seedling density (plants per m²)
1 (25 m)	0.6	76.1	82.1
2 (15 m)	0	25.4	25.4
3 (10 m)	6.5	16.5	23.0
4 (10 m)	4.3	12.3	16.6

DISCUSSION

It was surprising to find a peak of *Penstemon haydenii* numbers in 2005 in the midst of drought, and equally surprising to find a plummet in *P. haydenii* numbers in one of the mildest years since *P. haydenii* discovery in Wyoming (Figure 24). It is intuitive to expect that plants of arid habitat are moisture dependent, so this pattern runs counter to intuition.

The 5-Year Review for *Penstemon haydenii* (USDI Fish and Wildlife Service 2012) that sets the stage for its recovery calls for population census numbers, growth rates and meaningful viability standards. The 2015 documentation of a flush of recruitment suggests that there is a seedbank and that getting primary data is challenged by the cryptic stages of life history including the seedbank and the possibility of seasonally dormant plants, and by the episodic nature of recruitment. Any calculation of population growth rate will be incomplete without data on these cryptic stages and more information on the episodic factors in recruitment.

Figure 24. An example of an expanding blowout in 2015, and water flow where it has not been observed before. This expanding blowout divides Bear Mountain East from Bear Mountain West (left arrow points to the undercut blowout rim and shadow cast by it where expansion is reducing *Penstemon haydenii* habitat. Below, water flows from the base of the sand deposits for the first time since monitoring began (right arrow points to streamflow).

Nevertheless, we expect to have meaningful *Penstemon haydenii* population trend data after the short extensive monitoring from 2015-2017. It will not account for the above-mentioned life history stages, but we can at least insert a hypothetical ranges of values including those from similar species. Furthermore, there will be recruitment data to add to the picture. Population trend data may show decline rather than growth. The 2004-2006 monitoring window is hypothesized to represent peak drought leading to widespread dune destabilization and associated *P. haydenii* burial and mortality. If the 2015 monitoring results are any indication, then further declines are likely in the remainder of the 2015-2017 monitoring window, with viability hinging on recruitment and survival of both seedlings and hard-to-measure survival of buried plants.

Monitoring conventions have been developed to address seasonal dormancy but they require determining the mean length of dormancy and then monitoring the population longer than that length (Lesica 1994). If it took almost a day to excavate only 20 plants at three blowouts, and if burial patterns are local, then it would be difficult to collect robust data to determine the mean length of dormancy. The demographic monitoring of mapped seedling cohorts may offer a better dataset, which may require following the belt transects for more than three years.

All things being equal, habitat trends of *Penstemon haydenii* in Wyoming are fundamentally different than in Nebraska because there is decadenal continuity and roughly similar aerial extent in Wyoming rather than "healing over" and disappearing. We have not documented dispersal into new habitats to date but have documented emergence from "old" habitats, the blowout bowl. Searches for expansions of *P. haydenii* in new sand deposits, including at least Bradley Peak, are appropriate as part of 2015-2017 monitoring. Usually dunes move downwind but the bowl is upwind of occupied habitat. It is at least remotely possible that elements of the old bowl form a new blowout rim in the future, for a habitat-based cyclic nature of population trends. In light of *P. haydenii* habitat continuity over time, there may be little or no need for habitat manipulation and transplanting practices in Wyoming as there are in Nebraska.

The presence of seedlings in blowout bowl settings challenges the earlier notion that potential habitat is mainly the downwind active dune. It may be more appropriate to refer to the entire area of active sand as potential habitat than just the downwind zones as used in determining dune trends (Heidel et al. 2014). If established plants are generally absent from blowout bowls, this might indicate that the blowout rims are episodic, and subject to stabilization and destabilization cycles that recontour the blowout feature. It is possible, but by no means demonstrated, that the propensity of seeds of *P. haydenii* and *Psoralidium lanceolatum* (Lemon scurfpea) to germinate in discrete bands may set the stage for formation of new blowout rims upwind of the old ones, anchored by either or both of these species as observed in bands in 2015.

The ages of big and small *Penstemon haydenii* seedlings are not known, but it is inferred that the small seedlings still holding their cotyledons had germinated in the spring of 2015, possibly reflecting the relatively moist spring conditions that were influenced by major snowstorms in both April and May 2015. Likewise, there was heavy snowfall in May of 2014, and it is possible that the big seedlings found in 2015 are one-year-old plants. Small seedlings had never been seen in prior monitoring work and “big seedlings” were the only class of “seedling” observed in prior years. Intermediate sizes were not observe in 2015, and no matter the exact age of the big seedlings, they are inferred to represent one cohort. The high seedling densities that were documented in 2015 far surpass the densities of established plants, or that of seedlings ever observed. Future seedling mortality is to be expected.

In 2014, we searched for *Penstemon haydenii* seedlings because it had been a moist spring, but may have been looking in the wrong places. One of the two places we looked warrants special discussion, a trough at the base and downwind end of Bear Mountain East. This zone was not censused until 2005 and may or may not have been new at the time. A sub-census of just the trough in 2005 documented over 1400 established plants that year. The 2014 search for seedlings yielded a limited number of what seemed to be new shoots if not seedlings. A sub-census at the same place in 2015 documented only 30 established plants and burial was evident. It remains to be seen whether or not this locale has many plants that are surviving belowground, but is an extreme example of the kind of local flux in just one part of a blowout.

The demographic monitoring of seedlings may put 2015 results into context. It will be appropriate to chronicle any seedling deaths found in 2016. If no seedlings persist in the permanent belt transects, then sampling by excavation would be warranted, at least one quadrat per transect, to determine if there is survival or mortality below the surface.

Three recommendations are made to augment the current extensive monitoring project. It is recommended that census in 2016 and 2017 keep track of tallies by blowout zone (bowl, rim, side arms, lee slopes) in order to draw direct parallels between numbers and habitat succession. Some of the 2015 data can be reformatted in these categories. These spatial categories may be more important than the reproductive stage categories (flowering, nonflowering and browsed), if this added distinction becomes too much information to keep organized. Compilation of meteorological data was initiated for the most recent status report (Heidel 2012). That data along with field observations suggest that we should evaluate at least spring precipitation levels of 2014-2015 as they compare with past years, and ensuing meteorological data, as part of the final report. Consultation and meteorological data review may shed light on the episodic nature of recruitment. It may also be appropriate to replicate the aerial photointerpretation conducted through 2012 (Heidel et al. 2014) to determine rates of movement and appearance/disappearance of blowout features such as blowout rims and major new deposits. Previously, it was hypothesized that gentle lee slopes had the highest mortality rates based on demographic monitoring (Heidel 2007). An alternative explanation may be that they have the greatest rates of burial. If this were the case, it would offer hope despite the documented downturn of established plants in 2015.

To carry out the balance of extensive, short-term monitoring, an interim report of 2016 results will be produced, followed by a final report of cumulative 2015-2017 results, or else a memo requesting extension if an additional year of monitoring is warranted. This report serves as a reference for carrying out the work and in presenting additional information on species biology and ecology as monitoring context.

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LITERATURE CITED

Blomquist, F. and B. Heidel. 2002. Census of Blowout penstemon (*Penstemon haydenii*) in 2002 at the Bear Mountain – Junk Hill population. Memo prepared for U.S. Fish and Wildlife Service, Bureau of Land Management and Wyoming Natural Diversity Database.

Blomquist, F. and B. Heidel. 2003. Census of Blowout penstemon (*Penstemon haydenii*) in 2003 at the Bear Mountain – Junk Hill population. Memo prepared for U.S. Fish and Wildlife Service, Bureau of Land Management and Wyoming Natural Diversity Database.

Elzinga, C., D. Salzer and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Tech. Ref. 1730-1. U.S. Government Printing Office.

Fertig, W. 2000. Status of blowout penstemon (*Penstemon haydenii*) in Wyoming. Report prepared for the Wyoming Cooperative Fish and Wildlife Research Unit, US Fish and Wildlife Service, and Wyoming Game and Fish Department by the Wyoming Natural Diversity Database, Laramie, Wyoming.

Fertig, W. 2001. 2000 survey for blowout penstemon (*Penstemon haydenii*) in Wyoming. Prepared for the Bureau of Land Management Wyoming State Office by Wyoming Natural Diversity Database, Laramie, WY.

Freeman, C.C. 2015. Final report on an assessment of the status of blowout beardtongue (*Penstemon haydenii* S. Watson, Plantaginaceae) using molecular and morphometric approaches. Prepared for Bureau of Land Management. University of Kansas, Lawrence, KS.

Fritz, M., J. Stubbendieck, and W. Jobman. 1992. Blowout penstemon (*Penstemon haydenii* S. Watson) recovery plan. US Fish and Wildlife Service Region 6, Denver, CO.

Gaylord, D.R. 1982. Geological history of the Ferris Dune Field, south-central Wyoming. pp. 65-82. In: Marrs, R.W. and K.E. Kolm. Interpretation of Windflow Characteristics from Eolian Landforms. Geological Society of America Special Paper 192. Boulder, CO.

Gaylord, D.R. 1984. Recent eolian activity and paleoclimate fluctuations in the Ferris lost Soldier Area, south-central Wyoming. PhD Thesis. Department of Geology, University of Wyoming, Laramie, WY.

Gaylord, D.R. and P.J. Dawson. 1987. Airflow-terrain interactions through a mountain gap, with an example of eolian activity beneath an atmospheric hydraulic jump. Geology 15:789-792.

Heidel, B. 2005. Survey of *Penstemon haydenii* (Blowout Penstemon) in Wyoming – 2004. Prepared for the Casper and Rawlins field offices of Bureau of Land Management. Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY.

Heidel, B. 2007. *Penstemon haydenii* (blowout penstemon) final monitoring report 2004-2006, Carbon County, Wyoming. Unpublished report prepared for the Bureau of Land Management by the Wyoming Natural Diversity Database, Laramie, WY.

Heidel, B. 2012. Status of *Penstemon haydenii* (blowout penstemon) in Wyoming. Unpublished report prepared for the Bureau of Land Management Rawlins and Rock Springs Field Offices by the Wyoming Natural Diversity Database, Laramie, WY.

Heidel, B. 2013. Results of preliminary underground excavation of *Penstemon haydenii* (Blowout penstemon). Email memorandum to Adrienne Pilmanis, cc: Frank Blomquist, Bureau of Land Management. August 20, 2013.

Heidel, B., S. Cox and F. Blomquist. 2014. Dune habitat trends of an Endangered species, *Penstemon haydenii* (blowout penstemon) in Wyoming. Prepared for Bureau of Land Management (BLM). Wyoming Natural Diversity Database in collaboration with BLM, Laramie, WY.

Heidel, B. 2015. Private Land Surveys - *Penstemon haydenii* (Blowout penstemon), Carbon County, Wyoming. Prepared for the USDI Fish & Wildlife Service – Ecological Services Office by the Wyoming Natural Diversity Database - University of Wyoming, Laramie, Wyoming.

Lesica, P. 1987. A technique for monitoring nonrhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7:65-68.

Lesica, P. 1994. Prolonged dormancy in vascular plant and implications for monitoring studies. Natural Areas Journal 14(3): 209-212.

Menges, E.S. and D.R. Gordon. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal 16: 227-237.

Roderick, A. J., B. E. Nelson, and R. L. Hartman. 1999. Final report on the general floristic inventory of the Upper North Platte and Laramie River drainages. Unpublished report prepared for the Bureau of Land Management Rawlins and Casper Districts by the Rocky Mountain Herbarium, University of Wyoming, Laramie, WY.

Stubbendieck, J. J.A. Lamphere and J.B. Fitzgerald. 1997. Nebraska's Threatened and Endangered Species Brochures: Blowout Penstemon. Published by NEBRASKAland Magazine and the Nebraska Game and Parks Commission.

Stubbendieck, J. and K. Kottas. 2004. 2004 Blowout Penstemon Monitoring. Prepared for the Nebraska Bureau of Plant Industry. University of Nebraska, Lincoln, NE.

Taylor, A. R. 2000. The vascular flora of the Upper North Platte River drainage, Wyoming. Masters Thesis. Department of Botany, University of Wyoming, Laramie, WY.

Tepedino, V. J., T. R. Toler, B. A. Bradley, J. L. Hawk, and T. L. Griswold. 2006. Pollination biology of a disjunct population of the endangered sandhills endemic *Penstemon haydenii* S. Wats. (Scrophulariaceae) in Wyoming, U.S.A. Plant Ecology 193:59-69.

Tepedino, V.J. 2012. Overestimating population sizes of rare clonal plants. Conservation Biology 26(5): 945-947.

Tilini, K.L. 2013. The seed ecology of rare and endangered Gibbens' beardtongue (*Penstemon gibbensii*) and blowout penstemon (*Penstemon haydenii*). Three chapters of research work. M.Sc. in Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT.

USDI Bureau of Land Management. 2008. Record of decision and approved Rawlins Resource Management Plan for public lands administered by the Bureau of Land Management, Rawlins Field Office, Rawlins, Wyoming.

USDI Bureau of Land Management. 2012a. BLM Rawlins Field Office Resource Management Plan. Including: Appendix A. Supplemental evaluation and importance criteria for proposed ACECs. Posted at: http://www.blm.gov/style/medialib/blm/wy/programs/planning/rmps/rawlins/vrm/DraftEA.Par.97898.File.dat/VRMPrelimEA-ApA.pdf .

USDI Bureau of Land Management. 2012b, with 2013 update. Statewide programmatic biological assessment: Blowout penstemon (*Penstemon haydenii*). Submitted to USDI Bureau of Land Management.

USDI Fish and Wildlife Service. 1987. Final rule to determine the plant *Penstemon haydenii* (blowout penstemon) to be an endangered species. Federal Register 52(169): 32926-32929.

U. S. Fish and Wildlife Service. 2012. Blowout penstemon (*Penstemon haydenii*) 5-year review: summary and evaluation. Page 41. U.S. Fish and Wildlife Service Nebraska Ecological Services Field Office, Grand Island, NE. Available at: http://ecos.fws.gov/docs/five_year_review/doc4048.pdf .

USDI Fish and Wildlife Service. 2013. Biological Opinion: Formal statewide programmatic consultation for the impacts from the Wyoming Bureau of Land Management Resource Management Plans and their effects to the Blowout penstemon (*Penstemon haydenii*).