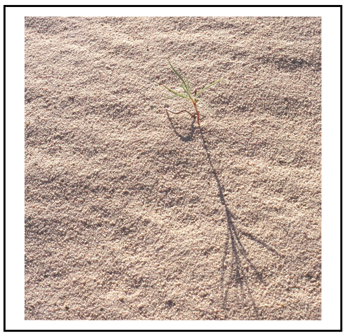
Penstemon haydenii (Blowout Penstemon)

Final Monitoring Report

2004-2006

Carbon County, Wyoming

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ABSTRACT

This report represents the first monitoring study of *Penstemon haydenii* (blowout penstemon) in Wyoming. The objective was to document population numbers and trends for the species in Wyoming, using both census and demographic monitoring techniques, to address recovery goals in the original recovery plan (Fritz et al. 1992). By those goals, downlisting was to be considered when a minimum of 10,000 individuals in at least five stable populations have the minimum level of protection that will ensure their continued existence. Delisting was to be considered when a minimum of 15,000 plants in at least ten populations are protected.

Wyoming contributes significantly to *Penstemon haydenii* numbers, such that downlisting is warranted by the original criteria, assuming that both states have the same taxon, and that at least three sites among those in Nebraska maintain adequate indigenous numbers. Population census numbers for *Penstemon haydenii* peaked in Wyoming at 19,343 plants in 2005 under cool, moist spring conditions following at least five years of drought. Population number dropped to 13,897 (28%) in 2006 under hot, dry spring conditions and renewed drought.

Penstemon haydenii population demographic data suggests that any given sector of a colony is subject to decline over time, consistent for a pioneer species, so that the population is in continual flux. This may place a premium on recruitment and mortality rates. Sporadic recruitment was documented in the demographic monitoring, but mortality was ongoing and differed between the three settings where transects were laid. The mortality data suggests that the gentlest slopes have the highest mortality rates, and the smallest and largest plant size classes have the highest mortality rates, thought to include the youngest and oldest plants. The *Penstemon haydenii* plants in steep and gentle slope settings also differed in that those on steep slopes tended to have higher flowering rates. Browse levels were slightly lower and much more consistent for *P. haydenii* plants on steep slope as compared to gentle slope settings. The steep and gentle slope habitat diversity across multiple blowout colonies buffer the population as a whole.

The short three-year period of monitoring was entirely within extreme drought conditions, and it is hypothesized that the fluctuations documented within the monitoring period represent key fluxes that set the course of inter-drought trends for *Penstemon haydenii.* Resiliency is conferred but not guaranteed by demographic differences associated with habitat diversity, with seedbank formation, and with the intrinsic instability of blowout settings in Wyoming.

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

Cover photo: Blowout penstemon (*Penstemon haydenii*) in the four different states in which it was monitored (upper left to lower right): seedling, nonflowering, flowering, and browsed. Photos by B. Heidel

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INTRODUCTION

Penstemon haydenii Wats. (blowout penstemon) was listed as an Endangered species in 1987 (USDI Fish and Wildlife Service 1987), and 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 at a minimum number of sites where it is naturally-reproducing and self-sustaining over time. Long-term monitoring was initiated in Nebraska to gauge progress in meeting recovery goals (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 and botanist colleagues in 1999 (summarized in Fertig 2000, 2001). Hence there was an immediate for *Penstemon haydenii* status and trend information in Wyoming as part of species' recovery. These needs are the impetus behind this monitoring project.

Census of *Penstemon haydenii* in this study was designed to document overall trends, and demographic monitoring was designed to document the life history changes associated with those trends. In the rest of this report, "monitoring" is used to refer to both census and demographic monitoring techniques unless otherwise stated.

Available information on the species biology and habitat of *Penstemon haydenii* for Wyoming is presented in Fertig (2000, 2001) and in Heidel (2005a); and for Nebraska in Fritz et al. (1992) and Stubbendieck et al. (1997). New pollination information that compares pollination of *P. haydenii* in Nebraska with it in Wyoming is provided by Tepedino et al. (2006 a, b).

STUDY AREA

Penstemon haydenii occurs in dune blowouts of northwestern Carbon County, Wyoming. The three known occurrences are named in this report by local land features, and numbered in the order in which they were discovered (001-003). The Bradley Peak occurrence (001) is comprised of a single large continuous blowout area at three different levels with a steep slope. The Bear Mountain – Junk Hill occurrence (002) is comprised of thirteen discontinuous blowouts, and the 13 associated blowout colonies are similarly named. The Pathfinder population (003) is comprised of two discrete blowouts supporting the species. The populations scattered between 16 blowouts have been mapped from aerial photos from Geographical Positioning System (GPS) points using ArcView so that their area can be calculated and distribution changes over time monitored as well. Table 1 represents each occupied blowout, the occurrence number, the date of discovery, and characterization of slope steepness, as referenced throughout this report. Complete documentation of local distribution would ideally have been finished before implementing a monitoring program; thus the scope of work as distribution expanded.

The Bradley Peak occurrence was discovered by Frank Blomquist in 1996 and documented in 1999 by Walter Fertig and Frank Blomquist (Fertig 2000). Systematic survey of six landscapes in south-central Wyoming was pursued by Walter Fertig in 2000, documenting an additional Carbon County population in the Bear Mountain – Junk Hill area, surveyed by Walter Fertig and Frank Blomquist (four blowouts; Fertig 2001). This same occurrence was completely surveyed as having 13 blowouts. Systematic surveys in Converse and Natrona County was conducted in 2004, and a third Carbon County occurrence added at the Pathfinder Reservoir (two blowouts; Heidel 2005a). GPS points were taken to map occupied habitat, and project onto aerial photographs. Complete printouts and maps of the occurrences are presented in this report (Appendix A), spanning 200 acres. The same dune names are used throughout this report.

Table 1. Blowout colonies occupied by *Penstemon haydenii* in Wyoming

Dune	**Occur. No.**	**Acreage**	**>300 Plants**	**First Discovery**	**Slope of Primary Occupied Habitat**
Bradley Peak	001	16	Y	1996	Steep
Junk Hill Main	002	64	Y	2000	Gentle
Junk Hill West 1	002	4	Y	2004	Gentle
Junk Hill West 2	002	7	Y	2004	Gentle
Junk Hill West 3	002	19	Y	2004	Gentle
Junk Hill West 4	002	7		2004	Gentle
Bear Mt Valley	002	1		2004	Steep
Junk Hill Upper Outlier	002	1		2000	Steep
Bear Mt East	002	31	Y	2000 +'05	Steep
Bear Mt West	002	7	Y	2000	Steep
Bear Mt East Outlier	002	15		2002	Gentle
Ferris 1	002	16		2005	Gentle
Ferris 2	002	5		2005	Gentle
Ferris 3	002	4		2005	Gentle
Pathfinder South	003	1		2004	Gentle
Pathfinder North	003	2		2004	Gentle
TOTALS	3	200	7	-	4 steep, 12 gentle

Re-visit and estimate of the Bradley Peak population was conducted in 2000 (Fertig 2001). Re-census of the three largest Bear Mountain – Junk Hill blowout colonies was conducted by Frank Blomquist and Bonnie Heidel in 2002. The following year represented a monitoring transition, in which the merits of a late summer monitoring in July were gauged, and the first two demographic monitoring plots were established by Frank Blomquist and Bonnie Heidel. Re-census of the three largest Bear Mountain - Junk Hill blowout colonies was conducted that year by four biologists without benefit of flowering plants, aerial photographs or prior familiarity.

The study area for monitoring work originally focused on the four largest dune colonies as of 2003. It was expanded to include all populations or subpopulations that have over 300 individuals as priorities for trend analysis. Ultimately, weven locations met this size criterion. These include the Bradley Peak occurrence, and the five largest blowouts of the Bear Mountain –

Junk Hill metapopulation (Junk Hill Main, Bear Mountain East, Bear Mountain West, West Junk Hill 1, West Junk Hill 2 and West Junk Hill 3). A one-time census was conducted in the nine other blowout colonies to incorporate census numbers from recent years and similar survey effort in tallies and estimates.

MONITORING DESIGN

Overview

The monitoring design of *Penstemon haydenii* in Wyoming has five components (following Elzinga et al. 1998): define what is being monitored, why it is monitored, when it is monitored, how long it is monitored, and where it is monitored. The census provides overall trend data and the demographic work provides life history information to help interpret census results.

1. What. The goal is to determine *Penstemon haydenii* population numbers and trends, and to follow individuals within a permanent belt transect if feasible. The feasability of returning to the same belt transect was confirmed in a pilot study (Heidel 2005b), in the sense of Vesely et al. (2006), though the rebar marking the endpoint of one 50 m transect had to be moved almost 2 meters by 2006 because the blowout rim encroached. It was determined in the pilot study that plants do re-appear at the same coordinates between years, and it is inferred that these are the same individuals.
2. Why. The monitoring of *Penstemon haydenii* in Wyoming is a baseline census and demographic monitoring project and there are no management actions or contingencies tied to the monitoring. There may potentially be recovery decisions or revision of standards resulting from the monitoring of *Penstemon haydenii* in Wyoming.
3. When. The monitoring of *Penstemon haydenii* in Wyoming was conducted concurrently with census at a time when the plants are in flower and most conspicuous. By noting browse at this time of year, all later browse of fruits are missed, so it is a trade-off between getting robust census information rather than frequency of browse over the growing season.
4. How long. Three years were proposed as the study duration at the onset. The monitoring was conducted entirely within a period of drought. This monitoring study has answered questions about short-term trends and patterns of local persistence under drought conditions. There is a fundamental question how these trends relate to trends under non-drought conditions, and the importance of transitions between drought and non-drought. This is addressed in the discussion section.
5. Where. Annual census of subpopulation numbers was planned for all four known blowout colonies of greater than 300 plants (Bear Mountain East, Bear Mountain West, Bradley Peak and Junk Hill Main) based on available distribution information. A minimum of one-time census was planned for the one other blowout colony (Junk Hill Upper Outlier). Survey in 2004 added seven new blowout colonies, and review of 2004 results identified three overlooked areas that proved to be three new blowout colonies when surveyed in 2005. Thus, the scope of annual census was changed to include the seven colonies having greater than 300 plants, and one-time census of nine smaller blowout colonies.

Census Methods

The census would ideally count the entire population numbers of *Penstemon haydenii* individuals in Wyoming each year to determine the trends in population numbers. Considering the scope of this work, and the need to put census results in demographic context, we instead sought to annually census those blowout colonies that had over 300 individuals, following the criteria used in the recovery plan. In addition, there was a complete census of all other blowout colonies at least once during the monitoring period.

The prospect of doing a random sample to determine total numbers was considered as an alternative to conducting complete census, but is greatly complicated by the non-random distribution of *Penstemon haydenii.* Alternate methods of censusing or estimating were pondered in pilot studies that originally aimed to census the two occurrences as they were known at that time in two days (Blomquist and Heidel 2002, 2003). Instead, census 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 the survey pattern unless there has been recent rain as there was in 2005. Census was conducted across broad areas of habitat by one or two people walking parallel lines in series across discrete segments of the subpopulations, taking sightings on features near the boundary. The distance between the parallel lines varied depending on the vegetation cover in the habitat, the density of the *Penstemon haydenii*, and the conspicuousness of the individuals, as influenced by stage(s) and browse levels. In all cases, the tallies are based on actual counts rather than partial counts augmented by estimates.

During census, separate tallies were kept for flowering vs. nonflowering (vegetative) plants. A single plant may produce stems that are all flowering, all nonflowering (vegetative), 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 affects 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.

Census requires consistency in distinguishing individuals. *Penstemon haydenii* plants have 1-many stalks. They have not been demonstrated to expand vegetatively by rhizomes, mentioned in unpublished remarks (Stubbendieck 2001), and no clear patterns of vegetative reproduction were found in demographic monitoring. The possibility of vegetative reproduction does not change the tally of functionally independent plants, but it would change the demographic context. In census, flowering and nonflowering stems (ramets) that are within about 15 cm apart were inferred to be part of the same individual (genet); this generalization was adjusted if they were buried or eroded out, and clearly converging at a subterranean axis. The stems are generally upright to spreading, but may be decumbent with erosion, in which case the axis of the stalk may be the only clue of connectivity to distant upright stalks.

Consistency in distinguishing individuals is enhanced by consistency in the timing of monitoring. In 2002, monitoring was conducted by Frank Blomquist and Bonnie Heidel on June 25 and 27. In 2003, census was moved on a trial basis to July 22 in order to get missing life history information including levels of fecundity, check if fruit abortion is present in the population as indication that pollination limits reproduction, and to record if seedlings are present. Low flowering levels and high browse levels and environmental extremes were documented instead. The inconspicuousness of browsed plants compromised the thoroughness of the 2003 census. All subsequent monitoring work was conducted in late June.

In 2004, 2005 and 2006, seedlings were also noted, and tallied or estimated, but were not incorporated in census tallies. There had been no prior observation of seedlings in 1999, 2000, 2002 or 2003.

For trend analysis, 2004-06 tallies are used without any effort to make adjustments. Different personnel were involved each year, and despite all efforts to standardize census methods, omissions and double-counting were possible. In light of the importance placed on covering large areas in limited time, errors of omission were the more likely.

This monitoring project started in the same year as a *Penstemon haydenii* survey project, and thus the scope of the monitoring expanded with surveys. The census in 2004 did not get systematic census numbers from the two large blowout colonies that were discovered for the first time that year (West Junk Hill 2 and West Junk Hill 3). It was also missing a major extension of one of the original blowout colonies as remapped in 2005 (Bear Mountain East). In addition, a smaller of the West Junk Hill blowout colonies was censused in detail for the first time in 2006 (West Junk Hill 1) and had over 300 plants, representing a major blowout colony by the original recovery numerical standards. Thus, for three of the six major colonies, there are three years of data, three others have only two years of complete census data, and for the seventh major colony, there is only one year of census data.

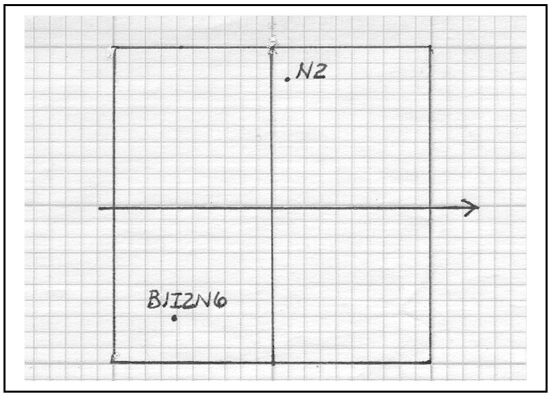
Demographic Methods

Demographic monitoring was set up on a trial basis to track individual plants over time. Two 50 m belts were marked by rebar stake endpoints at Junk Hill in July 2003, and one 20 m belt was marked by rebar stake endpoints at Bradley Peak in June 2004. The plots are permanent belt transects, subjectively placed in areas of relatively high *Penstemon haydenii* density and homogeneous settings, following conventions of Lesica (1987). The three settings represent a gentle downwind slope from the blowout rim (Junk Hill Main 1), a gentle side slope from the blowout rim (Junk Hill Main 2), and a steep side slope from the blowout rim (Bradley Peak). The GPS endpoints for the three belt transects are shown in the aerial photos of Appendix A.

At the time of monitoring, a measuring tape was placed taut between rebar endpoints. A 1 m sq monitoring frame constructed of 1 m^2 PVC piping (3/8 in with fitted joints) was marked in 10 cm increments and used to delimit 1 m^2 plots that were read above and below the tapeline for a total of 240 m^2. One person read the plot and another person recorded results on graph paper.

The series of plots in the belt were drawn onto graph paper and individual *Penstemon haydenii* plants were mapped to the nearest 5 cm as represented by a point. The same conventions used in census were used to distinguish individuals. Each point was labeled to represent the number of flowering stems, nonflowering stems, and browsed flowering stems of the individual, e.g., B1I2N6 represents a browsed plant with one browsed flowering stem, two intact flowering stems, and six nonflowering stems; and N2 represents a nonflowering plant with two nonflowering stems. A schematic diagram of the belt transect is presented below.

Figure 1. Schematic diagram of permanent belt transect and data recording conventions



Four plots are diagrammed to the left; two above the tape and two below. The plot in Frame 1 - below the tape has a browsed plant with one browsed flowering stem, two unbrowsed flowering stems, and six nonflowering stems at coordinates 4,3. The plot in Frame 2 - above the tape has a nonflowering plant with two stems at coordinates 1,8.

The plot data were transcribed in the office onto excel spreadsheets, recording location coordinates, and indicating disparities between years as tentative recruitment or mortality. The raw data are presented in Appendix C.

An establishment report was submitted in 2005 to document the study area, methodology and address fundamental demographic monitoring questions. An abbreviated monitoring report was submitted in 2006. Data from the first two years of demographic monitoring (2003-04) were interpreted to indicate that:

- 1. Permanent monitoring can be conducted continuously in unstable dune habitat. Five of the six rebar stakes were becoming buried and one was eroded out with the expansion of the blowout; reducing one transect by less than 4 1 m² between 2005-06.
- 2. Individual plants can be reliably relocated from year-to-year. Remnant of pervious year's plants were often visible and coordinates were recorded each year to match plant locations between years (usually +/- 0.5 dm).
- 3. Stage-based transitions (i.e. size classes) are feasible for demographic analysis. In it, stage-based transitions were calculated in the establishment report for the first two years of data (Heidel 2005b). Four tentative size classes were defined based on the total number of stems:

  A. 1 stem
  B. 2-4 stems
  C. 5-10 stems
  However, it was proposed that the fate of browsed plants in the following year, or the status of plants that died the year prior to their death would be more important analyses to run rather than shifts in plant size.

In comparing plants in the first two years of demographic data (Heidel 2005b), it was determined that individuals are more apt to remain the same or similar size classes from one year to the next than to change, that both increases and decreases are possible, and that there was no flowering of single-stemmed plants in 2003 and 2004; and very low rates of single-stemmed plants in 2003 producing multiple stems or flowering in the following year.

The Bradley Peak data in 2006 was collected without a tape measure, so it was not possible to ensure consistent delimitation of the belt transect. Thus there are only two years of robust data from this site for comparison (2004-05). Most demographic analyses address the two Junk Hill Main transects.

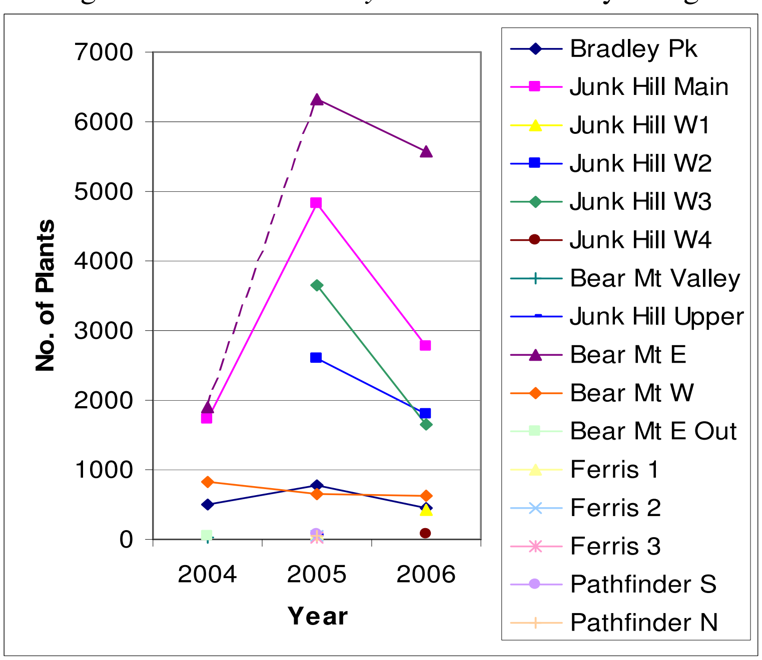
. The Bradley Peak transect covered only 40% of the area in the Junk Hill Main transects so numeric results were multiplied by a factor of 2.5X for direct comparisons[1]. Alternatively, data from all three transects could have been converted to density values for direct comparison.

RESULTS

Census

Trends are presented by blowout colony for all 16 blowouts occupied by *Penstemon haydenii* (Table 1, Figure 2). The three years of census results are graphed in Figure 2, based on actual counts and consistent methods.

Figure 2. *Penstemon haydenii* trends in Wyoming[2]



[1] Though there was not a 50 m long segment of high density habitat at Bradley Peak, all values from the Bradley Peak are multiplied by 2.5X in order to make direct comparisons between the absolute and relative numbers in three transects from three fundamentally different settings.

The 3-year trends in *Penstemon haydenii* plant numbers demonstrate three patterns (next page).

Table 1. *Penstemon haydenii* trends in Wyoming[3]

Dune blowout	Occur. No.	1999 estim.	2000 estim.	2002 near-complete census	2003 partial census	2004 census	2005 census	2006 census
Bradley Peak (total)	1	300-500	200-300	-	-	488	776	452
Junk Hill Main (total)	2		2000-3000	1762 (1900-2200)	830	1729	4816	2770
Junk West 1 (western)	2					95 partial (150-200)	(95)	431
Junk West 2 (mid-north)	2					711 partial (900-1200)	2593	1811
Junk West 3 (mid-south)	2					603 partial (800-1000)	3646	1648
Junk West 4 (eastern)	2					16 partial (25-50)	(16)	86
Bear Mt Valley	2					24 partial (30?)	(24)	(24)
Junk Upper Outlier	2		80 (100-120)	-	-	-	60	(60)
Bear Mt East[4]	2		1001 partial (1550-1850)	1563 partial (1600-1900)	997 partial	1902 partial	6317	5584
Bear Mt West	2		191 (300-570)	-	-	801	658	622
Bear Mt North	2					30	(30)	(30)
Bear Mt East Outlier 1	2			52 (60-80)	-	22 partial (50)	(22)	(22)
Ferris 1 (western)	2						79	(79)
Ferris 2 (mid)	2						55	(55)
Ferris 3 (eastern)	2						30	(30)
Pathfinder South	3					19 partial (-35)	80	(80)
Pathfinder North	3					10 partial (-15)	46	(46)
TOTAL		300-500	1272 (4000-5610)	3377 (3960-4920)	-1827	6450	19,343	13,897

[2] Bear Mountain East has a dashed line connecting 2004 and 2005 census results because boundaries of the blowout colony were expanded in 2005 that results inclusion of an area with local numbers of 1398 plants. Even though

[3] Dark-shaded areas represent colonies before they were discovered. Light-shaded areas represent estimates or those with parentheses represent placeholder values from previous years. Values without shading represent complete counts with the exception that the 2004 census of Bear Mountain East and all earlier censuses did not include an eastward boundary expansion documented in 2005 (containing 1398 plants in 2005).

[4] Note that all counts and estimates of Bear Mountain East prior to 2005 did not include an eastern arm that had 1398 plants in 2005, and which might be expected to have increased earlier totals by roughly 1000 plants.

To summarize the patterns:

1. The numbers of plants in most dune blowout colonies peaked in 2005 in almost all cases.

2. The drop in numbers of plants between 2005 and 2006 was sharp in most of the Junk Hill dune colonies compared to the Bear Mountain colonies and the Bradley Peak colony. It is possible that stability is related to the degree of habitat slope because it appears that the predominantly steep dunes (Bear Mountain and Bradley Peak) did not exhibit the sharp 2005-06 decline evident on most of the gentle dunes (Junk Hill).

3. It appears that the two largest dune colonies exhibit a net increase over the three-year period (Bear Mountain East and Junk Hill Main). This interpretation is provided as a provisional conclusion with two lines of supporting evidence and caveats.

Table 2. Levels of Flowering and Browse for *Penstemon haydenii* in Wyoming
(See Figures 3-9; next page)

Bradley Peak	**Fl**	**Br**	**NonFl**
2004	231	Gap	257
2005	348	72	356
2006	27	230	195
Junk Hill Main	**Fl**	**Br**	**NonFl**
2004	519	Gap	1210
2005	2273	349	2194
2006	259	529	1982
Junk Hill West 1	**Fl**	**Br**	**NonFl**
2006	6	5	420
Junk Hill West 2	**Fl**	**Br**	**NonFl**
2005	688	322	2636
2006	6	43	1762
Junk Hill West 3	**Fl**	**Br**	**NonFl**
2005	348	83	2162
2006	27	24	1597
Bear Mountain East	**Fl**	**Br**	**NonFl**
2004	1291	Gap	611
2005	2477	845	2937
2006	786	641	4157
Bear Mountain West	**Fl**	**Br**	**NonFl**
2004	425		376
2005	365	150	143
2006	161	127	334

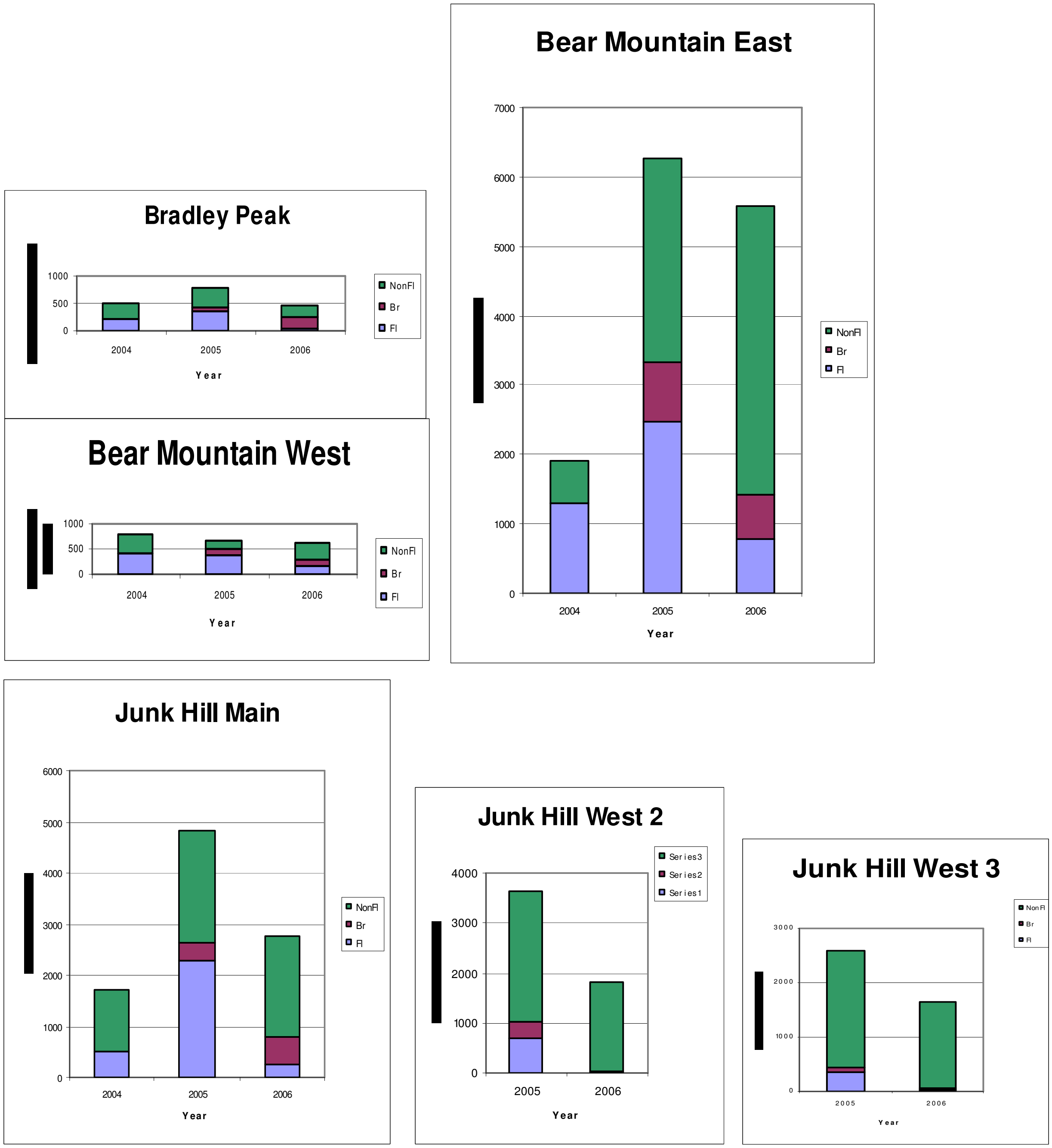
Clues to the nature of these trends and context for interpreting them is provided by accompanying census data on the levels of flowering and browsing (Table 2, Figures 3-8). The steep dunes of Bear Mountain generally have higher levels of flowering (average 49.5%; range of 25%-74%) than the gentle dunes of Junk Hill (average 19.7%; range of 2%-54%).

The major dunes of Bear Mountain have relatively consistent levels of browsing (average 35.7%; range of 24%-45%) though the major dunes of Junk Hill have a higher average level of browse across the monitoring period (average of 44.6%; range of 13%-89%).

The Bradley Peak area has high levels of flowering similar to the Bear Mountain dunes (average 55.5%; range of 54%-57%) which is consistent in that both areas have predominantly steeply sloping occupied habitat. But it also has high levels of browse, like the Junk Hills dunes (average 53%;range of 17%-89%).

The following patterns appear over time. Flowering levels were high in 2005 in almost all blowout colonies, in absolute and relative terms. The browsing levels in 2006 were exceptionally high at most but not all sites.

Figures 3-8. *Penstemon haydenii* trends and levels of flowering and browse in Wyoming[5]



[5] Note: These six graphs represent the six largest blowout colonies of *Penstemon haydenii*, at approximately the same scale for direct comparison. The 2004 census did not distinguish browsed plants from flowering and nonflowering plants. In addition, the 2004 census was incomplete for a major sector of the Bear Mountain East blowout colony.

RESULTS

Demography

The demographic data provide compelling evidence that localized *Penstemon haydenii* trends are independent from the overall census trends of the colony. Both Junk Hill colonies declined (2003-06; Figure 9-10) while the Bradley Peak colony appears to have a 2005 peak. The raw data are presented in Appendix B.

Figure 9. *Penstemon haydenii* trend in number of stems

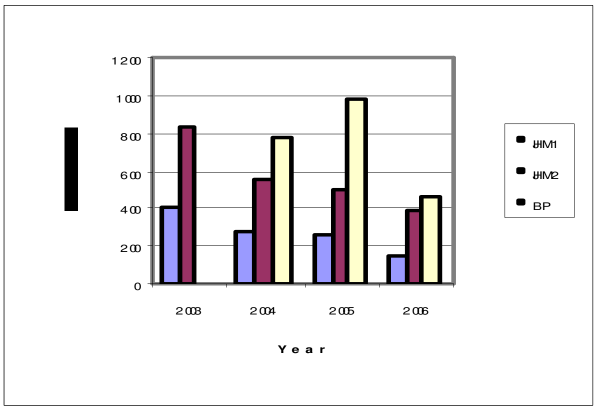
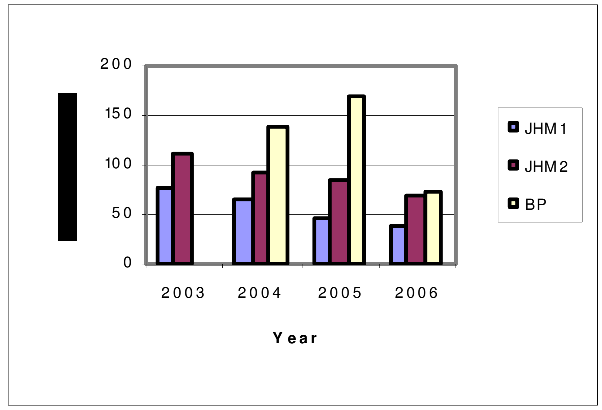


Figure 10. *Penstemon haydenii* trend in number of individual plants



Trends in the number of stems and the number of individuals follow the same patterns of decline (Figures 10, 11) but the decline in number of stems is steeper. It is interesting to note that the two transects at the blowout rim side slopes had the highest numbers (Junk Hill Main 2 and Bradley Peak), and the adjusted Bradley Rim numbers were consistently higher than those at Junk Hill.

The associated pattern of mortality and recruitment indicated that mortality was ongoing over the monitoring period, while recruitment varied considerably by place and year (Figures 13-14). Recruitment was absent in the Junk Hill Main 1 transect in 2005. In all three transects and all years, mortality levels exceed recruitment levels, explaining the overall decline in numbers of individual plants.

Figure 11. *Penstemon haydenii* trend in recruitment – number of plants

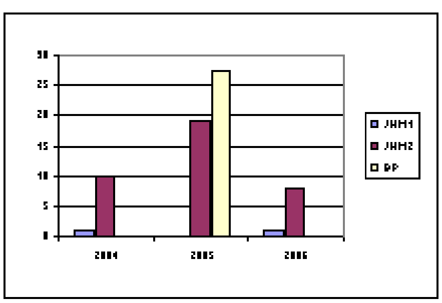
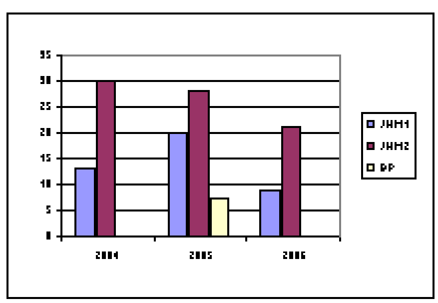
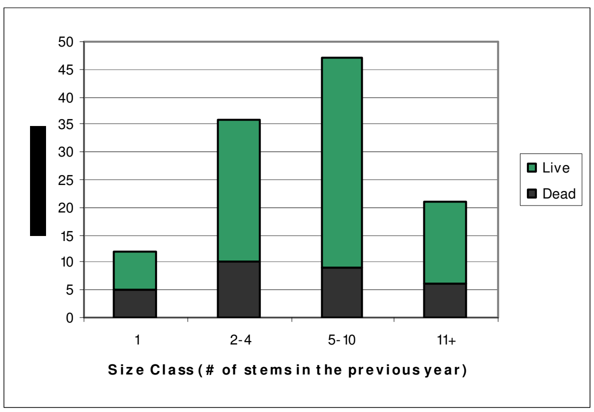


Figure 12. *Penstemon haydenii* trend in mortality - number of plants



It is noteworthy that mortality was not limited to any one size class of plants, though a greater proportion of the smallest and of the biggest plants were likely to die between years. For example, Figure 13 is a graph of mortality levels in the Junk Hill Main 2 transect between 2003-04 for plants in each size class of 2003 that died in 2004 (n+1). The highest net mortality numbers were for medium-sized plants (5-10 stems), while the highest proportions of mortality was for the single-stemmed plants, followed by the largest plants (11+ stems). As a rule, the smallest plants are likely to include the youngest, and the largest plants are likely to include the oldest. Thus, the data indicate that mortality levels are skewed to most strongly affect the youngest and oldest plants.

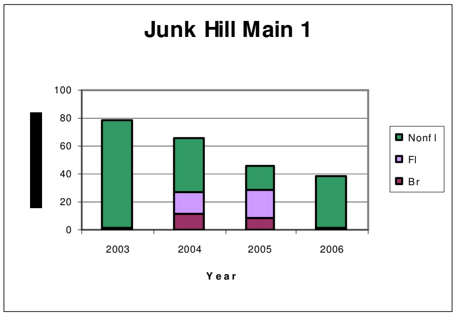
Figure 13. Mortality levels in 2004 among *Penstemon haydenii* plants of different size classes in 2003 (Junk Hill Main 2)



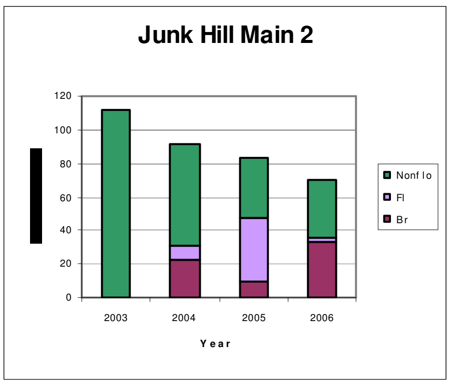
Since we did not know the age of plants at the start of demographic monitoring, we do not know the longevity of individual plants. Of the 189 plants present in Junk Hill Main plots in 2003, at least 71 persisted through 2006 (38%). From this data, if all plants were 1 year old at the start of monitoring, and if the monitoring period were representative, then the mean longevity would be less than four years old. Since many of the plants were multi-stemmed at the start of the monitoring, and since a drought episode is apt to represent high mortality, it is reasonable to expect that average longevity is significantly greater than four years.

The trends in flowering and browse levels within the belt transects (Figures 16-19) are similar to the flowering and browse results for the census as a whole, except for a few marked differences between Transect 1 and Transect 2 on Junk Hill Main. The total numbers of plants declined at a faster rate in Transect 1 than Transect 2. It is hypothesized that the breach of the blowout rim upwind from Junk Hill Main Transect 1 between 2004 and 2006 accelerated burial of that particular transect, and that burial is a major mortality factor. In addition, browse levels were markedly higher in two of four years on Transect 2, suggesting some wildlife use preference whether for a higher density of plants or for the setting.

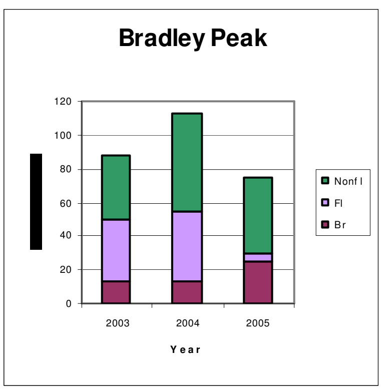
Figures 14-16. *Penstemon haydenii* trends in nonflowering, flowering and browse levels in transects



Junk Hill Main 1 lies downwind from the blowout (gentle slopes)



Junk Hill Main 2 lies on a side rim of the blowout (gentle slopes)



Bradley Peak lies on a side rim of the blowout (steep slopes)

This was not set up as a browse study, but the transect results provide preliminary data on the fate of browsed plants (Tables 3-6). Of all the plants that were browsed in any given year of monitoring, 11%-32% of them died by the following year. In general, browsed plants tended to become fewer-stemmed in the year following browse, particularly in 2005-06. The flowering levels of browsed plants resemble that of the population sector overall in that the majority of 2004 browsed plants flowered in 2005, while none of the 2005 browsed plants flowered in 2006. The sample size is inadequate to determine if the mortality, size, and flowering levels of browsed plants differed significantly from unbrowsed plants in the belt transect samples.

Table 3. Size fate of browsed *Penstemon haydenii* plants (2004-2005)

2004-05	**Dead**	**Smaller**	**Same**	**Larger**
JH1	3 (23%)	3	1	5
JH2	7 (32%)	9	4	2
BP	0	1	0	4
Total	10 (26%)	13	5	11

Table 4. Size fate of browsed *Penstemon haydenii* plants (2005-2006)

2005-06	**Dead**	**Smaller**	**Same**	**Larger**
JH1	2 (29%)	3	0	2
JH2	1 (11%)	5	2	1
Total	3 (19%)	8	2	3

Table 5. Flowering fate of browsed *Penstemon haydenii* plants (2004-2005)

2004-05	**Dead**	**Br**	**Fl**	**Nonfl**
JH1	3 (23%)	1	7	2
JH2	7 (32%)	3	7	5
BP	0	1	3	1
Total	10 (26%)	5	17	8

Table 6. Flowering fate of browsed *Penstemon haydenii* plants (2005-2006)

2005-06	**Dead**	**Br**	**Fl**	**Nonfl**
JH1	2 (29%)	0	0	5
JH2	1 (11%)	2	0	6
Total	3 (19%)	2	0	11

Browse did not appear to be a cause of mortality in and of itself. But a significant number of the plants that had browsed stems had all stems browsed to stubs (see cover photo). This it thought to make them vulnerable to burial, and explain the accelerated mortality in 2006 on gentle slopes that were highly browsed in 2005.

By tracking individuals over time, it is possible to develop stage-based transition matrices. The relocating and consistently mapping plants with certainty is critical to the analysis. Instead of pursuing the transition analysis, there are four cases presented below as representative of plants that persisted over the four year time span (next page; from Junk Hill Main 1 dataset). They are a reminder that the composite trends in any population sector, as represented in Figures 14-16, are comprised of contrasting trends among individual plants.

Figure 17. A small *Penstemon haydenii* plant that remained vegetation

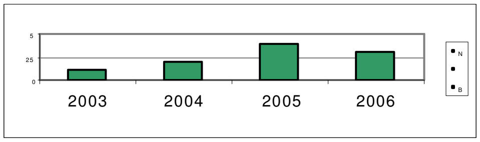


Figure 18. A large *Penstemon haydenii* plant that flowered two of four years

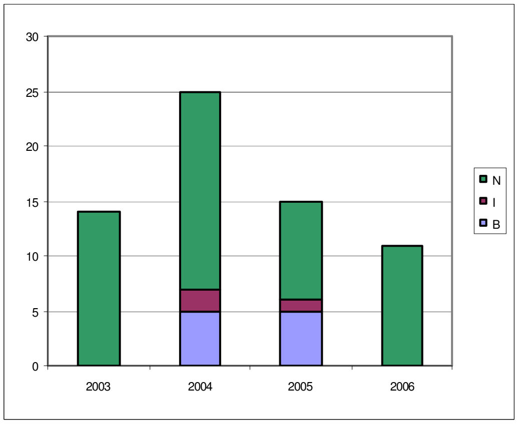


Figure 19. A *Penstemon haydenii* plant that grew in stem numbers over the period

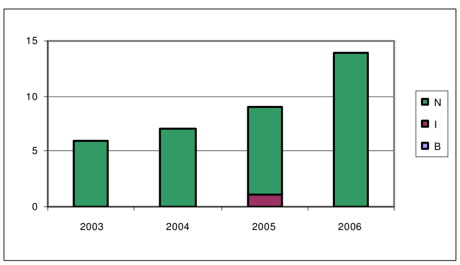
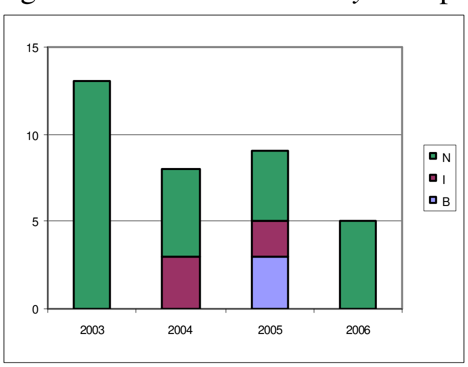


Figure 20. A *Penstemon haydenii* plant that diminished in stem numbers over the period



DISCUSSION

The initial period required for downlisting and delisting *Penstemon haydenii* was originally estimated at 10 and 15 years, respectively, from the initiation of the recovery plan (Fritz et al. 1992). While it is not possible to characterize long-term trend of *P. haydenii* in Wyoming from three years of monitoring during a drought period, this pilot study has documented significant results that contribute to the 15-year review:

1. Unprecedented high species' numbers (19,343 in 2005),
2. Sixteen blowout colonies, at least seven of which have numbers over the 300-plant threshold as major contributions to recovery,
3. Indication of net population increase between 2004-06 in at least the two largest blowout colonies, at Bear Mountain East and Junk Hill Main.
4. Evidence that the colony shifts over time, or at least has a short-term decline of well-established plants during drought.

This is interpreted to mean that Wyoming contributes significantly to *Penstemon haydenii* numbers, such that downlisting is warranted as long as both states have the same taxon, and that a major portion of Nebraska sites (minimum three) maintain adequate numbers that include indigenous colonies.

The high number of *Penstemon haydenii* plants flowering in 2005 dropped in 2006 (81% decline, from 6665 flowering plants to 1275 flowering plants). All pollination research on *P. haydenii* in Wyoming was conducted in 2005 (Tepedino et al. 2006a), in which evidence for reproductive limitation was documented in Wyoming, in contrast with absence of reproductive limitation in Nebraska (Tepedino et al. 2006b). This monitoring study suggests that the phenomenal flowering levels of 2005 were not a regular event. Thus, the reproductive limitation that was documented among *P. haydenii* in 2005 may have been partially compounded or primarily caused by lags between the population sizes of the pollination vectors with the numbers of flowering plants.

In addition, the census and monitoring data has documented contrasting patterns of flowering and browse by habitat and by climate condition; results that provide a framework for understanding trends. In general, higher levels of flowering were found on steep slope settings, and were also evident in years with cool, moist spring conditions. The steep and gentle slope settings also had different levels of browse and consistency in browse. Relatively stable levels of browse were documented on steep-slope habitats (possibly associated with big game trails), while oscillating levels of browse were found on gentle slopes (at extremely high levels during the most severe drought years). The variable habitat conditions, as they respond to climate condition and browse, lend resiliency within and between blowout colonies.

It is hypothesized that the 2005 peak in total numbers represents a population pulse that corresponds with episodic germination, in part attributed to prolonged drought has a synchronizing affect during which time seed banks are built up. Of the three blowout colonies that had complete 2004 census, two increased (59% to 178%).

It is hypothesized that the 2005-06 decline reflects mortality, particularly of the newly-established plants that might be expected to be especially vulnerable. It appears that mortality is associated much more with burial than with stress-induced conditions. Thus, the blowout colonies on gentle dune slopes, particularly downwind from blowouts, were much more subject to burial under destabilized conditions than the blowout colonies on steep slopes. This is supported by demographic monitoring conducted in areas of high density near blowout rims.

The three transect settings did not exhibit the same pattern as census results and are either subject to waves of colonization and decline, or else the drought conditions (2000-present) destabilized the habitat conditions that are necessary for prolonged occupancy. The possibility that plants that “disappeared” under burial but did not die was addressed in looking for and finding a low incidence of “reappearance” among plants over three-year intervals with disappearance in the second year. It appears that the continuity of decline depends very much on climate conditions as they dictate over mortality and burial.

Historic drought was thought to have contributed to the decline of *Penstemon haydenii* in Nebraska (Fritz et al. 1992). It is appropriate to consider the climate conditions during the monitoring project. The 2006 conditions represent the seventh year of significantly below-average moisture as indicated by the Palmer Drought Severity Index (USDI NOAA 2006 records for Region 10, Wyoming; Appendix B). It is only the second drought episode of such duration since record-keeping began in 1895, and the previous one was during the 1980’s. It is hypothesized that drought episodes may set the trend trajectory between drought depending on the episodic seedling survival or mortality.

Some of the demographic data interpretation hinges on premises about reproduction of *Penstemon haydenii*. It is clear that the species reproduces from seed, and resprouts in a remarkably stationery position despite the shifting sands. It is not clear if there are stems produced from rhizomes for vegetative reproduction. Excavation of *P. haydenii* plants is proposed in 2007 to settle whether the census is addressing only genets or both genets and ramets.

The challenge of drawing a conclusion from the limited time that *Penstemon haydenii* has been studied in Wyoming is particular great in this instance. It appears that the 2004-06 monitoring period represents maximum habitat instability. This is based on four sets of observations:

1. The Bradley Peak developed a new downwind “tail” in two years (2005-06) that doubles the length of the blowout,
2. The Bradley Peak spring-fed wetland had entirely dried up in 2006 for the first time since it was discovered (1996),
3. By 2006, all four original major dune blowouts breached parts of their rims that were otherwise continuous and held together by perennial root material when visited in 2002 and 2003, and
4. Blowout basins were markedly filling in at nearly all of the blowout colony sites by 2006.

If the monitoring period does represent a critical flux associated with drought, then some level of scaled-back monitoring in 2007 would help corroborate this interpretation. Three measures are proposed for 2007.

1. Census Junk Hill Main in 2007 to gauge the continuity or break in 2005-06 decline.
2. Re-read the two oldest monitoring transects on Junk Hill Main in 2007 to determine the associated life history changes with census results.
3. Excavate the Junk Hill Main demographic monitoring site in 2007 to determine if there is connectivity between what may or may not be genetically distinct plants. If there is frequent connectivity, then this indicates that vegetative reproduction is an unaddressed factor in demographic analysis and in census.

The short-term trend and the longer-term trajectory may hinge on survivorship of plants that became established in 2005. It is inappropriate to use the adjective "stable" in connection with *Penstemon haydenii* numbers, but the three-year intensive study and earlier monitoring efforts suggest that the habitat diversity and species life history in combination confer a remarkable resiliency.

In addition, four future tasks are identified for consideration:

1. Periodically check/re-census the four dune colonies that seem most vulnerable to extirpation in recent years based on their low numbers and marginal recruitment habitat (Pathfinder North and South, Bear Mountain East Outlier, and Bear Mountain Side Valley; e.g., every five years).
2. Periodically recensus the four major dune colonies (Bear Mountain East, Bear Mountain West, Bradley Peak, and Junk Hill Main) with the longest record of census data, particularly in years of climate shifts and extremes. If there is a decline of greater than 35%, repeat the census at least two consecutive years.
3. The four dune colonies in the West Junk Hill series appear to be a textbook set of succession studies. Any re-census in this area would ideally be done for all four at once, to test the hypothesis that population numbers will follow the wind and shift downwind (upslope).
4. Initiate demographic monitoring concurrent with seedling establishment to determine mean and maximum longevity, and produce robust transition matrices.
5. Make visits in late summer or fall to gauge livestock grazing and consider any separate monitoring needs.

The monitoring of *Penstemon haydenii* during a prolonged drought has tempered the premises behind setting numeric recovery thresholds for successional species. It is hypothesized that the fluctuations documented within the monitoring period represent the key fluxes that set the course of inter-drought trends for *P. haydenii*, including episodic germination, ensuing establishment, and flowering. The fluctuations also appear to differ by habitat including, but not limited to slope steepness, aspect, and wind direction. The extent and diversity of habitat, and evident destabilization of much habitat during the monitoring period, confer resiliency and provides a framework for hypothesizing that *P. haydenii* will persist at approximately current population sizes given two consecutive years favorable for germination and establishment.

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