



Lemhi Penstemon Monitoring in Big Hole National Battlefield

2012 Annual Report

Natural Resource Data Series NPS/UCBN/NRTR—2013/733



ON THE COVER

Big Hole National Battlefield staff person surveying for Lemhi Penstemon (*Penstemon lemhiensis*) on the Horse Pasture overlooking the Big Hole River and Nez Perce encampment.

Photograph courtesy of National Park Service

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on an established, peer-reviewed methodology (Stucki et al. 2013) and a forthcoming protocol (Stucki et al. *forthcoming*) and were analyzed and interpreted within the guidelines of the manuscript and protocol.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

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Abstract

Lemhi penstemon (*Penstemon lemhiensis*) is a rare regional endemic forb found only in a single county in Idaho and in four counties in Montana, including Beaverhead County where Big Hole National Battlefield (BIHO) is located. The species is thought to be at risk as a result of habitat loss and altered fire regimes (Stucki et al. 2013). Monitoring of *P. lemhiensis* in the Battlefield began in 2007 with an incomplete walking census performed partly by student volunteers that identified two subpopulations on the Howitzer Hill and the Horse Pasture hillslope. This information was used to guide development of a prototype sampling design, which was implemented and modified during field work in 2009-2011 (Stucki and Rodhouse 2009, Stucki et al. 2013). A third smaller subpopulation was discovered in 2011 near the Battlefield Visitor Center and has been incorporated into the monitoring program. This report documents results from a 2012 survey in which methods established during the previous three years involving a large, spatially-extensive sample ($n=299$) of 50 m x 2 m belt transects was used to provide a fourth estimate of population size, establishing an initial description of year-to-year variation and trend. Additionally, a new intensive survey methodology involving forty-two 1 m x 2 m permanent plots was also implemented to augment existing efforts and to provide the Battlefield staff with better information about the relationship between prescribed fire, microsite habitat, and regeneration. A monitoring protocol is now being developed that will support long-term monitoring using both the spatially extensive methods that provide for population estimation and the intensive methods that provide precise information on habitat characteristics and plant density, regeneration, and mortality at fine spatial scales (Stucki et al. *in preparation*). A prescribed fire program is planned for the Battlefield and this new protocol will help ensure that both short-term management questions and long-term ecological questions can be answered.

Big Hole National Battlefield is home to the largest known population of *P. lemhiensis*, with estimates ranging from 1,362 to 2,973 established plants (excluding seedlings) over the study period beginning in 2009 (Stucki et al. 2013). In 2012, based on a spatially-extensive sample of 299 belt transects placed at random locations drawn from a spatially-balanced sampling algorithm (i.e., Generalized Random Tessellation Stratified [GRTS]), the population of established plants was estimated to be 2,424 (95% confidence interval 1,838-3,010), down slightly from the 2011 estimate but within the 2011 margin of error. From these extensive plot data, mean density of established plants per m^2 was estimated to be 0.007 (95% confidence interval 0.005-0.009), an indication of just how sparsely distributed the species is across the hillslopes of the Battlefield. Mean number of rosettes per plant, a measure of plant age, was 4.6 (95% confidence interval 4.1-5.2). Mean number of inflorescences per plant, a measure of plant reproductive vigor, was 0.34 (95% confidence interval 0.24-0.51). The mean number of rosettes is higher and the mean number of inflorescences is lower than what has been reported for other populations (Stucki et al. 2013). In 2012, 42 new permanent plots were established for purposes of intensive monitoring. Permanent plots were placed at known patches of *P. lemhiensis* associated with the spatially-balanced random plot locations visited during the 2011 survey. From these intensive plot data, mean density of established plants per m^2 was estimated to be 1.5 (95% confidence interval 1.1-2.3). Mean number of rosettes per plant was 4.5 (95% confidence interval 3.7-5.5). Mean number of inflorescences per plant was 0.60 (95% confidence interval 0.4-1.0). Mean number of seedlings per m^2 , a measure of reproductive success, was 0.5 (95% confidence interval 0.2-1.4). These 42 plots represent a range of microsite conditions, with %

cover of exposed bare mineral soil in plots ranging from 3% to 65%, and vegetation and litter cover combined ranging from 18% to 94%. The number of seedlings counted in these 42 plots in 2012 covaried negatively with vegetation cover. Using negative binomial regression which accounts for overdispersion of seedling counts, we estimated that for each 1-standard deviation (15%) increase in the combined cover of litter, graminoids, and forbs, the expected seedling count for 2012 declined on average by 30% (95% confidence interval 13% to 68%). This provides preliminary evidence in support of our working hypothesis that Lemhi penstemon requires open microsites for successful germination and may be prone to population decline in the absence of fire or other periodic disturbance events. Unfortunately, spotted knapweed (*Centaurea stoebe*) is increasing across the hillslopes. Since 2009, we have documented an increase in the estimated number of knapweed plants from the spatially-extensive plot data from 243 to 17,395 plants, although only 1 knapweed plant was found in one of the 42 intensive study plots in 2012. The apparent explosion of the knapweed population across the hillslopes represents a serious threat to the long-term persistence of Lemhi penstemon and to the overall ecological integrity of the hillslope plant community.

Acknowledgments

This project could not have been developed and sustained without the strong support of Big Hole National Battlefield and Nez Perce National Historic Park superintendents and resource staff. Housing and logistical support was provided by Battlefield staff. Field support was provided by Jimmer Stevenson, Mandi Wick, Leslie Lula, Bessie Blackeagle, Jayden Hudson, Jason Lyon, Jannis Jocius, Heidi Becker, Kristen Tiede, and Dan Esposito. Gordon Dicus provided excellent data management support.

Introduction

Lemhi penstemon (*Penstemon lemhiensis* (Keck) Keck & Cronq.) is a rare regional endemic forb found only in a single county in Idaho and four counties in Montana, including Beaverhead County where Big Hole National Battlefield (BIHO) is located (Stucki et al. 2013). There are approximately 191 reported occurrences of Lemhi penstemon, with 102 in Idaho and 89 in Montana (Heidel and Shelly 2001). Based on past surveys, the average population size is small, and NatureServe reports global abundance of approximately 3,000 – 10,000 individuals, and assigned a global ranking for the species of vulnerable (G3; NatureServe 2010). There are three large populations reported to contain over 300 individuals each and half of all other occurrences have populations made up of 30 plants or less (Elzinga 1997, NatureServe 2010, Stucki et al. 2013). The population at BIHO was included among the three core populations noted in the species conservation assessment (Elzinga 1997) and was suspected of containing more individuals than any other population (Elzinga 1997, Heidel and Shelly 2001). However, no formal assessment of the population size in the Battlefield had been attempted prior to National Park Service monitoring initiated in 2009 (Stucki et al. 2013).

Monitoring of *P. lemhiensis* in the Battlefield began in 2007 with an incomplete walking census performed partly by student volunteers that identified two subpopulations on the Howitzer Hill and the Horse Pasture hillslope. This information was used to guide development of a prototype sampling design, which was implemented and modified during field work in 2009-2011 (Stucki and Rodhouse 2009, Stucki et al. 2013). A third smaller subpopulation was discovered in 2011 near the Battlefield Visitor Center and has been incorporated into the monitoring program as well. Population estimates from 2009-2011 ranged from 1,362 to 2,973 (Stucki et al. 2013), and clearly established that the population at BIHO is the largest known population and globally significant from the perspective of Lemhi penstemon conservation.

This report documents results from a 2012 survey in which methods established during the previous three years involving a large, spatially-extensive sample ($n=299$) of 50 m x 2 m belt transects was used to provide a fourth estimate of population size, establishing an initial description of year-to-year variation and trend. Additionally, a new intensive survey methodology involving 1 m x 2 m permanent plots was also implemented to augment existing efforts and to provide the Battlefield staff with better information about the relationship between prescribed fire, bare soil microsite habitat, and regeneration. A monitoring protocol is now being developed that will support long-term monitoring using both the spatially extensive methods that provide for population estimation and the intensive methods that provide precise information on habitat characteristics and plant density, regeneration, and mortality at fine spatial scales (Stucki et al. *in preparation*). A prescribed fire program is planned for the Battlefield and this new protocol will help ensure that both short-term management questions and long-term ecological questions can be answered. The results presented here, coupled with previous reports from Stucki and Rodhouse (2009) and Stucki et al. (2013) provide a robust baseline of information for long-term monitoring.

Lemhi penstemon is thought to be at risk primarily as a result of habitat loss and altered fire regimes, and competition from the non-native invasive forb spotted knapweed (*Centaurea stoebe*; Elzinga 1997, Heidel and Shelly 2001, Stucki et al. 2013). In particular, Lemhi penstemon is believed to require bare-soil microsites for germination, and in the absence of fire,

other vegetation may occupy these potential germination sites over time. Competition for resources may be a more general source of stress in the absence of fire and when spotted knapweed infestations are particularly severe. Within BIHO specifically, risks to the species include an increasing population of spotted knapweed and lack of fire (Stucki et al. 2013). Park operations, including weed and vegetation management, also pose a risk. The core of the BIHO population is on the Howitzer Hill and Horse Pasture hillslopes (Figure 1) where park activities such as the removal of lodgepole pine saplings and the use of prescribed fire has historically occurred. This raises important management questions about the impacts of these kinds of activities on the long-term persistence of Lemhi penstemon in the Battlefield. Stucki et al. (2013) noted that penstemon regeneration in the Battlefield may be low, possibly resulting from lack of fire. Also, the Battlefield staff has initiated plans for a prescribed fire program on the hillslopes in order to maintain the historic look and feel of the Battlefield (Stucki et al. 2013). It is hoped that fire will simultaneously maintain the open slopes characteristic of the Battlefield during the time of the 1877 battle and benefit Lemhi penstemon population persistence. Accordingly, in an effort to support both short-term management decision-making and long-term NPS Inventory and Monitoring Program goals (Fancy et al. 2009), the objectives of Lemhi penstemon monitoring in BIHO are to:

1. Provide annual estimates of the total number of established (excluding seedlings) Lemhi penstemon plants in Big Hole National Battlefield from spatially-extensive plot surveys in the Horse Pasture and Howitzer Hill and from an annual census of penstemon plants in the Visitor Center subpopulation.
2. Provide annual estimates of the average number of Lemhi penstemon basal rosettes and flowering stems (inflorescences) per plant in Big Hole National Battlefield from spatially-extensive plot surveys and from the annual census of the Visitor Center subpopulation.
3. Provide annual estimates of the density of all Lemhi penstemon plants, including seedlings, and the attributes of age (number of rosettes) and reproductive vigor (number of inflorescences) of each penstemon plant within permanent intensive plots in Big Hole National Battlefield.
4. Provide annual estimates of bare ground and vegetation cover within permanent intensive plots in Big Hole National Battlefield.
5. Provide annual estimates of the total number of spotted knapweed plants within the Horse Pasture and Howitzer Hill monitoring areas from the spatially-extensive plot surveys.
6. Provide annual estimates of the density of spotted knapweed plants within permanent intensive plots in Big Hole National Battlefield.

Study Species

Lemhi penstemon is a robust and showy blue-flowering perennial penstemon (family Plantaginaceae) that can grow to a height of 70 cm (Hitchcock and Cronquist 1973). Plants consist of one or many basal rosettes of leaves growing from a branching underground caudex (Hitchcock et al. 1959). Inflorescences are produced on stems that arise from the center of the

rosettes, allowing for a single plant with multiple rosettes to also have multiple flowering stems. Lemhi penstemon reproduces only through seed and is a near-obligate outcrosser, which requires cross-pollination to reproduce (Ramstetter 1983, Heidel and Shelly 2001). The primary pollinator for the species is a vespid wasp (*Pseudomasaris vespoides*; Ramstetter 1983). The species does not have any specialized morphological adaptations or known animal hosts for seed dispersal, and the seeds fall to the ground within 1 m of the base of the parent plant after the seed capsules dehisce and open in late summer (Heidel and Shelly 2001). Such a low dispersal capacity may partially explain its restricted distribution, and likely contributes to its overall rarity. Seeds of the species are reportedly viable for at least eight years and considerable year-to-year variability in germination associated with variable winter and spring precipitation patterns has also been reported (Heidel and Shelly 2001).

Occurring in early- to mid-successional habitats, Lemhi penstemon is usually found in association with big sagebrush (*Artemisia tridentata*) on steep, sparsely vegetated slopes (Heidel and Shelly 2001) but is also found in other habitat types, including edges and open spaces within coniferous forest (Ramstetter 1983, Elzinga 1997). Road cuts also provide habitat for small populations, probably because of the species' need for bare soil microsites for germination (Elzinga 1997). Competition from other vegetation due to natural succession, including grasses, shrubs, and invasive plants, such as spotted knapweed, appear to have negative consequences on Lemhi penstemon populations (Ramstetter 1983, Elzinga 1997, Heidel and Shelly 2001). Heidel and Shelly (2001) provided evidence from a small experiment that the species might respond favorably to prescribed fire, presumably because of reduced litter accumulation and competition from other plants.

Study Site

Elevation in BIHO ranges from 1,913 m to 2,134 m, and the climate is semi-arid with a thirty-year precipitation average of approximately 30 cm (weather station 249067, Western Regional Climate Center, <http://www.wrcc.dri.edu/>). The 265-hectare Battlefield includes two steep southeast facing slopes, Horse Pasture and Howitzer Hill (Figure 1), that overlook the river and whose plant communities are composed of lodgepole pine (*Pinus contorta*) forest and sagebrush steppe dominated by mountain big sagebrush (*Artemisia tridentata vaseyana*), perennial bunchgrasses including bluebunch wheatgrass (*Pseudoeregeneria spicata*) and Idaho fescue (*Festuca idahoensis*), and perennial forbs including arrowleaf balsamroot (*Balsamorhiza sagittata*), sulphur buckwheat (*Eriogonum umbellatum*), and Lemhi penstemon. Lemhi penstemon subpopulations occur within the Horse Pasture and Howitzer Hill. Ancillary searches for Lemhi penstemon in 2011 resulted in the discovery of a small subpopulation (Figure 1) below the visitor center that is likely the subpopulation described by Ramstetter (1983).



Lemhi Penstemon Monitoring Areas

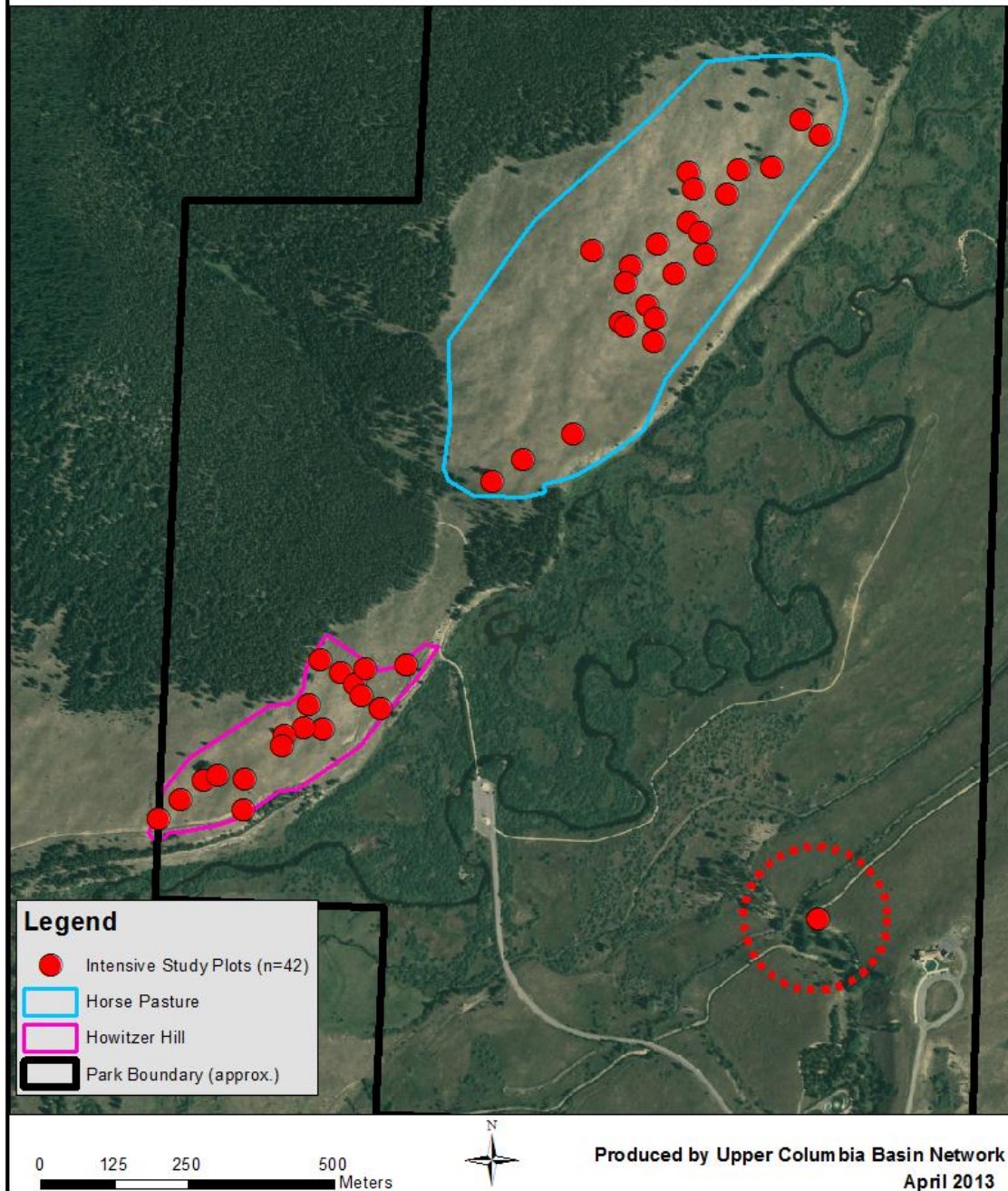


Figure 1. The location of the Howitzer Hill and Horse Pasture hillslope sampling frames and the Visitor Center subpopulation (dashed circle). The 42 permanent intensive study plots are shown as solid red circles.

Methods

Spatially-extensive surveys

We used pilot data from the 2007 survey to develop convex polygons within the Horse Pasture and Howitzer Hill using a Geographic Information System (GIS) from which to draw spatially-extensive samples of point locations to locate plots. In 2012, target sample sizes were 100 in the Howitzer Hill and 200 in the Horse Pasture. One plot was overlooked in the Horse Pasture, resulting in an overall realized sample size of 299 rather than 300. The 2012 sample was drawn using the GRTS algorithm for spatially-balanced sampling (Stevens and Olsen 2004). We surveyed for mature Lemhi penstemon plants in the Battlefield during late June when the species was in flower, or nearly so. Lemhi penstemon plants were considered mature when one or more fully developed basal rosette(s) of leaves were present. Seedlings were excluded from spatially-extensive surveys in order to reduce observer bias associated with imperfect detection. Plots were 100 m² belt transects 50-m long and 2-m wide, modified from an approach described by Lesica (1987). Plots originated at the randomly-selected point locations, and were oriented perpendicular to the slope in a northeasterly direction. Staff searched for penstemon and spotted knapweed plants in plots by walking down the center of the plots, using a 2-m long PVC pole to determine plot boundaries.

Intensive surveys

Intensive plots were established in 2012 at 42 locations based on the 2011 survey following the spatially-balanced ordered list of GRTS locations. The first 41 plots were selected in consecutive order from among the 2011 spatially-balanced (GRTS) ordered list of those plots where Lemhi penstemon plants were found in 2011. This resulted in 18 plots in the Howitzer Hill and 23 plots in the Horse Pasture. A 42nd permanent plot was non-randomly placed in the center of the Visitor Center subpopulation on a steep southwest facing bank of the irrigation canal. For the permanent plots in the Howitzer Hill and Horse Pasture, plots did not remain at the original 2011 plot origin, but rather were placed along the transect so that at least one Lemhi penstemon plant was located inside the plot. Plot dimensions were 1 m × 2 m plots, oriented with the long axis (2 m) oriented perpendicular to the slope. Plots were divided into two 1 m² subplots, a left (L) subplot and a right (R) subplot (see Figure 2). Intensive plots were then monumented with a 5/8" × 10" piece of rebar at the two lower/downslope corners and the location of the lower left (southeast) corner was recorded using GPS. Within intensive plots, we counted all mature Lemhi penstemon plants rooted in plot boundaries, as well as the number of basal rosettes and inflorescences on each plant. We also counted Lemhi penstemon seedlings within the intensive plot. We counted all spotted knapweed plants within the plot. We then estimated ground cover within plots using a point-intercept frame with 91 intersection points within the 2 m² plot (Figure 3). The intercept counts for each physiognomic ground cover category (bare ground, litter, shrub, forb, graminoid, Lemhi penstemon, tree, rock, soil crusts, wood) were totaled, averaged, and then converted to a percentage for each intensive plot. Photographs were also taken of each plot for later reference.

Intensive Plot Design penstemon and knapweed counts

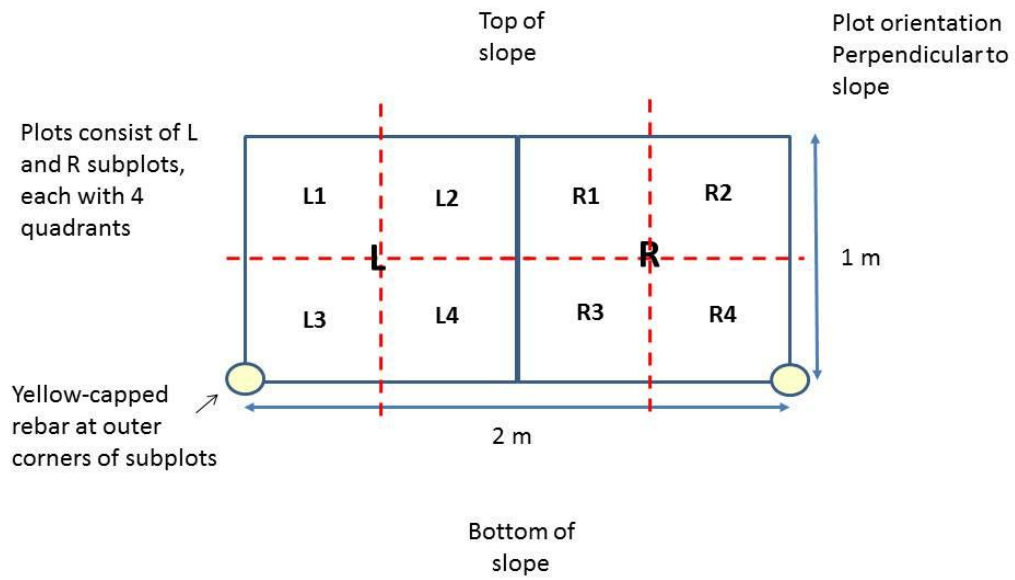


Figure 2. The diagram for counting Lemhi penstemon and knapweed plants in the 42 permanent intensive study plots.

Intensive Plot Design Point-intercept Cover Estimation

Plots consist of L and R subplots, each with 42 intercepts (7 extra shared between L and R) and a total of 91 intercepts

Grid of monofilament for point-intercept cover estimation

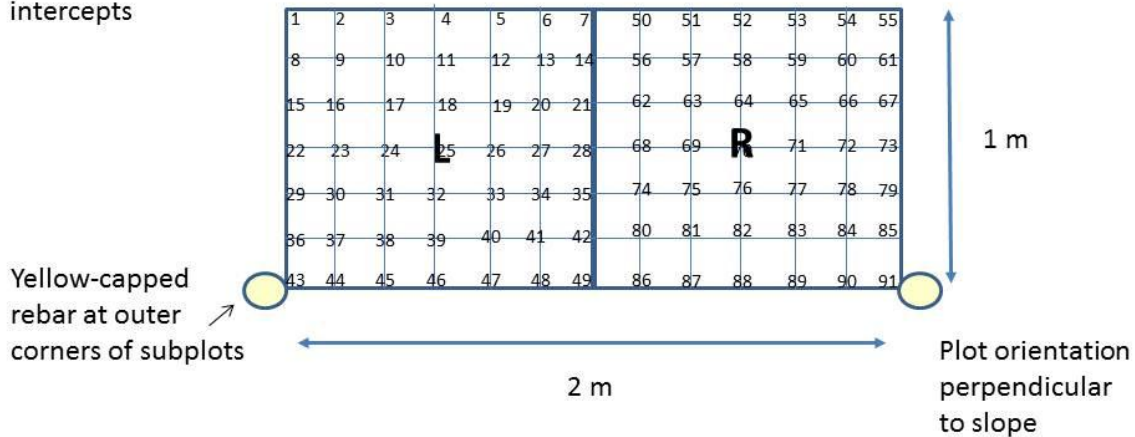


Figure 3. The diagram for estimating ground cover in intensive study plots with a point-intercept frame.

Data Analysis

We used the *spsurvey* library in the R statistical environment for drawing GRTS samples and for estimating population sizes and densities and their 95% confidence intervals (Kincaid and Olsen 2012). We used the “local” GRTS variance estimator, which is more efficient than the usual Horvitz-Thompson variance estimator (Stevens and Olsen 2004). We estimated 95% confidence intervals for mean rosettes and inflorescences per plant with bias-corrected accelerated percentile bootstrap methods using the *boot* library in R (Crawley 2007:322, Cauty and Ripley 2011). We used negative binomial regression with the *MASS* library in R, which accounts for overdispersion in count data (Venables and Ripley 2002), to provide a preliminary estimate of the relationship between ground cover and seedling counts in intensive plots.

Results

Spatially Extensive Plots and Visitor Center Census

The estimated total number of mature Lemhi penstemon plants across both the Howitzer Hill and Horse Pasture sampling frames based on the survey of 299 extensive plots (the 100 m² belt transects) was 2,424 ($n=299$; 95% confidence interval 1,838-3,010). This was within the margin of error of the 2011 estimate, and provides evidence for a stable or slightly increasing trend since 2009 (Figure 4). From these extensive plot data, mean density of established plants per m² was estimated to be 0.007 (95% confidence interval 0.005-0.009), an indication of just how sparsely distributed the species is across the hillslopes of the Battlefield. Mean number of rosettes per plant, a measure of plant age, was 4.6 (95% confidence interval 4.1-5.2). Mean number of inflorescences per plant, a measure of plant reproductive vigor, was 0.34 (95% confidence interval 0.24-0.51). We counted an additional 42 Lemhi penstemon plants during the census of the Visitor Center population in 2012, up from 33 plants in 2011. Within this small subpopulation, the number of rosettes per plant varied from 1 to 23 and the mean number of rosettes per plant was 5.0. The number of inflorescences per plant varied from 0 to 3, averaging 0.24.

Table 1 provides summary results for each subpopulation. In the Howitzer Hill, one plot was overlooked during sampling, resulting in a realized sample of 99 instead of 100 plots. A total of 120 Lemhi penstemon plants were counted, occurring in 24 of 99 plots (24%). Mature plant counts per 100 m² plot ranged from 0 to 27. In the Horse Pasture sampling frame, we completed 200 extensive survey plots and counted a total of 125 plants in 46 of 200 plots (23%). Mature Lemhi penstemon plant counts per 100 m² plot ranged from 0 to 11 within the Horse Pasture sampling frame.

A total of 1,411 knapweed plants were found within extensive plots in 2012. We counted 195 spotted knapweed plants within extensive plots in the Howitzer Hill sampling frame and 1,216 plants within plots in the Horse Pasture sampling frame. The frequency of occurrence of knapweed (i.e., the percentage of plots with knapweed) in the Howitzer Hill in 2012 was 29%, up from 25% in 2011. In the Horse Pasture, frequency of occurrence in 2012 was 22%, up from 2% in 2011 and 0% in 2009 and 2010. Counts of spotted knapweed plants per plot ranged from 0 to 120. The mean number of spotted knapweed plants per m² in the Howitzer Hill sampling frame was 0.02. The mean number of spotted knapweed plants per m² within the Horse Pasture was 0.06. The combined population estimate for spotted knapweed plants within the two sampling frames is 17,395 ($n=299$; 95% confidence interval 13,569-21,222). This represents a substantial and alarming increase over estimates from previous years (Figure 4).

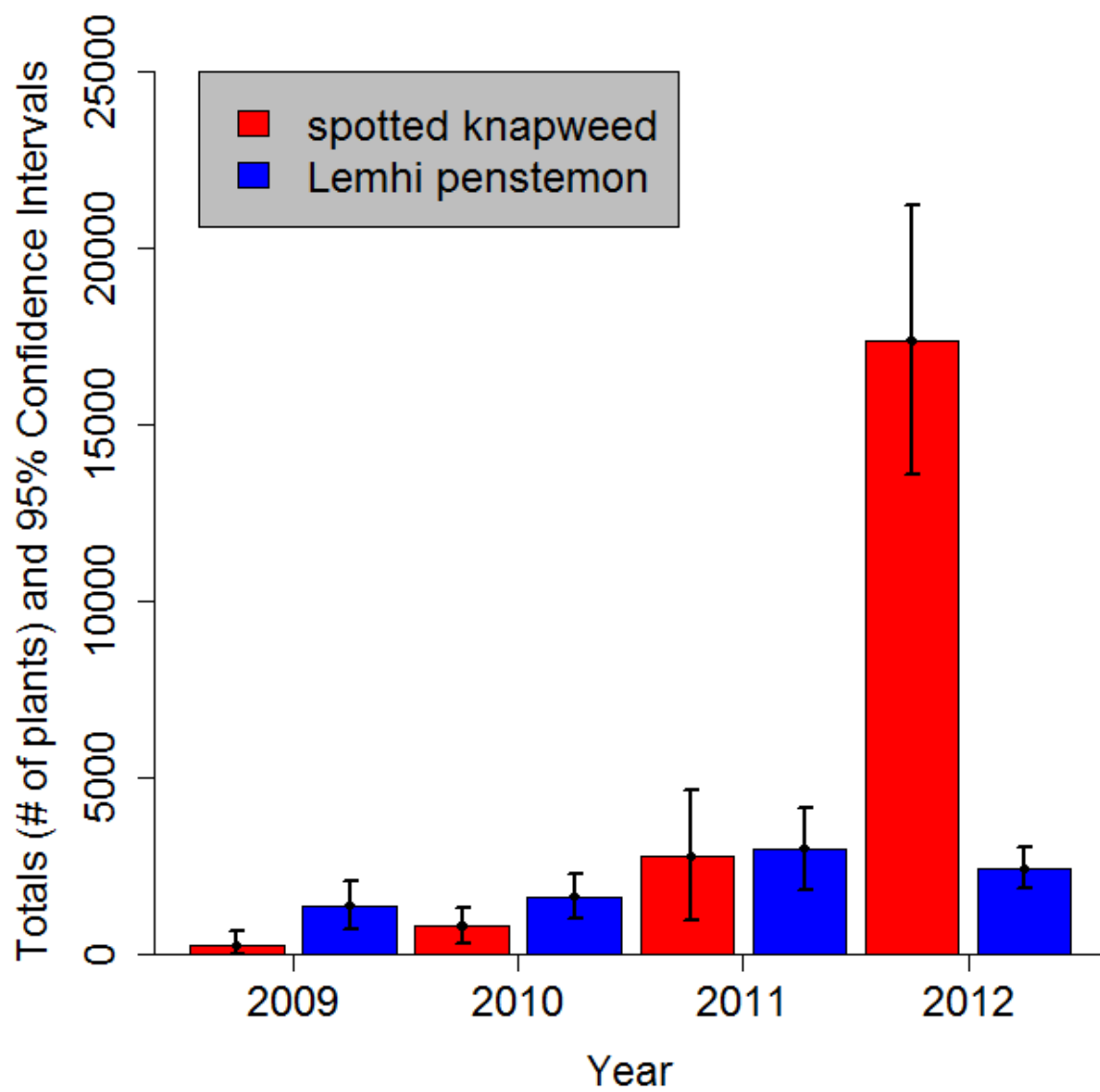


Figure 4. Population estimates for spotted knapweed and established Lemhi penstemon plants in the Howitzer Hill and Horse Pasture hillslope study area of BIHO, 2009-2012.

Table 1. Results from 2009-2012 surveys for Lemhi penstemon in the spatially-extensive 100 m² monitoring plots for the Howitzer Hill and Horse Pasture. Standard deviations are provided in parentheses. The Visitor Center census results are included for reference.

Subpopulation	Year	Plots	Plants	Frequency	$\bar{x}_{\text{Plants per m}^2}$	$\bar{x}_{\text{Rosettes}}$	$\bar{x}_{\text{Inflorescences}}$
Howitzer Hill	2009	75	61	0.25	0.0081(0.024)	3.7(3.1)	1.0(1.3)
	2010	149	76	0.19	0.0051(0.015)	4.2(2.6)	0.5(0.8)
	2011	60	97	0.30	0.0162(0.077)	2.7(2.7)	1.0(1.5)
	2012	99	120	0.24	0.0121(0.037)	4.7(4.8)	0.3(0.9)
Horse Pasture	2009	73	24	0.12	0.0033(0.012)	3.4(2.0)	0.6(0.6)
	2010	150	65	0.18	0.0043(0.014)	3.5(2.7)	0.4(0.6)
	2011	250	184	0.20	0.0074(0.025)	2.7(2.1)	1.2(1.5)
	2012	200	125	0.23	0.0063(0.015)	4.6(4.3)	0.4(1.2)
Visitor Center	2011	-	33	-	-	4.7(5.4)	1.9(3.8)
	2012	-	42	-	-	5.0(5.3)	0.2(0.7)

Intensive Plots

Eighteen permanent intensive study plots were installed on the Howitzer Hill, and 23 were installed on the Horse Pasture. A 42nd plot was installed on the cut bank of the irrigation canal in the center of the Visitor Center subpopulation. Plot counts of established Lemhi penstemon ranged from 1 to 21 plants. A total of 36 plants were included in Howitzer Hill plots, and 73 plants were included in Horse Pasture plots. Fourteen plants were included in the Visitor Center plot. From these 42 intensive plots, mean density of established plants per m² was estimated to be 1.5 (95% confidence interval 1.1-2.3). The mean number of rosettes per plant was 4.5 (95% confidence interval 3.7-5.5). Mean number of inflorescences per plant was 0.60 (95% confidence interval 0.4-1.0). Only 4 inflorescences were noted as being browsed, 3 in one plot and 1 in another plot in the Howitzer Hill. Mean number of seedlings per m², a measure of reproductive success, was 0.5 (95% confidence interval 0.2-1.4). Only 10 plots (23%) contained any seedlings. These 42 plots represent a range of microsite conditions, with % cover of exposed bare mineral soil in plots ranging from 3% to 65%, and vegetation and litter cover combined ranging from 18% to 94%. The number of seedlings counted in these 42 plots in 2012 covaried negatively with vegetation cover (Figure 5). Using negative binomial regression which accounts for overdispersion of seedling counts, we estimated that for each 1-standard deviation (15%) increase in the combined cover of litter, graminoids, and forbs, the expected seedling count for 2012 declined on average by 30% (95% confidence interval 13% to 68%). This provides preliminary evidence in support of our working hypothesis that Lemhi penstemon requires open microsities for successful germination and may be prone to population decline in the absence of

fire or other periodic disturbance events. Only 1 knapweed plant was found in one of the 42 intensive study plots in 2012.

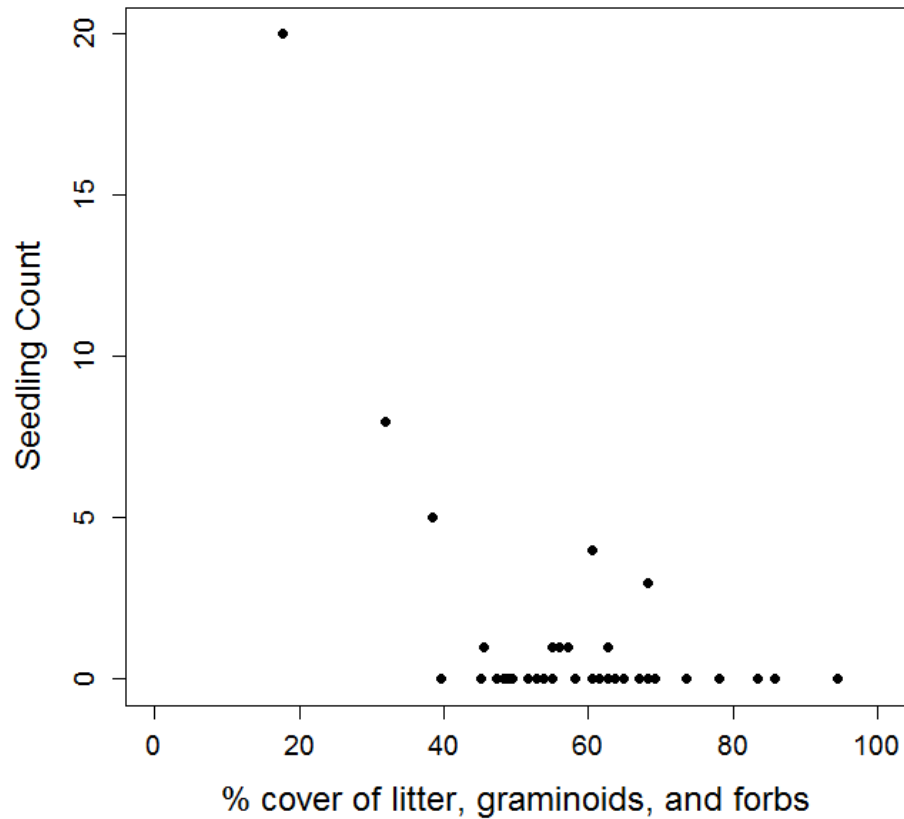


Figure 5. The spread of seedling counts from the 42 intensive study plots along the vegetation cover gradient represented by these plots. Litter, graminoid, and forbs are thought to prevent successful Lemhi penstemon germination by occupying otherwise bare soil microsites. They may also over-utilize valuable resources required by penstemon, including sunlight and soil nutrients.

Discussion

The Lemhi penstemon population appears to be on a stable or slightly increasing trend. In 2012, the population estimate was estimated with better precision than previous years, and 2012 confidence intervals fell within the larger population estimate from 2011, suggesting no statistically significant population change over the last 2 years (Figure 2). Our 2012 rosette and inflorescence counts were similar and consistent among the 3 subpopulations and surveys (i.e., extensive, intensive, and Visitor Center census), and indicate that, overall, the population appears to be dominated by older plants with multiple rosettes greater than those reported in other populations and lower flowering rates than those reported in other populations (Elzinga 1997, Stucki et al. 2013). The flowering rate in 2012 was substantially lower than estimates from 2011 as well (Table 1). Seedlings have generally been hard to find when searched for in BIHO (Stucki et al. 2013). In 2012, only 23% of the intensive study plots had seedlings, and all but the Visitor Center plot had <10 seedlings. The Visitor Center plot is noteworthy for the large numbers of seedlings found below one particular plant in 2012 (20 seedlings) and also in 2011 (47 seedlings; Stucki et al. 2013). One potential explanation for the apparent low rate of regeneration is competition from other vegetation (Elzinga 1997, Heidel and Shelly 2001, Stucki et al. 2013). We found preliminary evidence in support of this when we estimated the relationship between vegetation cover and seedling counts. Another potential explanation, browsing of inflorescences by elk or other animals, has also been suggested (Elzinga 1997, Heidel and Shelly 2001), although we have not found evidence for this during the June study period. We note that it is possible that browsing occurs later in the summer and interrupts seed maturation and dehiscence. Because Lemhi penstemon are so widely scattered across the hillslopes and are often camouflaged among the other plants, including large-stature bunchgrasses, forbs, and shrubs, it is unlikely that the species is preferentially targeted by herbivores. We hypothesize that the combination of varying climate and weather patterns and local site ground cover will emerge as the biggest drivers of variation in Lemhi penstemon regeneration and overall population change over time. The emerging pattern of annual variation in flowering rate is suggestive of a climate and weather influence. Long-term monitoring combined with a careful implementation of the anticipated prescribed fire program in the park will enable us to investigate these factors more thoroughly. Unfortunately, the rapid increase in spotted knapweed is a grave concern to the park and represents another, potentially more imminent threat to the Lemhi penstemon population, and will complicate the park's management decisions.

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Appendix A

Table 2. The location of permanent plots established in 2012 for intensive study. New permanent ID numbers were assigned based on the order of plot UTM X coordinates resulting in an east-west order across the hillslopes. Hill refers to Howitzer Hill. Horse refers to Horse Pasture.

Subpopulation	2011 Plot ID	Permanent ID	UTMX	UTMY
Hill	261	1	292694	5057833
Hill	298	2	292731	5057865
Hill	289	3	292769	5057898
Hill	301	4	292794	5057907
Hill	310	5	292837	5057848
Hill	285	6	292841	5057900
Hill	287	7	292903	5057957
Hill	299	8	292908	5057976
Hill	279	9	292940	5057988
Hill	276	10	292950	5058028
Hill	320	11	292970	5058105
Hill	311	12	292973	5057985
Hill	307	13	293003	5058082
Hill	275	14	293027	5058062
Hill	280	15	293038	5058043
Hill	284	16	293045	5058088
Hill	296	17	293072	5058021
Hill	312	18	293116	5058095
Horse	144	19	293262	5058408
Horse	160	20	293315	5058445
Horse	139	21	293399	5058489
Horse	22	22	293432	5058801
Horse	106	23	293480	5058680
Horse	99	24	293489	5058747
Horse	115	25	293489	5058673
Horse	110	26	293499	5058775
Horse	51	27	293527	5058708
Horse	26	28	293538	5058646
Horse	138	29	293540	5058685
Horse	3	30	293544	5058814
Horse	23	31	293574	5058763
Horse	19	32	293598	5058850
Horse	88	33	293598	5058935
Horse	24	34	293606	5058907
Horse	67	35	293617	5058833
Horse	131	36	293625	5058795

Table 2 (continued). The location of permanent plots established in 2012 for intensive study. New permanent ID numbers were assigned based on the order of plot UTM X coordinates resulting in an east-west order across the hillslopes. Hill refers to Howitzer Hill. Horse refers to Horse Pasture.

Subpopulation	2011 Plot ID	Permanent ID	UTMX	UTMY
Horse	101	37	293663	5058899
Horse	69	38	293682	5058940
Horse	85	39	293740	5058945
Horse	25	40	293789	5059025
Horse	117	41	293823	5059000
VC	NA	42	293819	5057662

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