



Population Monitoring Protocol for Lemhi Penstemon (*Penstemon lemhiensis*) and Spotted Knapweed (*Centaurea stoebe*) in Big Hole National Battlefield *Narrative Version 1.0*

Natural Resource Report NPS/UCBN/NRR—2018/1639



ON THE COVER

(Left to Right)

Observer searching for Lemhi penstemon, Big Hole National Battlefield.
Photograph by Jannis Jocius, NPS.

Lemhi penstemon on hillslope overlooking Big Hole National Battlefield.
Photograph by Tom Rodhouse, NPS.

Lemhi penstemon flower with pollen wasp (*Pseudomasaris vespoides*), Big Hole National Battlefield.
Photograph by Devin Stucki, NPS.

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Narrative Change History

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1. Version numbers increase incrementally by tenths (e.g., version 1.1, version 1.2, ...etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.
2. Notify the UCBN Project Lead and Data Manager of any changes to the Protocol Narrative or SOPs so that the new version number can be incorporated in the Metadata of the project database.
3. Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOPs. A list will be maintained in the protocol revision SOP.

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Executive Summary

The mission of the National Park Service (NPS) is “to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999). Through the Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring (I&M) networks, each tasked with designing and implementing a “vital signs” monitoring program for its respective constituent parks (Fancy et al. 2009).

The Upper Columbia Basin Network (UCBN) has identified priority park vital signs, indicators of ecosystem health that represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales (Garrett et al. 2007). Our intent is to develop a balanced and integrated suite of vital signs that meets the needs of current park management, and addresses unanticipated management questions in the future. Invasive weeds, including spotted knapweed (*Centaurea stoebe*), and rare and peripheral native populations, including Lemhi penstemon (*Penstemon lemhiensis*), were identified as important vital signs for the Network (Garrett et al. 2007). This document describes the details for implementing and sustaining long-term monitoring of Lemhi penstemon and spotted knapweed populations in Big Hole National Battlefield (BIHO). It is organized into a summary narrative and detailed standard operating procedures (UCBN-NPS 2018), following guidelines outlined by Oakley et al. (2003).

Lemhi penstemon was identified as a vital sign for BIHO because it is a rare regional endemic forb thought to be at risk of extinction from habitat loss stemming from weed invasion and altered fire regimes, and, over a longer time frame, from changes in climate and extreme weather (e.g., drought) patterns. The Lemhi penstemon species inventory and pilot monitoring conducted in the Battlefield by the NPS has provided clear evidence that BIHO supports the largest reported population of Lemhi penstemon anywhere within its restricted range, making the park globally significant in terms of Lemhi penstemon conservation. Unfortunately this early survey effort has also established that spotted knapweed invasion poses a serious threat.

Lemhi penstemon is thought to be dependent on early-seral, bare-soil microsites for successful seed germination and therefore possibly easily lost from ecosystems in which fire or other soil-disturbing processes are interrupted. This dependency creates both an opportunity and a challenge for aligning Battlefield cultural and natural resource management. Prescribed fire has been used in the past to maintain the open hillslopes of the Battlefield cultural landscape. These hillslopes host the core of the Lemhi penstemon population but, in the absence of fire, they are also prone to encroachment from the adjacent lodgepole pine forest and densification of native sagebrush and bunchgrasses. More recently, spotted knapweed has heavily infested some portions of these hillslopes, creating an additional threat to Lemhi penstemon persistence and to the historical and ecological integrity of the Battlefield in general. This infestation complicates the potential utility of using prescribed fire in the future if this invader also responds vigorously to fire.

Monitoring the Lemhi penstemon and spotted knapweed populations in BIHO over time will provide information critical to effective Battlefield resource management decision-making. It also provides an important opportunity for NPS to contribute knowledge about biological conservation in protected-area cultural landscapes more generally. This is a targeted, hypothesis-driven monitoring program, closely integrated with Battlefield management. The fundamental working hypothesis is that Lemhi penstemon population persistence in the Battlefield is dependent upon recruitment of germinants, and increased survival and reproductive vigor of established plants in bare-soil microsites where sunlight, water, and soil nutrients are available in adequate supply. The corollary is that encroachment of lodgepole pine and increasing density of native steppe vegetation and spotted knapweed will reduce the number and size of these microsites and cause a decline in the penstemon population through resource competition. When natural processes and Battlefield management activities, including fire, downslope soil movement, and herbicide application, create microsites and suppress competitive vegetation, we expect that the Lemhi penstemon population will respond with increased reproduction and survival. We have developed monitoring objectives and corresponding survey and analytical methods that will allow us to test these hypotheses. Both the monitoring itself and Battlefield management will be adaptive and incorporate knowledge about the ecological system as it is acquired through monitoring over time, reflected in updated versions of this protocol. There are several important sources of uncertainty that may obfuscate some of the clarity of information generated through monitoring. Most importantly, monitoring will be done against a complex backdrop of varying climatic processes. Initial results from the inventory and pilot monitoring suggest that fluctuations in precipitation and temperature patterns prior to and during the growing season may influence variation in spotted knapweed and Lemhi penstemon counts from year to year. Climate information from weather stations near the Battlefield will be used to account for some of this variation. Also, some of the mechanisms hypothesized to drive population change, such as competition among Lemhi penstemon and other vegetation for soil resources and sunlight, will not be measured directly. Rather, proxy measures of vegetation and bare soil cover will be used instead. In general, the design of this monitoring program reflects trade-offs between information content and logistical and financial costs; we believe the balance struck will satisfy both the objectives of the long-term monitoring program and the information needs of park resource managers.

Acknowledgments

We thank the staff of Big Hole National Battlefield and Nez Perce National Historical Park for assisting with inventory and monitoring activities, and for assisting with the development of monitoring and management objectives. We thank Steve Shelly, US Forest Service, for sharing with us his considerable knowledge of and experience with Lemhi penstemon. Numerous NPS, USFS, and cooperating University of Idaho and Oregon State University staff have assisted with fieldwork over many years.

List of Terms

Established plant	A plant that has developed one or more basal rosettes of leaves and a thickened caudex; leaves usually longer than 3 cm; most second year plants have become established.
Seedling	A recently germinated plant consisting of a pair of “seed” leaves and one to two sets of “true” leaves, leaves usually less than 2 cm long; plant not yet developing rosette of leaves or thickened caudex.
Sampling Frame	Large polygons encompassing Battlefield hillslopes that each contain a subpopulation of Lemhi penstemon and spotted knapweed within the Battlefield. The core of each subpopulation is concentrated along the center axes of the frames, which are steepest and provide the most bare soil microsites, and the frames are of sufficient size to capture potential spatial shifts in subpopulation distribution. The sample frames are a mapped representation of the target population, delineating the boundaries of monitoring effort and are used for drawing spatially-balanced random (GRTS) sampling locations each year.
Extensive Plot	The defined sampling unit of measurement (2 x 50 m) for counting established penstemon and knapweed plants to support population size estimates. Plot boundaries are framed temporarily by fixing a 50-m reel tape down the centerline from the origin to the end and using a 2-m long PVC rod to determine plot edges while searching for plants. The plot is anchored by a surveyor’s pin at the plot origin via GRTS UTM coordinates. The long axis of the plot is oriented perpendicular to the slope. These plots are not permanently marked, never revisited, and hillslope frames are re-sampled each year with independent GRTS draws.
Intensive Plot	The defined sampling unit of measurement (1 x 2 m) for counting Lemhi penstemon seedlings and established plants, and for recording the size (rosette counts) and live/dead status of established penstemon plants to support estimation of demographic vital rates. Plot corners are permanently marked with rebar and a PVC quadrat is used to temporarily delineate the quadrat during surveys. These plots are oriented perpendicular to the slope and are revisited each year.
Cultural Landscape	A geographic area (including both cultural and natural resources and the wildlife or domestic animals therein), associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values. There are four general types of cultural landscapes recognized by NPS, not mutually exclusive: historic sites, historic designed landscapes, historic vernacular landscapes, and ethnographic landscapes. Big Hole National Battlefield fits

the definitions of both historic sites and ethnographic landscapes, which contain a variety of natural and cultural resources that associated people (the Nez Perce, in this case) define as heritage resources. The camas meadow along the Big Hole River and the steppe vegetation of the Howitzer Hill and Horse Pasture where Lemhi penstemon grows are heritage resources.

Background and Objectives

This monitoring protocol consists of this protocol narrative and the following standard operating procedures (SOPs), available at <https://irma.nps.gov/DataStore/Reference/Profile/2253017>:

- SOP 1 – Preparation for the Field Season and Field Season Closeout
- SOP 2 – Training Field Personnel
- SOP 3 – Finding GPS Waypoints
- SOP 4 – Locating and Establishing Plots
- SOP 5 – Measuring Response Variables
- SOP 6 – Data Management
- SOP 7 – Data Analysis and Reporting
- SOP 8 – Protocol Revision History Log
- SOP 9 – Safety

Rationale for Monitoring Lemhi Penstemon and Spotted Knapweed in Big Hole National Battlefield

Lemhi penstemon (*Penstemon lemhiensis*) is a rare regional endemic forb found only in Lemhi County of eastern Idaho and four counties in western Montana, including Beaverhead County where Big Hole National Battlefield (BIHO) is located. To date only one published study (Stucki et al. 2013), a few unpublished reports describing the species' ecology prepared for state and federal agencies (e.g. Moseley et al. 1990, Elzinga 1997, Heidel and Shelly 2001, Rodhouse 2016), and an unpublished thesis (Ramstetter 1983), are available on the species ecology and conservation status.

Globally, there are 431 known and reported occurrences of Lemhi penstemon across its narrow endemic range, according to the Montana and Idaho state natural heritage programs. Based on past surveys, the average population size is believed to be small, and NatureServe reports global abundance of approximately 3,000-10,000 individuals, providing a global ranking for the species of vulnerable (G3; NatureServe 2014). There are three large populations reported to contain over 300 individuals each (Elzinga 1997, NatureServe 2014), while half of all other occurrences have populations made up of 30 plants or less (Elzinga 1997, NatureServe 2014). The population at BIHO has been included among the three core populations noted in the species conservation assessment (Elzinga 1997) and has been suspected of containing more individuals than any other population (Elzinga 1997, Heidel and Shelly 2001), although no formal assessment of the population size in the Battlefield had been attempted prior to our investigations. Results of inventory and pilot monitoring efforts from 2009-2013 show that the population of Lemhi penstemon at BIHO is the largest reported population, making BIHO globally significant from the perspective of Lemhi penstemon conservation (Rodhouse 2016, Rodhouse and Stucki 2013a, 2013b, Stucki and Rodhouse 2009, Stucki et al. 2013).

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

for seed 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. Park operations, including weed and vegetation management, also pose a risk. The core of the BIHO penstemon and knapweed populations are on two south facing hillslopes referred to as the Howitzer Hill and Horse Pasture (Figure 1) where park activities such as the removal of lodgepole pine saplings and the use of prescribed fire has historically occurred. Prescribed fire has been used in the past to maintain these open hillslopes that are integral to the Battlefield cultural landscape. These hillslopes host the core of the Lemhi penstemon population and are prone to encroachment from the adjacent lodgepole pine forest and densification of native sagebrush and bunchgrasses. Given that Lemhi penstemon is also thought to be dependent on fire-maintained bare-soil microsites, prescribed fire may be used as a means of achieving both cultural and natural resource management objectives. However, the extensive infestation of spotted knapweed in some portions of these hillslopes complicates the potential utility of prescribed fire if spotted knapweed also responds vigorously to fire. This complex decision-making environment underscores the importance of the focused, hypothesis-driven monitoring program outlined in this protocol.

Study Site

Big Hole National Battlefield is located in the upper Big Hole Valley of southwestern Montana (Figure 1), along the North Fork Big Hole River. Elevation in the battlefield ranges from 1913 m to 2134 m, and the climate is semi-arid with a thirty-year precipitation average of approximately 30 cm. BIHO is the site of an intense battle that occurred in August 1877 between the U.S. Army and members of the Nez Perce tribe. The Battle at Big Hole was one of several battles between the U.S. Army and the non-treaty Nez Perce during that summer and an estimated 70 to 80 Nez Perce and 31 soldiers and volunteers lost their lives in the 2-day battle. The Battlefield was recognized by Congress in 1883 and was administered by the War Department and later the U.S. Forest Service before becoming a unit of the NPS in 1936.

The NPS manages a 265-hectare area (654.8 acres) that includes two very steep southeast-facing slopes, the Horse Pasture and Howitzer Hill (Figure 1). They overlook the river and are composed of lodgepole pine (*Pinus contorta*) forest on the upper portions and open sagebrush steppe on the lower portions dominated by mountain big sagebrush (*Artemisia tridentata vaseyana*), perennial bunchgrasses including bluebunch wheatgrass (*Pseudoroegneria spicata*) and Idaho fescue (*Festuca idahoensis*), and perennial forbs including arrowleaf balsamroot (*Balsamorhiza sagittata*), sulphur buckwheat (*Eriogonum umbellatum*), and Lemhi penstemon. The low-lying areas of the battlefield are made up of a willow (*Salix* spp.) dominated floodplain along the river and includes wet meadows dominated by rushes (*Juncus* spp.), sedges (*Carex* spp.), and camas (*Camassia quamash*). These extant vegetation patterns, including the open and historically fire-maintained slopes where the core of the Lemhi penstemon population occurs, have remarkable resemblance to the period of historic significance and are crucial to the interpretation of the site and the quality of visitor experience (NPS 2008). An artists' sketch from 1878 (Figure 2a) and a modern day photo of the Horse Pasture in 2011 (Figure 2b) illustrate that the historic setting and rare plant habitat have not dramatically changed in over one hundred years and helps underscore the importance of maintaining the cultural landscape.

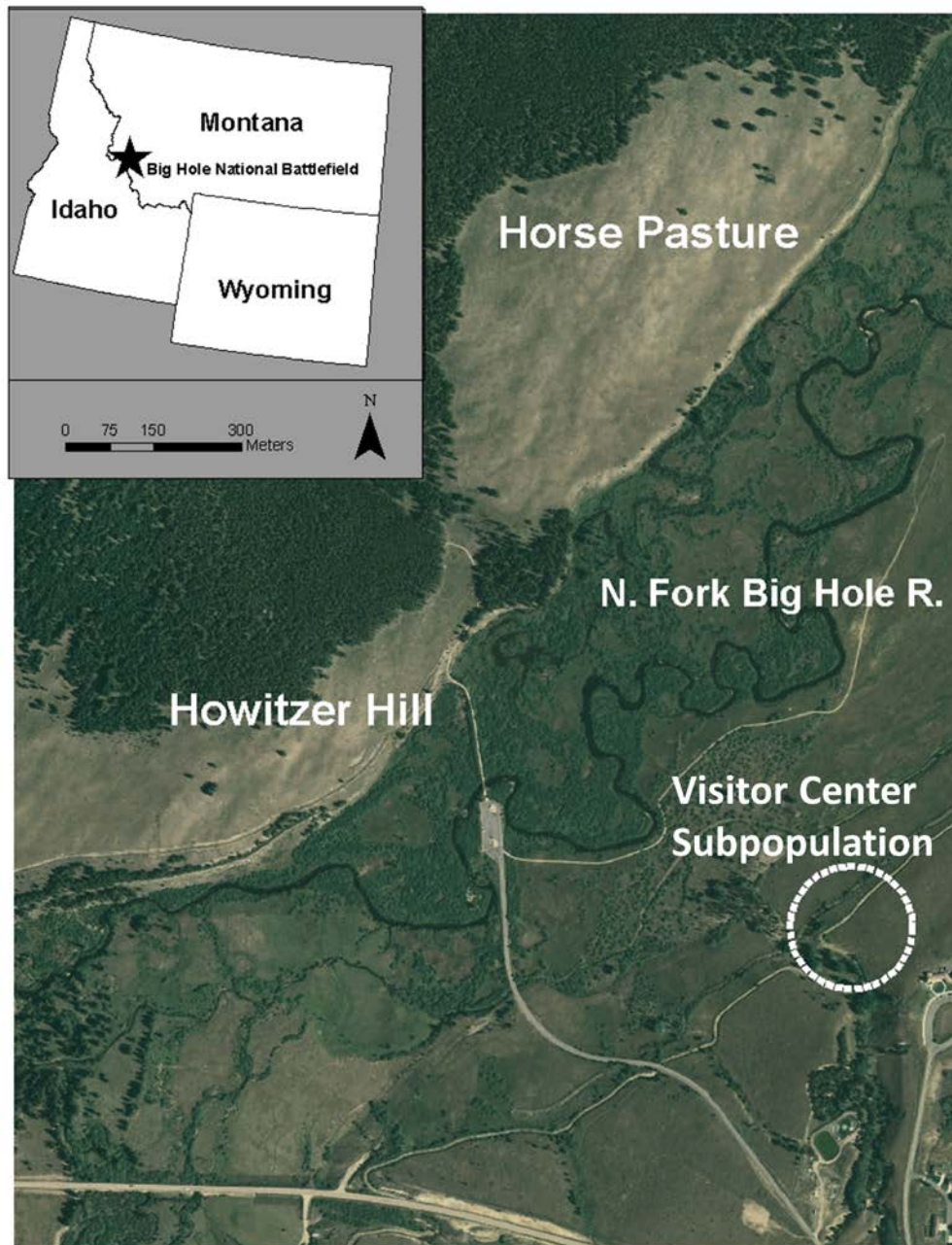


Figure 1. Map of Big Hole National Battlefield, located in southwestern Montana (inset). Monitoring surveys for Lemhi penstemon and spotted knapweed occur on the Horse Pasture and Howitzer Hill slopes, and along the banks of a portion of an irrigation canal below the visitor center (circled).

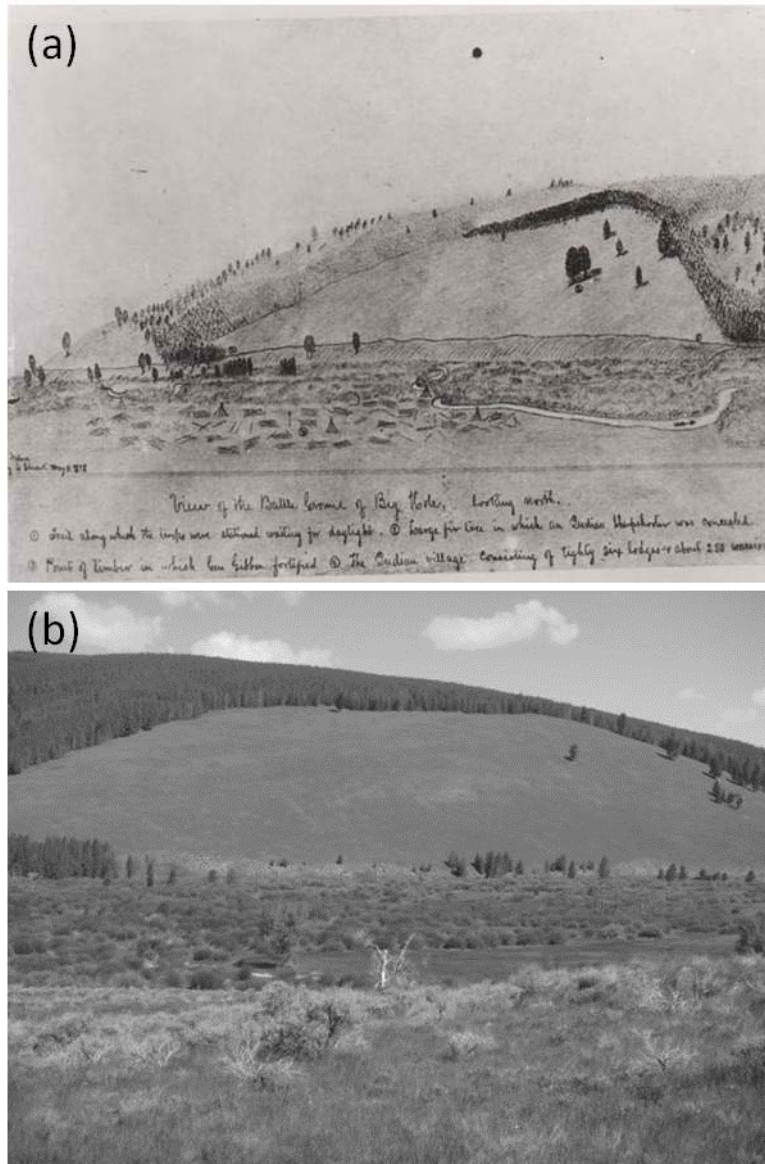


Figure 2. (a) A pioneer sketch of the Horse Pasture drawn by Granville Stewart in 1878 (courtesy of the Montana Historical Society Collection, X1968.43.17), and (b) NPS photo of the Horse Pasture in 2011.

Study Species

Lemhi penstemon

Lemhi penstemon [*Penstemon lemhiensis* (D. D. Keck) D. D. Keck & Cronquist] is a robust and showy blue-flowering perennial penstemon (family Plantaginaceae) that can grow to a height of 70 cm (Figure 3; Hitchcock and Cronquist 1973; Elzinga 1997). 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 that requires cross-pollination to reproduce (Ramstetter 1983, Heidel and Shelly 2001). The primary pollinator for the species is the pollen wasp

(*Pseudomasaris vespoides*; Ramstetter 1983). Lemhi penstemon does not have any specialized morphological adaptations or known animal hosts for seed dispersal and the seeds fall to the ground near the base of the parent plant after the seed capsules dehisce 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).

Lemhi penstemon occurs in early- to mid-succession habitats and 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). Recently disturbed areas such as 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 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.



Figure 3. Lemhi penstemon in flower at Big Hole National Battlefield (photo courtesy of Michael Durham, reproduced with permission).

Spotted knapweed

Spotted knapweed (*Centaurea stoebe* L.) is a perennial species of the Asteraceae family, introduced to North America from Eurasia. It is widespread across much of the continent and is an aggressive invader of disturbed ground in much of the intermountain West and Northern Rocky Mountains. It is also known to invade open, undisturbed plant communities as well, including in the Battlefield hillslopes. When well established, it can out-compete native vegetation. Flowering branches of the plant often reach ≥ 30 cm in height, growing from a stout taproot and producing one to many basal rosettes. Leaves are deeply lobed and typically have a silvery-gray cast from the fine hairs that cover the leaves. The dark tips of the involucre bracts are a distinguishing characteristic that gives the plant its name (Figure 4). The plant is easily recognized in BIHO, although young, small rosettes may be inconspicuous. In the Battlefield, the species is most heavily concentrated on the Howitzer Hill but has been expanding into the Horse Pasture as well, especially after 2011 (Rodhouse 2016). It also occurs outside the study area sampling frames along Battlefield roads and adjacent to buildings and disturbed areas (e.g., maintenance yards).



Figure 4. Spotted knapweed with its characteristic dark (spotted) involucre bracts.

Management Hypotheses and Objectives

The landscape of the Big Hole Valley at the time of the 1877 battle was devoid of human development, including roads, buildings, and other structures (NPS 2008). What defined the landscape were the natural components, including the vegetation, topography, hydrology, and

sweeping vistas of the valley and surrounding mountains (NPS 2008). These features not only set the scene and defined the character of the battle that was to occur; they played a significant role in the events and outcome of the battle itself (NPS 2008). It is only through preservation and maintenance of these natural features, and the ecological processes that allow for their continued existence, that the significance of the site can be fully understood and appreciated.

As with any living landscape, the natural systems of BIHO are in constant flux, evolving, growing, declining, and dying over time. With a few exceptions, the composition of the vegetation that exists today cannot be definitively identified as having been present at the time of the battle. However, the integrity of the Battlefield landscape depends not on individual features, nor on freezing the landscape in an unchanging historic state, but rather on maintaining the overall natural patterns, general composition, and processes that produced the organization of the landscape that comprised the historic scene (NPS 2008).

Today, those elements of the landscape that are essential to convey the site's significance are relatively intact, combining to set a scene very similar to the one that greeted the battle participants on the morning of August 9, 1877. Preservation and maintenance of these natural features and systems is of primary importance to park managers. Both the Howitzer Hill and Horse Pasture were integral to the historic events in 1877 and are likewise central to the contemporary Battlefield landscape and visitor experience. As they were in 1877, the hillslopes today are covered in native steppe vegetation bordered by dense lodgepole pine forest on the upper edges. Descriptions of the site from battle participants, as well as photographs, drawings, and maps produced in the years following the battle give a relatively clear picture of the extent and character of the forested areas in 1877 (Figure 2; NPS 2008:48). It is believed that at the time of battle the forest covered the majority of the mountain slopes, with the noted exceptions of the southeastern facing Horse Pasture and Howitzer Hill, much as it does in the present era.

Battlefield managers hypothesize that these open slopes were maintained through natural fire cycles aided by the topographic aspects of the site. Supported with historic documentation, park management has periodically utilized prescribed fire and mechanical thinning to remove encroaching overstory trees and shrubs in attempts to replicate natural processes and maintain the open slopes. These efforts began in the late 1960's with the last treatment occurring in 1997.

More recently, as knowledge regarding the importance of the Battlefield landscape to the conservation of Lemhi penstemon has grown, park management has engaged in efforts to better understand the local, site-level ecological processes necessary for long-term preservation of the penstemon population. Park managers feel that the NPS has an opportunity at BIHO to integrate rare plant conservation into long-term historic landscape preservation objectives (Stucki et al. 2013). To achieve this end, a plan aimed at using prescribed fire at BIHO was developed (Figure 5; Harris 2013) and partially implemented in 2014 with the burning of block 1 (Appendix A). Burn objectives focus on reducing tree and shrub cover to effectively maintain the open hillsides and thereby preserve the historic scene. Secondary burn objectives focus on benefiting Lemhi penstemon, conditional on *not* inadvertently benefiting spotted knapweed (which may also respond favorably to fire). If burn objectives are met, including a demonstrable increase in Lemhi penstemon seedlings and overall

population size and, importantly, a manageable response by spotted knapweed, the remaining half of the Howitzer Hill and Horse Pasture will sequentially be burned in future years, pending available resources from Glacier National Park Fire Management which support prescribed fire operations for BIHO. Note too that wildfires are also a possibility in the Battlefield and could be capitalized upon as a natural experiment to address these same goals and objectives.

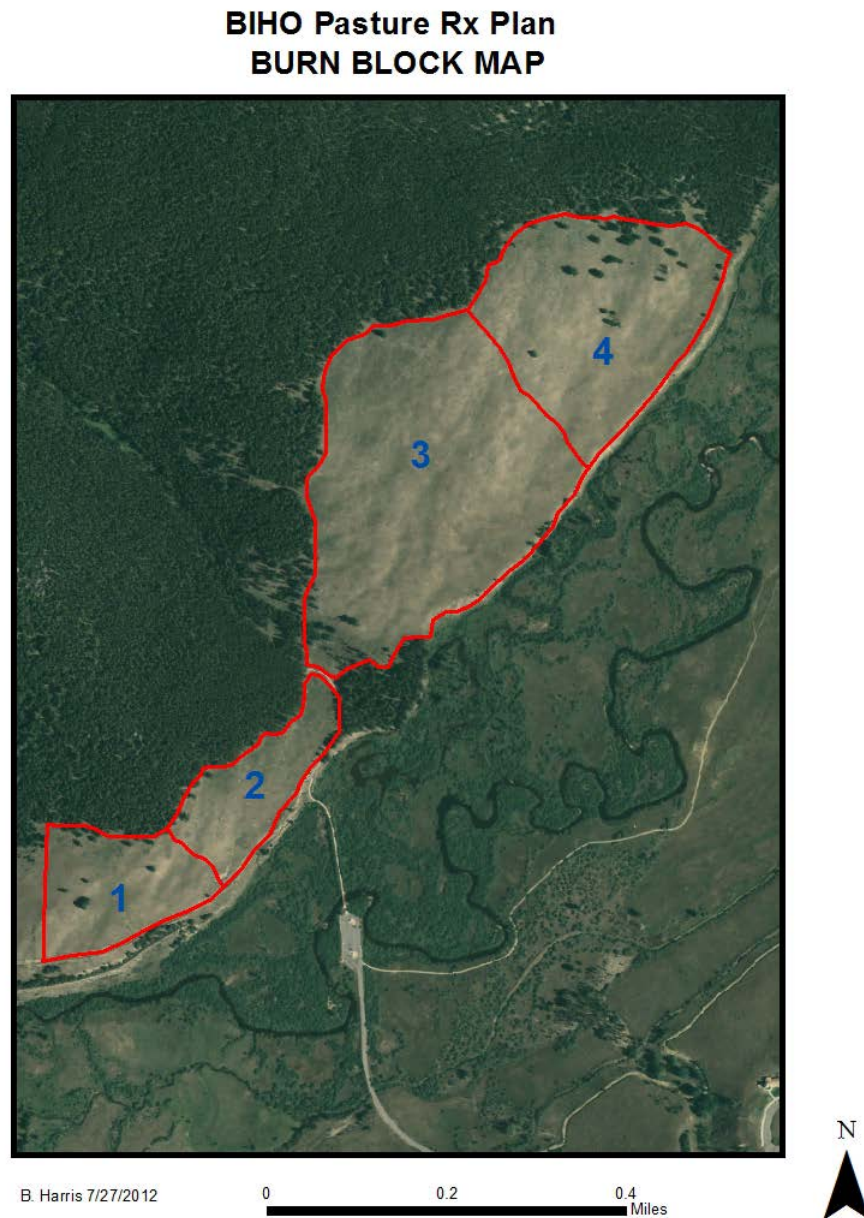


Figure 5. Proposed prescribed fire perimeters prepared to be burned sequentially over several years in the battlefield hillslopes to stimulate Lemhi penstemon reproduction. These burn blocks provide the foundation for a before-after control-impact (BACI) experimental design. Burn block 1 burned in 2014, and blocks 2-4 serve as control blocks. Pending acceptable outcomes and available funds and staff resources, block 4 may be burned in future years in order to provide a statistically-powerful replicated BACI experimental design.

Monitoring Hypotheses and Objectives

This monitoring protocol will support the Battlefield's assessment of Lemhi penstemon and spotted knapweed population trends in the context of successional, climatic, and management-induced hillslope vegetation change. The primary focus is on the subpopulations on the Howitzer Hill and Horse Pasture hillslopes. However, a small Lemhi penstemon subpopulation along the irrigation canal below the BIHO visitor center (Figure 1) is also monitored, providing a useful out-group for testing hypotheses.

The fundamental working hypothesis for monitoring is that persistence of the relatively closed (i.e., very low rate of seed dispersal and colonization from outside the Battlefield) Lemhi penstemon population in the Battlefield is dependent upon germination of seedlings (fecundity, generally) and increased recruitment, survival, and reproductive vigor of established (mature with ≥ 1 rosette) plants in bare-soil microsites where sunlight, water, and soil nutrients are available in adequate supply. The corollary is that encroachment of lodgepole pine, densification of native steppe vegetation, and spread of spotted knapweed will reduce the number and size of these microsites and cause a decline in the penstemon population through resource competition. When natural processes and Battlefield management activities (e.g., fire and downslope soil movement [i.e., solifluction], herbicide application) create microsites and suppress competitive vegetation, we expect the Lemhi penstemon population to respond (approximately within 3-5 years although this is not yet understood) with increased reproduction and survival, resulting in an overall increase in population size. We believe it takes 2-3 years before a seedling is recruited into the established population and begins to reproduce, exhibited by ≥ 1 well-developed basal rosettes and by ≥ 1 inflorescence (Elzinga 1997, Heidel and Shelly 2001).

We have developed monitoring objectives and corresponding survey methods that will allow us to test these hypotheses. Both the monitoring itself and Battlefield management will be adaptive and incorporate knowledge about the ecological system as it is acquired through monitoring over time, reflected in updated versions of this protocol and corresponding Battlefield management actions.

Figure 6 is a simple conceptual model of Lemhi penstemon population change over time as a function of survival and fecundity rates and the external ecological influences on those rates including both biotic and abiotic forces. Monitoring of hillslope penstemon and knapweed populations with large ($n=300$), spatially-extensive samples of temporary belt transects (referred to as "extensive plots") will enable annual estimation of population sizes of both species (N in Figure 6), with population (frame)-wide inferences. The growth rate λ can then be derived from the time series of population estimates, and estimated with models. Model-based estimation of penstemon survival and fecundity rates will be accomplished with data about seedlings and tagged established plants obtained from 42 permanent intensive-study plots, with a restricted but nonetheless informative scope of inference. Ecological mechanisms hypothesized to influence penstemon population change, and of significance to Battlefield management strategies, will also be quantified, either directly (specifically ungulate browsing and drought) or, in the case of competition, indirectly with proxy estimates of bare ground and vegetation cover. Spotted knapweed abundance estimation will provide crucial feedback to Battlefield adaptive exotic plant management decision-making and will also be an

additional proxy measure of resource competition. To assess the impact of fire on Lemhi penstemon and spotted knapweed populations, a before-after control-impact (BACI; Green 1979) experimental design has been integrated into the monitoring study design, with non-random assignment of replicate prescribed fire treatments to blocks of ~10 intensive plots each replicate, with remaining plots serving as experimental control. Extensive plot surveys will also provide important information about the net effect of fire on the penstemon and knapweed populations. Figure 5 shows the prescribed fire treatment blocks included in the BIHO prescribed fire plan (Harris 2013). Burn block 1 was treated (burned) in September 2014 and is described in detail in Appendix A. Non-random treatment assignment to blocks of experimental units was a logistical necessity but will result in an appropriately conservative implementation of prescribed fire to the smallest block. If goals are met, including positive response by Lemhi penstemon and a manageable response by spotted knapweed, and fire management resources made available, blocks 2-4 will be burned in future years (Harris 2013). The other important management action that may influence penstemon and knapweed populations is Battlefield and NPS Exotic Plant Management Team herbicide application to spotted knapweed plants within sampling frames. Knapweed control efforts are periodically conducted by exotic plant management teams and by a variety of staff from Nez Perce National Historical Park (NEPE) and BIHO, resulting in highly dispersed treatments over space and time. Accordingly, knapweed treatments will not be assigned to extensive plots; rather, treatments will be assigned to frames post-hoc from query reports from the National Invasive Species Information Management System (NISIMS) maintained by the NPS Biological Resources Division (see Rodhouse 2016).

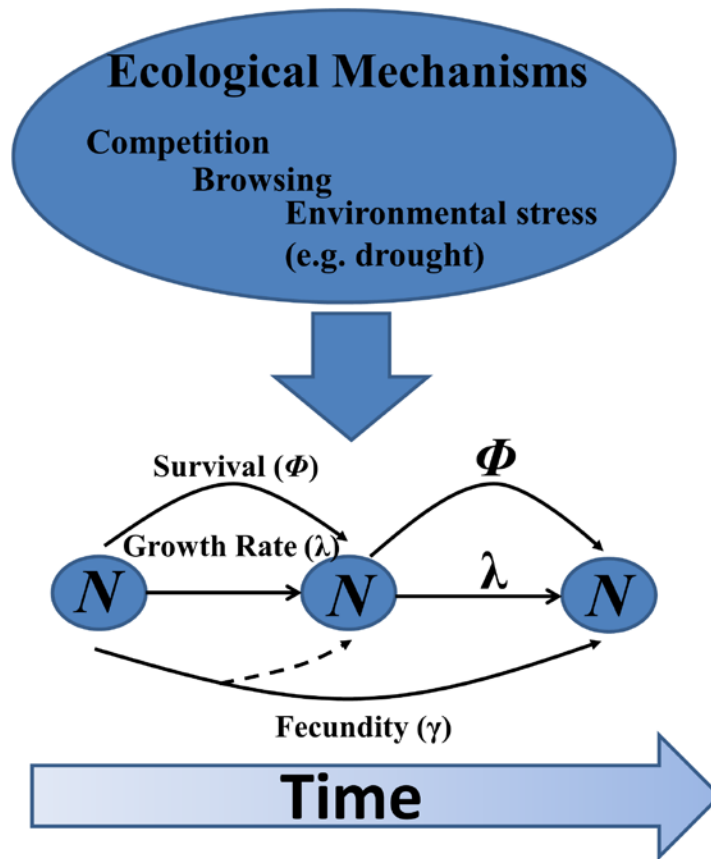


Figure 6. A conceptual model of Lemhi penstemon population change, or growth rate, represented by λ . Abundance, the state variable at each annual time step, is represented by N . Population change is governed by the vital rates survival (ϕ) and successful reproduction, or fecundity (γ). Vital rates are hypothesized to be influenced by external ecological mechanisms, particularly from competition from native steppe vegetation and from the invasive spotted knapweed, from ungulate browsing, and from climate and weather patterns in the Big Hole Valley. Fire is expected to be a major mechanism driving penstemon and knapweed population dynamics directly by causing plant mortality and indirectly by influencing competition and soil resource availability. Herbicide application targeted at spotted knapweed will strongly influence knapweed λ and overspray may also negatively impact the penstemon population.

Objectives

The monitoring objectives of Lemhi penstemon monitoring in Big Hole National Battlefield are to:

1. Provide status (N) and trend (λ) estimates of established Lemhi penstemon and spotted knapweed populations (excluding seedlings) from surveys (counts) of unmarked plants in randomly-selected spatially-extensive temporary plots in the Horse Pasture and Howitzer Hill and from annual censuses of the small area occupied by the penstemon subpopulation below the Battlefield Visitor Center.
2. Provide status and trend estimates of Lemhi penstemon demographic vital rates from counts of seedlings (γ) and of marked established (not seedlings; recruits with ≥ 1 established basal rosette) plants (Φ) in conditionally randomly-selected intensive permanent plots in the Horse Pasture, Howitzer Hill, and Visitor Center subpopulations.
3. Provide status and trend estimates in Lemhi penstemon and spotted knapweed plant densities (plants/m²) and of penstemon reproductive vigor from counts of penstemon basal rosettes and inflorescences, ungulate browse of inflorescences, and timing (phenology) of penstemon corolla opening from intensive plot surveys.
4. Track trends in microsite conditions of intensive plots over time with estimates of bare ground and vegetation cover and evaluate status and trend of penstemon and knapweed population growth and penstemon demographic rates within context of (along gradients of) prescribed fire and herbicide treatment events, and microsite and climatic variation.

Specific sampling objectives for monitoring are to:

1. Detect at least a $\geq 10\%$ annual rate of change in the population (population growth rate λ) of established Lemhi penstemon and spotted knapweed plants on the Battlefield hillslopes over a 10 year period with 90% confidence, from annual surveys of extensive plots.
2. Detect at least a 10% change in the rate of seedling germination (ratio of seedlings or fecundity [γ]) from one year to the next (i.e., before and after Rx fire) or among plots in treated and untreated blocks or in different microsites within the same year in the 42 intensive plots permanently established in the Battlefield.
3. Detect at least a 10% change in the survival rate of established Lemhi penstemon plants (Φ) from one year to the next in the 42 intensive plots permanently established in the Battlefield.

Power analyses using pilot data from 2009-2014 suggest that these objectives are achievable given the resources and sample sizes achieved during our 1-week annual survey events.

Sampling Design

A summary table (Table 1) at the end of this section outlines the sampling design characteristics of each of the components of this protocol.

Background and Development of the Sampling Design

In 2007, student volunteers acting in a community science capacity, along with staff from BIHO, Nez Perce National Historical Park (NEPE), and the Upper Columbia Basin Network (UCBN) Inventory and Monitoring Program (I&M) attempted an informal walking census of Lemhi penstemon plants that identified over 500 Lemhi penstemon plants in two geographically distinct subpopulations; one on the Horse Pasture and the other on the Howitzer Hill. These two subpopulations became the basis for the two sampling frames that have been developed for Lemhi penstemon monitoring.

A prototype sampling design for monitoring established Lemhi penstemon plants was developed and implemented in 2009 using information gathered during the 2007 census. This sampling design involved spatially-balanced sampling of the hillslope penstemon and knapweed subpopulations with a plot design modified from Lesica (1987) that was a 2 m × 50 m belt transect. We refer to these plots as “extensive” plots because of the broad spatial distribution and large sample sizes achieved with them across the two hillslope subpopulations. These plots were placed with the long axis perpendicular to the steep slopes at random locations selected with a spatially-balanced random sampling algorithm, the Generalized Random Tessellation Stratified (GRTS) sampling design (Stevens and Olsen 2004).

This sampling design was further developed and used during the field seasons of 2010-2017. In 2010, we also experimented with a strip adaptive cluster sampling (SACS) approach (Thompson 2002) in which a grid of 1-m² secondary sample units were nested within the large 100-m² belt transects (Stucki et al. 2013). Comparisons of variances between equal-probability GRTS samples and the SACS sample indicated that GRTS sampling was more efficient, reflecting the very small size (~ 1 m² on average) of Lemhi penstemon patches (i.e., clusters from which to sample in a SACS approach were too small). Sampling was conducted during late June in all years, when the plants were in flower or budding. All established Lemhi penstemon plants rooted within the extensive plots were counted, as well as the numbers of basal rosettes and inflorescences growing from each plant. All spotted knapweed plants within the plots were also counted. Seedlings were excluded from extensive plot surveys in order to reduce observer bias associated with imperfect detection.

Given the goal of estimating the total number of established Lemhi penstemon plants and the sparsity of penstemon plants across the hillslopes, a very large sample of ~300 extensive plots were surveyed each year. This large sample size precluded the establishment of permanent plots and therefore a new GRTS sample was drawn and surveyed each year with temporary plots. This method worked well and has yielded a tremendous amount of information that has stimulated new questions and hypotheses requiring more detailed information about penstemon survival and regeneration (e.g., Stucki et al. 2013). In response to these growing information needs, we established 42 permanent plots in 2012 across both hillslopes and also in the visitor center subpopulation. We refer to these plots as “intensive” plots.

The location of these plots was conditionally-random based on the 2011 extensive plot GRTS survey. The first 41 intensive plots were placed following the spatially-balanced (GRTS) ordered list of extensive plot locations where Lemhi penstemon plants were found in 2011 (i.e., following GRTS order conditional on at least 1 established Lemhi penstemon plot). This resulted in 18 plots in the Howitzer Hill and 23 plots in the Horse Pasture. A 42nd plot was non-randomly placed in the center of the Visitor Center subpopulation on a steep southwest bank of the irrigation canal. A sample size of 42 was determined ad hoc based on the logistics and resources anticipated to be available over the life of the program, and in order to have approximately 10 permanent plots on each half of each of the two hillslopes for addressing the effects of prescribed fire.

The final location of the 41 established intensive plots on the hillslopes did not remain at the original 2011 extensive plot origin, but instead were placed along the 50-m axis of the original belt transect so that at least one established Lemhi penstemon plant was rooted within the plot. Plot dimensions were 1 m × 2 m, oriented with the long axis (2 m) perpendicular to the slope, generally along the same azimuth as the original extensive plot orientation. This allowed observers to work along the down-slope edge of the plots and avoid trampling and soil disturbance in plots. Plots were divided into two, 1-m² subplots and further subdivided into four, 0.25-m² quadrants to provide spatial resolution for ground cover estimation. The corners of these subplots were monumented with rebar. Within these intensive plots mature Lemhi penstemon plants and seedlings were counted, as well as the number of basal rosettes and inflorescences for each established penstemon plant. Mature Lemhi penstemon plants have been marked and tagged (steel pins placed adjacent to each plant) so that plant demographic vital rates can be monitored over time. Spotted knapweed plants were also counted if present (through 2017 spotted knapweed has been found in only one intensive plot). Ground cover within the intensive plots was estimated using the point intercept method (Elzinga et al. 2001).

In 2012, the UCBN and BIHO staff collaborated with Glacier National Park fire scientists to develop a prescribed fire plan that could be integrated with long-term monitoring so that the effectiveness of prescribed fire could be evaluated. A replicated BACI (Green 1979) experimental design was established involving non-random assignment of prescribed fire treatment to 1 of 4 burn blocks (Figure 5) and control treatment assigned to the remaining 3 blocks, with burning of block one occurring in September of 2014. Each burn block boundary was established to contain approximately 10 intensive plots, although this may change once burning is implemented and on-the-ground conditions drive the actual location of fire perimeters (Harris 2013; see Appendix A). Extensive plots will continue to be placed in an un-stratified manner across these blocks; the sample sizes are large enough that stratification is unnecessary. Six years of pre-treatment data are available from extensive plot surveys for the first replicate burn conducted in September 2014 (Stucki and Rodhouse 2009, Rodhouse 2016, Rodhouse and Stucki 2013a, 2013b, Stucki et al. 2013). Three years of pre-treatment data for the first replicate burn are available from intensive plot surveys (Rodhouse 2016, Rodhouse and Stucki 2013a, 2013b). Non-random treatment assignment to blocks of experimental units was a logistical necessity but will result in an appropriately conservative implementation of prescribed fire to the smallest block. If goals are met, including positive response by Lemhi penstemon and a

manageable response by spotted knapweed, blocks 2-4 may be burned in future years, dependent upon allocation of NPS resources from the Glacier Fire Management Program (Harris 2013).

Sampling Design Rationale

The sampling design described in the preceding section has been thoroughly tested and has worked very well (Stucki and Rodhouse 2009, Rodhouse 2016, Rodhouse and Stucki 2013a, 2013b, Stucki et al. 2013). It has therefore been chosen for long-term monitoring. The approach maximizes efficiency and accuracy while minimizing numbers of staff and amount of time required for sampling. Both Lemhi penstemon and spotted knapweed are sparsely distributed across the hillslopes (Stucki et al. 2013), requiring large linear plots in order to generate enough count data for efficient and sufficiently precise population estimation (Elzinga et al. 2001). This sparsity also required the approach taken for establishing intensive plots from a prior (2011) survey in which known locations of penstemon could be targeted, while retaining some element of random selection and spatial balance. A more straightforward approach of randomly selecting locations across the large hillslopes would have provided stronger scope of inference but would have been unlikely to include any penstemon plants at all because of the small size of plots and the sparse distribution of penstemon on the hillslopes.

The extensive and intensive surveys can be completed within one week with six people assembled from park and I&M staff. Safety is a key priority during sampling on steep slopes and has been an important consideration during protocol development. Sampling occurs during late June when Lemhi penstemon plants are in flower, or nearly so, and when spotted knapweed rosettes are well developed and conspicuous. This is important as it gives the best opportunity to count plants which might not be visible earlier in the year or after senescence later in the summer. Timing of sampling can be adjusted if warranted depending on the climate and weather conditions and shifting phenology of target species.

Pilot data from the 2007 walking census were used to develop polygons within the Horse Pasture and Howitzer Hill hillslopes using a Geographic Information System (GIS). These polygons, or “sampling frames,” comprise the area surrounding the known populations of Lemhi penstemon within BIHO, excluding the small subpopulation located along the canal bank downhill from the visitor center. Thorough searches of the Battlefield have been made each year in an effort to relocate overlooked subpopulations (Stucki et al. 2013). The visitor center subpopulation was re-discovered in 2011 after being reported by a graduate student (Ramstetter 1983) in 1983 and apparently forgotten during the intervening years until we found the thesis with a hand-drawn map in the University of Montana library. This visitor center subpopulation is small enough that a census can be accomplished in several hours (Rodhouse 2016).

Target Populations and Sampling Frames

There are three spatially-disjunct subpopulations of Lemhi penstemon in the Battlefield, shown in Figure 1 and in Figure 7. Each of these subpopulations is targeted for monitoring. The two hillslope subpopulations are large enough that statistical sampling is required. However, the visitor center subpopulation is small and discrete enough for effective censusing. Sampling frames were established in the Howitzer Hill and Horse Pasture in 2009 by drawing polygons around each subpopulation (Figure 7). The Howitzer Hill frame contains 6 hectares (ha; 14 acres) and the Horse

Pasture contains 26 ha (64 acres) of steppe habitat on steep hillslopes. The core of each subpopulation is concentrated along the center axes of the frames where slopes are steepest, and, in the case of the Howitzer Hill, along the roadcut near the lower boundary of the frame. Should the targeted penstemon population shift away from areas of current concentration, perhaps as a result of long-term hillslope vegetation change, the extent of the frames are sufficient to enable detection and monitoring of these shifts. Expanded sampling frame areas would result in few, if any, additional encounters with Lemhi penstemon plants, increase the zero-inflated distribution of counts, reduce the precision of population estimates, and require an increase in sample size and time and resources committed to the project.

The spotted knapweed population in the Battlefield is concentrated in the center of the Howitzer Hill, but also occurs across the Battlefield in many discrete patches. It is not feasible to establish a Battlefield-wide sampling frame for spotted knapweed monitoring. Therefore, only the portions of the spotted knapweed population that occur within the two hillslope sampling frames and within the additional (42nd) permanent intensive plot in the visitor center subpopulation are targeted for monitoring and captured within the sampling design. Scope of inference of penstemon and knapweed population estimates is restricted to within the hillslope sampling frames. Given the size of these frames, the alignment of these frames with the core areas for the two species of study, and the intensive Battlefield management focus on these two hillslopes (e.g., to preserve the cultural landscape integrity and historical fidelity via Rx fire and weed control), this restricted scope of inference is acceptable and the inferences drawn from the program have already proven to be extremely invaluable to improve Battlefield resource management efficiencies (see Rodhouse 2016). The census of penstemon below the visitor center is not included within this scope of inference, but the plant counts can be added to hillslope estimates.

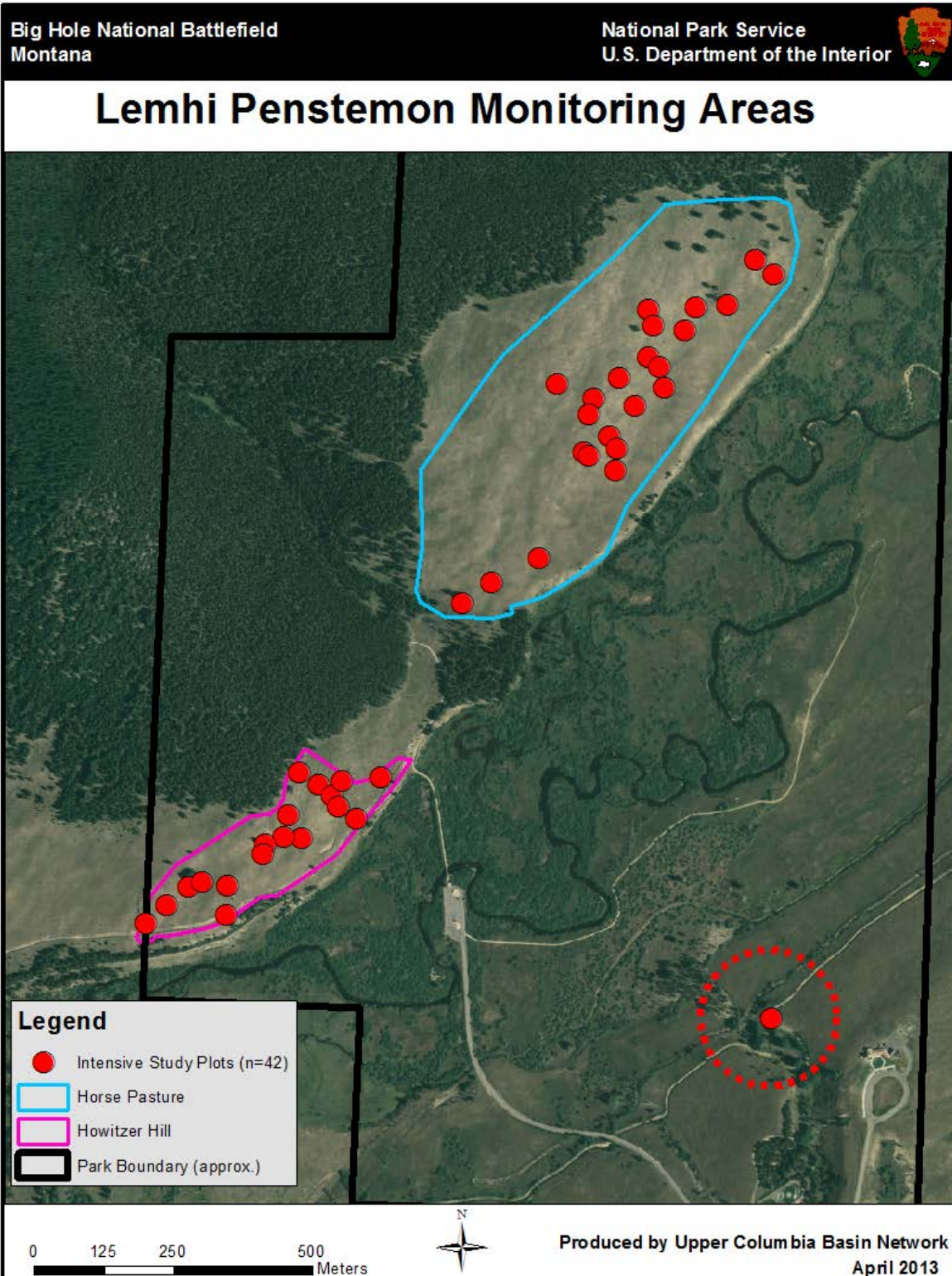


Figure 7. Sampling frames and intensive plot locations for monitoring Lemhi penstemon and spotted knapweed in Big Hole National Battlefield.

Response Design

Extensive Plot Surveys

Temporary plots, called extensive plots because of their spatially-extensive distribution, are used to develop population estimates for established Lemhi penstemon and spotted knapweed across both of the hillslope subpopulations (Figure 7). As described in the preceding section, plot locations are generated using the GRTS algorithm to ensure random, spatially-balanced plot placement (Stevens and Olsen 2004). The GRTS algorithm has also been shown to be statistically efficient for spatial surveys of environmental resources, generally, and a statistically-efficient “local” variance estimator has been developed for estimating state variables (e.g., N) from GRTS surveys that yields much more precise estimates than if standard Horvitz-Thompson population estimators are used (Stevens and Olsen 2003, Rodhouse et al. 2011). Target sample sizes are 100 plots in the Howitzer Hill sampling frame and 200 plots in the Horse Pasture sampling frame, with sample sizes reflecting the difference in area between the two sampling frames. The area sampled ($300 \times 100 \text{ m}^2$) represents 9% of the total frame area.

Extensive plots are 100-m^2 belt transects $50 \text{ m long} \times 2 \text{ m wide}$, modified from an approach described by Lesica (1987). Plots originate at the randomly selected GRTS point locations and are oriented perpendicular to the slope in a northeasterly direction. This orientation allows for observers to traverse the steep slopes safely. Plots are searched for mature Lemhi penstemon plants and spotted knapweed plants by walking down the center of the belt transect, using a 2-m long PVC pole to determine plot boundaries. Lemhi penstemon plants are considered mature when one or more fully developed basal rosette(s) of leaves are present. Lemhi penstemon seedlings are difficult to detect and are excluded from spatially-extensive surveys in order to reduce observer bias due to imperfect detection. All established Lemhi penstemon and spotted knapweed plants are counted in extensive plots, as well as the number of penstemon rosettes and inflorescences. Temporary irrigation pin flags are used to mark plants during surveys, eliminating risk of double-counting plants. The slope (in degrees) and aspect of each plot is recorded with a compass at the plot origin.

Intensive Plot Surveys

Permanent plots, known as “intensive” plots, were established in 2012 to support marking (tagging) of established Lemhi penstemon plants for the study of demographic vital rates in relation to microsite characteristics, climate and weather, and prescribed fire. The first 41 plots were selected in consecutive order from the 2011 spatially-balanced ordered list of GRTS locations where Lemhi penstemon plants were found during the 2011 survey. This order resulted in 18 plots located in the Howitzer Hill sampling frame and 23 plots in the Horse Pasture sampling frame (Figure 7). These locations are therefore the result of a *conditional* random sample process. A 42nd intensive plot was non-randomly placed within the center of the subpopulation below the Visitor Center on a steep southwest facing bank of the irrigation canal. The permanent plots within the Horse Pasture and Howitzer Hill sampling frames are not located in the original position of the spatially-extensive plot origins but were instead placed along the 50-m transect so that at least one mature Lemhi penstemon plant was located within the intensive plot. The intensive plots are 2-m^2 in size with dimensions of $1 \text{ m} \times 2 \text{ m}$ and are oriented with the long axis (2 m) oriented perpendicular to the slope (see Figure 8). Each intensive plot is divided into two, 1-m^2 subplots, a left (L) subplot and a right (R) subplot. Plots

were monumented with a 1/2" × 12" section of rebar and capped with yellow plastic caps stamped with "NPS MONITOR SITE" at each of the lower (downslope) corners and the location of the lower left (southeast) corner was recorded using GPS. Within intensive plots, all mature Lemhi penstemon are tagged and counted, along with the number of basal rosettes and inflorescences on each plant. Lemhi penstemon seedlings and spotted knapweeds plants are counted, but not tagged. In each plot, it is noted if any Lemhi penstemon corollas have opened or not, a practice that if continued over the long-term could help to define the phenology of the species at BIHO. Inflorescences that have been browsed are also noted. Percent ground cover is estimated using the point interception technique (Elzinga et al. 2001) at 98 positions within the 2-m² plot (Figure 9). Values for each of the physiognomic ground cover categories [which include bare ground (B), soil crust (C), forb (F), graminoid (G), litter (L), Lemhi penstemon (P), rock > 5 mm in diameter (R), shrub (S), tree (T) and wood (W)] are totaled and converted to a percentage for each intensive plot.

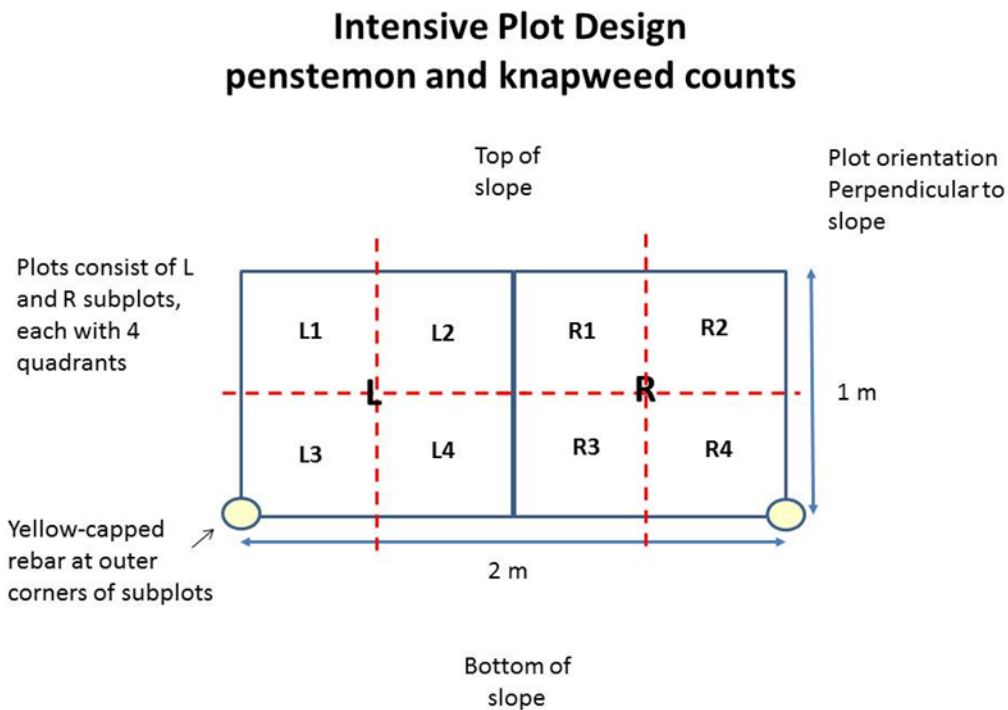


Figure 8. Diagram for counting Lemhi penstemon and knapweed plants in the 42 permanent intensive study plots.

Intensive Plot Design

Point-intercept Cover Estimation

Plots consist of L and R subplots, each with 49 intercepts and a total of 98 intercepts

Grid of pvc pipe for point-intercept cover estimation

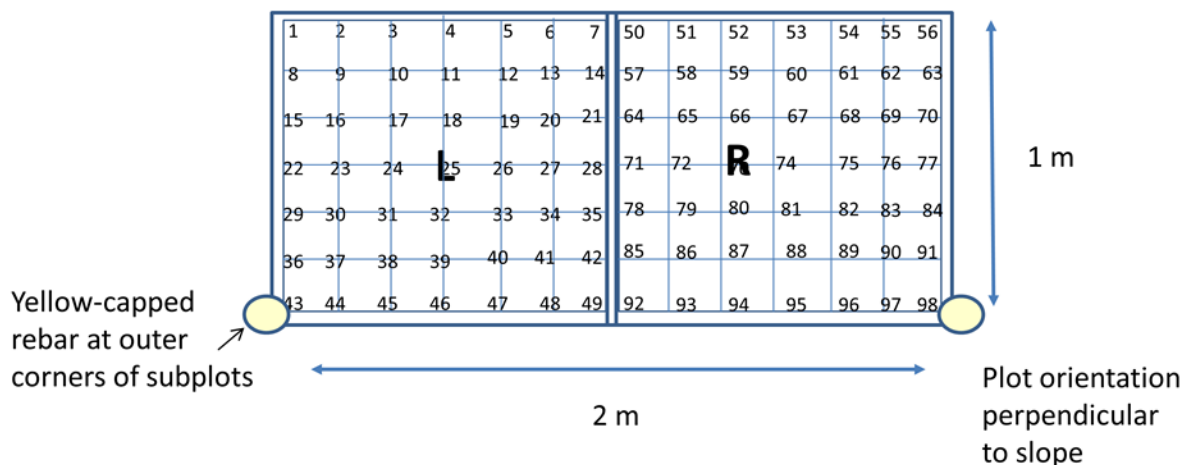


Figure 9. The diagram for estimating ground cover in intensive study plots with a point-intercept frame.

Visitor Center Subpopulation Census

The visitor center subpopulation is concentrated along the banks of an irrigation canal that bisects the middle of the west-facing slope below the visitor center on an old alluvial fan that was reportedly influenced by mining activity prior to the establishment of the Battlefield. Figure 7 illustrates the exact location of this subpopulation. Extensive searches in each year beginning in 2010 have confirmed that the subpopulation is small and does not extend away more than ~ 10 m from the portion of the canal that bends sharply to the northeast. Each year beginning in 2011 we have utilized all available staff and volunteers to spend the final afternoon of the week-long field effort locating every established plant. Beginning in 2016, plants were tagged using the same methods as for intensive plots. During censusing, plants are temporarily marked with irrigation pin flags to enhance visibility and ensure all plants are included in the final tally. Plant tag numbers, live/dead status, rosettes, and inflorescences are recorded. The 42nd intensive plot, which is located on the east bank (visitor center side) of the canal, is also surveyed at this time using intensive plot methods.

Auxiliary Information Used to Characterize Microsites and Influential Climatic and Management Events

This protocol is designed to support evidence-based decision-making in the Battlefield. Testable hypotheses have been articulated about how the Lemhi penstemon and spotted knapweed populations will respond to prescribed fire and weed control, and how they will vary over space and time in relation to climate and weather and microsite conditions. Integrating auxiliary information that

represents management actions and microsite conditions is a critical component of this protocol. Fire and weed management activities will be retrieved from Battlefield (or proxy, e.g., Glacier Fire Management officers) on an annual, or in the case of infrequent fire, after each event (e.g., Appendix A). Weed management actions undertaken by Battlefield and Exotic Plant Management Teams is reported annually to NISIMS, and NISIMS reports will be used at the time of data analysis to construct binary indicator variables representing sprayed/not sprayed indicator variables in regression models. Appendix A provides all necessary information for constructing burned/unburned binary indicator variables and also quantitative burn severity covariates from the September 2014 Rx burn of block 1. Similar information will be provided by Battlefield staff or Glacier Fire Management staff if future blocks are burned. Climate and weather information will be extracted from the Climate Analyzer web portal (<http://www.climateanalyzer.org/>) at the time of analysis. Microsite characteristics will be constructed from slope, aspect, and ground cover measurements. Extensive plot analysis will benefit from other measures of ground cover, for example normalized difference vegetation indices (NDVI) developed from high-resolution near-infrared aerial photography produced and archived by the National Agricultural Imagery Project (<https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/>). Rodhouse (2016) provides a thorough example analysis that incorporates these auxiliary data sources into an assessment of trend in Battlefield Lemhi penstemon and spotted knapweed populations from 2009-2014.

Temporal Revisit Design

Annual surveys are achievable with the resources available and are planned. This schedule will allow for annual fluctuations in regeneration and survival to be investigated. For the extensive plot surveys, with temporary plots, this implies a “never-revisit” design, denoted as [1- n] following the notation of McDonald (2003). For intensive plots, which are permanent, this implies an “always-revisit” design [1-0] (McDonald 2003). Surveys are conducted during late June, during the same week that camas lily monitoring surveys are also conducted in BIHO.

Statistical Power to Detect Population Changes

We considered simple sample size equations that rely on large-sample asymptotic normal approximations provided by Elzinga et al. (1998:346-354). Based on annual estimates of variance (s^2) from pilot surveys, the precision (% of mean, 90% confidence interval half-width) for estimating the mean number of established plants per 100-m² extensive plot with a sample size of 300 was 37%, or approximately 0.37 plants. For estimating the population total using an estimate of s^2 obtained from the “local” GRTS estimator (Stevens and Olsen 2003), the estimated precision was 2%. The estimated minimum detectable change in the difference between two years of population total estimates using the 300 extensive (temporary) plots was 5%, or 140 plants. The estimated precision in the difference between two years in mean established penstemon plant counts for the 42 paired 2-m² intensive plots was 20%, or approximately 0.61 plants.

We also simulated data from the negative binomial distribution and estimated power to detect changes with $\alpha = 0.1$ (Type I error) using parameter values and error estimates from trend models fitted to existing pilot data. Although we did not exhaustively explore different scenarios, we found

ample evidence that our sample sizes are sufficient to detect declines of at least 10% per year or greater over 10 years with both extensive and intensive plot data. For example, using a generalized linear mixed model with random intercept and slope effects for each of the 42 permanent intensive plots (repeated measures induced serial correlation) with negative binomial error, power was estimated at 92% (Type I false change error $\alpha = 0.1$, Type II missed change error $\beta = 0.20$). The steps to duplicate this procedure using R software are included in SOP 7.

Table 1. Summary of key aspects of the protocol sampling design for the three core activities of extensive plot surveys, intensive plot surveys, and visitor center censusing. We organize this table by “what”, the frame (accessible target population); “where”, the actual spatial sample (survey) design; “when”, the revisit design; and “how”, the response design that describes how information will be generated and the kinds of inferences that will be made.

Core Activity	Subpopulation/ Sample Frame	Sample Units (Sample Sizes)	Sample (Survey) Design	Revisit Design	Response Design
Lemhi Penstemon and Spotted Knapweed Population Status & Trend (Extensive Plots)	Howitzer Hill	2x50m belt transects (n=100)	equal-probability GRTS	annual to the frame; never to the plot ([1-0]; temporary)	Pop. growth rate (λ) via counts of untagged established plants
	Horse Pasture	2x50m belt transects (n=200)	equal-probability GRTS	annual to the frame; never to the plot ([1-0]; temporary)	Pop. growth rate (λ) via counts of untagged established plants
Lemhi Penstemon Demographic Vital Rates (Intensive Plots)	Howitzer Hill	1x2m quadrats (n=18)	conditional GRTS	always ([1-1]; permanent)	fecundity (γ), survival(ϕ), growth (λ) via seedling and tagged established plant counts
	Horse Pasture	1x2m quadrats (n=23)	conditional GRTS	always ([1-1]; permanent)	fecundity (γ), survival(ϕ), growth (λ) via seedling and tagged established plant counts
	Visitor Center	1.2m quadrat (n=1)	Non-random (purposive)	Always ([1-1]; permanent)	fecundity (γ), survival(ϕ), growth (λ) via seedling and tagged established plant counts

Table 1 (continued). Summary of key aspects of the protocol sampling design for the three core activities of extensive plot surveys, intensive plot surveys, and visitor center censusing. We organize this table by “what”, the frame (accessible target population); “where”, the actual spatial sample (survey) design; “when”, the revisit design; and “how”, the response design that describes how information will be generated and the kinds of inferences that will be made.

Measure	Subpopulation/ Sample Frame	Sample Units (Sample Sizes)	Sample (Survey) Design	Revisit Design	Response Design
Auxiliary Population & Demography Information (Census) for Lemhi Penstemon	Visitor Center	areal search	non-probability census	annual	fecundity (γ), survival(ϕ), growth (λ) via seedling and tagged established plant counts

Field Methods

Field Season Preparations

This protocol and the associated standard operating procedures (UCBN-NPS 2018) must be reviewed by the project lead prior to the field season to determine if any changes are necessary. Safety materials must be reviewed to address any outstanding safety concerns. GRTS sample locations for extensive plots must be drawn and loaded into GPS units prior to each field season. The locations of intensive plots must also be uploaded to GPS units as well. A reference sheet of penstemon plant tag numbers, rosette, and inflorescence counts, by quadrant, for each intensive plot from the prior season must be prepared and printed on water-resistant field paper. Reference maps of plot locations must also be prepared and printed. Handheld computers used for field data entry must be updated with the most current version of the data entry software. Field equipment must be gathered and inventoried. Accommodations must be made with BIHO staff, if needed, for sleeping arrangements in park quarters. Camping is also available near the Battlefield, and limited lodging is available in the town of Wisdom.

Safety

Safety of field personnel is always the first priority in conducting a monitoring program. Advanced planning can reduce or eliminate many safety hazards and better prepare staff for dealing with these issues. The safety SOP included in the SOP document (UCBN-NPS 2018) provides safety information, checklists, and communication forms for Network, and contract personnel or cooperators, who are involved with field activities. Roles and responsibilities of each party in implementing a safety program are discussed. General safety preparation is reviewed and job hazards and mitigations measures are summarized for driving, wilderness travel, and monitoring fieldwork. An emergency contact form is provided to obtain emergency information for each employee and park-specific contacts are provided for field-related emergencies. Field communications for backcountry travel are outlined. The purpose of the safety procedures, including completion of field season readiness reviews, is to engage all personnel and to provide a foundation for an on-going open and dynamic process for communicating about and addressing field safety. Park safety officers shall be consulted to ensure that crews comply with all park-specific safety policies.

Fieldwork requires an awareness of potential hazards and knowledge of basic safety procedures. Risks include working in small teams on steep and rugged hillslopes, hiking over rough terrain, potential contact with dangerous insects, exposure to extreme weather, and long driving trips between BIHO and other park or Network offices. Further details are contained in appendixes to the safety SOP, including the Lemhi penstemon monitoring Job Hazard Analysis (JHA), which will be reviewed and updated each year by all field staff (a fundamental step in building operational leadership capacity).

Roles and Responsibilities

The roles and responsibilities outlined in the safety SOP are adapted from the NPSafe program. In addition, we have incorporated principles from the NPS operational leadership training program (https://www.nps.gov/training/nrs/academy/G_both_graphic/operational_leadership.html) to

empower all employees to take responsibility for safety and wellness. All Program Managers and Project Leads will participate in Operational Leadership (OL) training and apply OL principles in assessing risk and managing field crew safety. According to these principles, program managers and team leaders are responsible for setting the standards, articulating the standards to employees, and following and enforcing the standards. All staff is responsible for knowing, understanding, following, and encouraging others to follow safety standards. Standards include the SOPs specific to this protocol as well as overall safety standards for the monitoring program (i.e. those that are common across protocols such as communication and vehicle safety, and annual readiness reviews).

Prior to the start of each field season, certain safety documents must be reviewed, signed, and returned to the park contact and the network coordinator. These documents include fieldwork itinerary forms that outline when and where field operations will take place, readiness reviews that detail necessary safety items that have been prepared for the field season, and JHAs that highlight individual risks associated with fieldwork and ways to mitigate those risks.

Knowledge of Standard Operating Procedures

Reading and understanding the protocol and in particular, the SOPs, are crucial prior to initiating fieldwork. This basic understanding of the protocol and the ability to recognize bad data in the field can improve safety by enabling teams to address errors before leaving the plot, eliminating unnecessary sampling trips, and reducing unnecessary exposure to risk. Recognition of data errors on site allows for immediate adjustment in the field. The protocol lead will allow adequate time for all field crewmembers to become familiar with SOPs and check their work in the field. Field-related SOPs will also be covered as part of the hands-on training.

Weather and Field Gear

Fieldwork in BIHO can involve challenging weather extremes. Weather can be variable and change quite rapidly during the sampling period in late June and field crews may encounter cold rainy weather and thunderstorms, unseasonably hot weather, or anything in between. It is essential to the success of the program that all field staff and associates are well prepared for weather extremes. Good rain gear, clothes for a range of temperatures, sunhats, sunscreen, and protection from mosquitoes and biting insects are essential.

First Aid and CPR

Training in the basic first aid and CPR is required for all field crew leaders, is strongly recommended for all crewmembers, and will be paid for by the Network. Certification is valid for two years. Protocol leads should make arrangements for those needing training far in advance to the start of the field season. BIHO is in an area that can experience extreme weather conditions, with conditions varying considerably on a daily, or even hourly, basis. Snow, heavy rain, thunderstorms with lightening, high winds, or hot and sunny conditions can occur during field operations with little warning. Field crews should watch the skyline for cumulonimbus cloud development and avoid being on the exposed hillslopes if thunderstorms and lightening are threatening. As a result, fieldwork requires preparation for this range of conditions. Hypothermia and heat-related injuries are possible. Extreme weather can also contribute to fatigue and increase the risk of injury from falls.

Field crew leaders should check the National Weather Service website for an up-to-date forecast before initiating fieldwork in BIHO.

Driver Safety

Travel between park offices and BIHO often requires long road trips under varied weather and road conditions. Field staff shall drive responsibly and obey all traffic laws. Employees must monitor fatigue while driving and pull over to rest when necessary. Roads in BIHO are paved and driving access within the park is limited, though this doesn't mitigate all driving risks. Restrictions on road trip duration will be consistent with current NPS policy. See SOP 9 for further details.

Field Safety for Lemhi Penstemon Monitoring

Safety of field personnel is always the first concern when sampling field sites. No sample or sampling site is worth the risk of injury or death. If employees of any level perceive a risk at any time, they should stop the task immediately and mitigate the risk. This policy applies to all aspects of the work including preparation for field work, travel to and from sites, and actual field sampling.

Access to sampling frames and plots within BIHO requires off-trail hiking. Sampling areas may be steep, slippery with loose materials, and have tall vegetation that requires appropriate footwear and technique to traverse. It is important for crews to be trained in orienteering using GPS and map/compass techniques. Maps will be provided to crews showing the location of sampling plots. Crews will be responsible to navigate safely to the sampling plot.

Fieldwork requires an awareness of potential hazards and knowledge of basic safety procedures. Advanced planning can reduce or eliminate many safety hazards. This protocol uses Job Hazard Analyses (JHAs) to critically examine tasks, identify specific hazards, and reduce or eliminate these risks. A set of these documents is created for each protocol, is reviewed prior to field implementation, and evolves with the input of subsequent employees to remain a current and effective safety tool. All employees are expected to know, understand, and contribute to these documents.

Working in Small Teams

Field staff will primarily operate in teams of two or more when traveling to and from plots and when sampling vegetation in the field. Field staff will work alone only when necessary and when safe monitoring practices allow for it. The on-site project lead will determine if and when solo work is appropriate. When working in such small teams, particular attention must be given to safety and communication. Team members must make an extra effort to work within sight and earshot of one another. See the Field Communications section of the safety SOP for further guidelines on establishing travel plans and check-in/check-out procedures.

Field Communications

Having established lines of communication and a Check-in/Check-out procedure are essential to employee safety and ensuring timely assistance in case of a mishap or delay. These procedures are explicitly described in the annual field readiness review and itinerary forms. Upon arrival and check-in at the park, establish a clear procedure of communication between field teams and park staff. Cell phone coverage in BIHO is intermittent and should not be relied upon in case of an emergency. Crews

will carry 2-way radios to communicate with other field crews. Park radios will be provided to at least one field crew member (crew lead or park staff assisting field work). Radios may also be carried by park staff members assisting with the Lemhi penstemon monitoring effort. Park radios are used to maintain contact with the Visitor Center in BIHO and to report an emergency. Telephone access is available in the Visitor Center. Check with park contacts for radio availability and use procedures. Crews will be trained on the use of 2-way radios and park radios prior to fieldwork. At least one UCBN crew member will carry a satellite beacon (SPOT or InReach).

Driving to Big Hole National Battlefield

Staff from UCBN and NEPE offices drive to BIHO on the Sunday or Monday beginning the survey week. The Battlefield is located along highway 43 in southwestern Montana, approximately 10 miles west of the town of Wisdom. Driving time from NEPE/UCBN headquarters is approximately seven hours. Once on site, staff are housed within the BIHO staff housing compound or at the May Creek Campground (US Forest Service) adjacent to the Battlefield and commute each morning down to the Battlefield trailhead parking lot.

Personnel Requirements and Training

Three groups of two field observers each are necessary to efficiently complete sampling in BIHO within the period of a week. Arrangements for field crews must be made early in the year prior to sampling. At least one observer on each team should be experienced with the Lemhi penstemon monitoring protocol and able to confidently and accurately identify the target plant species while in all stages of growth. Field observers should be physically fit and prepared to hike on the steep hillslopes where Lemhi penstemon is found. Field crews have typically been comprised of staff from the UCBN, NEPE, and BIHO. If there are not adequate numbers of field observers, scheduling must be adjusted to accommodate the extended sampling time.

It is crucial that field observers can accurately identify plants in the field, especially Lemhi penstemon seedlings and spotted knapweed rosettes. Misidentification of plants may possibly go unnoticed or will likely be very hard to correct for during later analysis. Prior to sampling, each field crew member should spend time studying Lemhi penstemon and spotted knapweed plants in the field in order to build confidence in identification and develop a sharp and reliable search image. Field methods should be illustrated before sampling begins and each field team should have at least one experienced crew member to confirm plant identification and lead sampling. Field training for inexperienced observers, and review of all methods and identification for returning experienced staff, is conducted as a group during the first field outing. Training continues for inexperienced personnel in 2-person team settings in the field during surveys. The roadcut below the Howitzer Hill is a convenient location to quickly find Lemhi penstemon and spotted knapweed plants in all stages of growth, and to set up plots and review procedures. Note that less-experienced must be paired with more experienced personnel for conducting surveys. Team leaders of intensive plot surveys must be very experienced – typically the most experienced – staff (e.g., UCBN Project Lead and botanist Crew Lead). For a full discussion on training field personnel see SOP 2.

Locating and Establishing Plots

Extensive plots are located with a GPS unit. Field maps (SOP 1) are also carried and referenced to help in navigation. Once at the pre-determined location, surveyor's pins and a compass are used to stake and then direct the unreeling of a metric reel tape out 50 meters perpendicular to the slope in a straight line. This operation requires 2 people; one person handles the tape and walks out to the end of the transect, and the other stands at the origin with a compass and guides the tape to stay on a straight course. Both observers participate in searching for plants, each traversing the entire transect twice (up and back). Colored irrigation pin flags are used to temporarily mark plants to avoid double counting of plants.

Intensive plots are also located by GPS and field reference maps. Rebar are located at the downslope corners of the subplots and capped with yellow marking caps. A PVC quadrat frame 1 m x 1 m in dimension with support legs is placed over each subplot to guide reading of the plot. Support legs are placed over the corner rebar to ensure proper alignment.

Conducting Plot Surveys

Extensive plots are surveyed by walking along the taut 50-m reel tape with a 2-m long section of PVC. The most efficient strategy is for the person handling the reel tape to also carry the PVC with them and walk back to the origin slowly, looking for penstemon and knapweed, then continuing the search while returning to the end of the transect, ensuring two thorough passes through the plot. The person remaining at the origin will enter data and then also assist in slowly searching the transect. Multiple passes by two observers greatly reduces the risks of overlooking target plants. Additional details are provided in SOP 5. Colored irrigation pin flags are used to temporarily mark plants to avoid double counting of plants.

Intensive plots are surveyed by standing and kneeling along the bottom and sides of the 2-m axis of the plot. Do not stand and work above the plot, as the steepness of the slope will cause slippage of debris into the plot. Thorough searches are conducted, by quadrant, in each 1-m² subplot. A reference sheet with the previous three year's tagged plant counts will help observers determine that all plants have been found, although this sheet should not be relied upon solely, as new seedlings and recruits must also be found. Two people are required to conduct these surveys; one searches while the second observer records data. Once all quadrants have been exhaustively searched for penstemon and knapweed plants, ground cover will be recorded using point interception. A thin, 1/8"-inch metal rod and a PVC guide bar (SOP 5) are used to accomplish ground cover estimation, following the grid illustrated in Figure 9.

Data Entry and Management

This protocol is set up for paperless field-data entry using personal assistant (PDA) handheld computers with Pendragon software (Pendragon Software Corporation 2016). Custom data entry forms were created with Pendragon and loaded into the PDAs. The Pendragon data entry form has built in quality assurance components such as pick lists, form controls, and warnings to prevent missing data or illogical entries. Details are provided in SOP 6. UCBN provides Trimble Juno and Juniper Archer ruggedized PDAs to crews for data entry.

Because this protocol is set up for paperless field-data entry, extra care should be taken to review both the data entry during field work and the resulting data uploaded into the project database. Data forms are quick and easy to fill out, and given the relative rarity of penstemon and knapweed encounters, this in-field data entry and review requirement is not burdensome. Data will be backed up daily (each afternoon following field work). Once back in the office, the UCBN Data Manager will expedite uploading of data from all PDAs into the project database. Delaying this process will increase the risk of errors and memory lapses of key notes and observations that may not have been captured on the data entry forms. The Project Lead will review the Lemhi penstemon monitoring database and address inconsistencies and errors before certifying the database and proceeding with analysis and annual reporting

After the Field Season

Following field season, all equipment will be cleaned and returned to the UCBN, NEPE, or BIHO headquarters for storage as appropriate, see SOP 1 for further details. All digital equipment including GPS and PDA units must be returned to the UCBN for downloading and preparation for use with other UCBN protocols. Equipment will be checked for damage and the equipment check list (SOP 1) will be reviewed to ensure that nothing has been lost or in need of repair or replacement. Repairs and replacements will be made as soon as possible and the equipment list updated with this information.

After a survey season has ended, the UCBN Data Manager is responsible for ensuring that all field data are uploaded into the project database from the PDAs. A management actions query will be made of BIHO staff and information provided will be entered into the management actions table in the project database.

Data Handling, Analysis, and Reporting

The following section outlines procedures for Lemhi penstemon monitoring data handling, analysis, and report development. Additional details and context for this section may be found in the Lemhi penstemon and spotted knapweed monitoring data quality standards report (Lonneker and Rodhouse 2017) and the UCBN network data management plan (Dicus and Garrett 2007), which describes the overall information management strategy for the network. The UCBN monitoring plan also provides a good overview of the network's information management and reporting plan (Garrett et al. 2007).

Overview of Database Design

The UCBN Lemhi penstemon monitoring database is an application developed within Microsoft Access. It adheres to Natural Resource Database Template standards (NRDT v. 3.2). The database application consists of a front-end user interface linked to a back-end database file. The front-end provides forms for managing data, queries for facilitating QA/QC, and tools for exporting data. The back-end of the database holds the core data, PDA-related tables and also various lookup tables. The UCBN data management staff is responsible for development and maintenance of the database, including customization of data summarization and export routines. This database may undergo revisions that will be reflected in future protocol narratives and data management SOP revisions. However, the underlying data structure (tables, fields and relationships) will remain unchanged, as will that of the front-end database applications ("user interface" with forms, queries, etc.) accessed through a user-friendly "switchboard".

The data management strategy employs a "working copy" of the database application to enter and store the current season's data and to perform error-checking and validation. A "master copy" of the database application stores all validated data and is used to support multi-year analyses and provide specific data report and export formats. Details of the database, including a description of core and peripheral tables, a logical model of table relationships, and a data dictionary, are presented in SOP 6.

Data Entry

Accurate data recording is a central step in the overall QA/QC process. Data entry occurs directly into the PDAs so extra care should be taken to review all survey data while the observers are still in the field. In addition, the data entry form's built-in validation rules help detect missing data or illogical combinations. Uploading of data from the PDAs into the project database should be accomplished as soon as the UCBN data manager receives all units from field crews. The basic components for data entry into the handheld computers are described in SOP 6.

Quality Review

The Project Lead will review database for quality, completeness, and logical consistency. The working database application also facilitates the review process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. If some errors and inconsistencies cannot be fixed, they will be documented and included in the metadata and certification report.

Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are useable for their intended purposes well into the future. This documentation involves the development of metadata, which can be defined as structured information about the content, quality, and condition of data. Additionally, metadata provide the means to catalog data sets within intranet and internet systems, making data available to a broad range of potential users. Metadata for Lemhi penstemon monitoring data will conform to Federal Geographic Data Committee (FGDC) and NPS guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized. For long-term projects like this one, metadata creation is most time consuming the first time it is developed; after which most information remains static from year to year. Metadata records in subsequent years then only need to be updated to reflect current publications, references, taxonomic conventions, contact information, data disposition and quality, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for metadata development and posting are outlined in the UCBN Data Management Plan (Dicus and Garret 2007). In general, the Project Lead, UCBN Ecologist (if different from the project lead), and the Data Manager (or Data Technician) work together to create and update an FGDC- and NPS-compliant metadata record in XML format. The UCBN Ecologist will update metadata content as changes to the protocol are made, and each year, during analysis, reporting, and project close-out processes. Edits within the document should be tracked so that any changes are readily apparent to those who will use it to update the XML metadata file. At the conclusion of the field season, the Project Lead will be responsible for providing a completed, up-to-date metadata interview form to the Data Manager and UCBN Ecologist. The Data Manager will facilitate metadata development by creating and parsing metadata records, and by posting such records to national clearinghouses as described below.

Sensitive Information

Metadata development includes determining if the data contain sensitive information such as specific locations of rare, threatened, or endangered species, and cultural resources. In some cases, it may be necessary to restrict access to data containing sensitive information, except where a written confidentiality agreement is in place. The Project Lead and Park Resource Manager should work together to identify any sensitive information in the data. Their findings should be documented and communicated to the Data Manager and UCBN Ecologist.

Data Certification

Data certification is a benchmark in the project data-management process that confirms 1) the data are complete for the period of record; 2) the data have undergone and passed quality assurance checks; and 3) the data are appropriately documented and suitable for archiving, posting, and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may not have been detected during quality assurance reviews.

To ensure that only data of the highest possible quality are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead and UCBN Ecologist (if different than the project lead) together are responsible for

completing certification. The certified data and updated metadata should be delivered to the Project Lead as well as the UCBN Data Manager at the end of the field season. Additional details of the certification and delivery processes are included in SOP 6.

Data Analysis

Annual Status Analysis

Status results will be summarized and reported in an NPS Natural Resource Technical Report or Data Series report (<http://www.nature.nps.gov/publications/nrpm/>) each October following field work. Four annual reports (Rodhouse 2016, Rodhouse and Stucki 2013a, 2013b, Stucki and Rodhouse 2009) from pilot surveys provide excellent templates for future reports. Point estimates and 95% confidence intervals for Lemhi penstemon and spotted knapweed population totals (N) from extensive plot survey data are obtained using the Horvitz-Thompson estimator and the modified Horvitz-Thompson “local” variance estimator developed for GRTS surveys (Stevens and Olsen 2003, 2004). The *spsurvey* library (Kincaid and Olsen 2012) in the R statistical software environment (R Development Core Team 2013) makes these calculations very fast and accessible. Details, including R scripts, are provided in SOP 7. A summary table similar to those provided by Rodhouse 2016 or published in Stucki et al. (2013) of survey and population attributes, including the total number of plots surveyed, number of penstemon and knapweed plants counted, and frequencies and averages per plot, will also be routinely reported. Summaries of intensive plot data will be reported similarly. These simple summaries can be used in State of the Parks reporting, resource briefs, and other interpretive media. Figure 10 shows the annual status estimates for Lemhi penstemon and spotted knapweed population sizes generated with *spsurvey* from extensive-plot data from 2009-2017. R code to produce this figure is included in SOP 7.

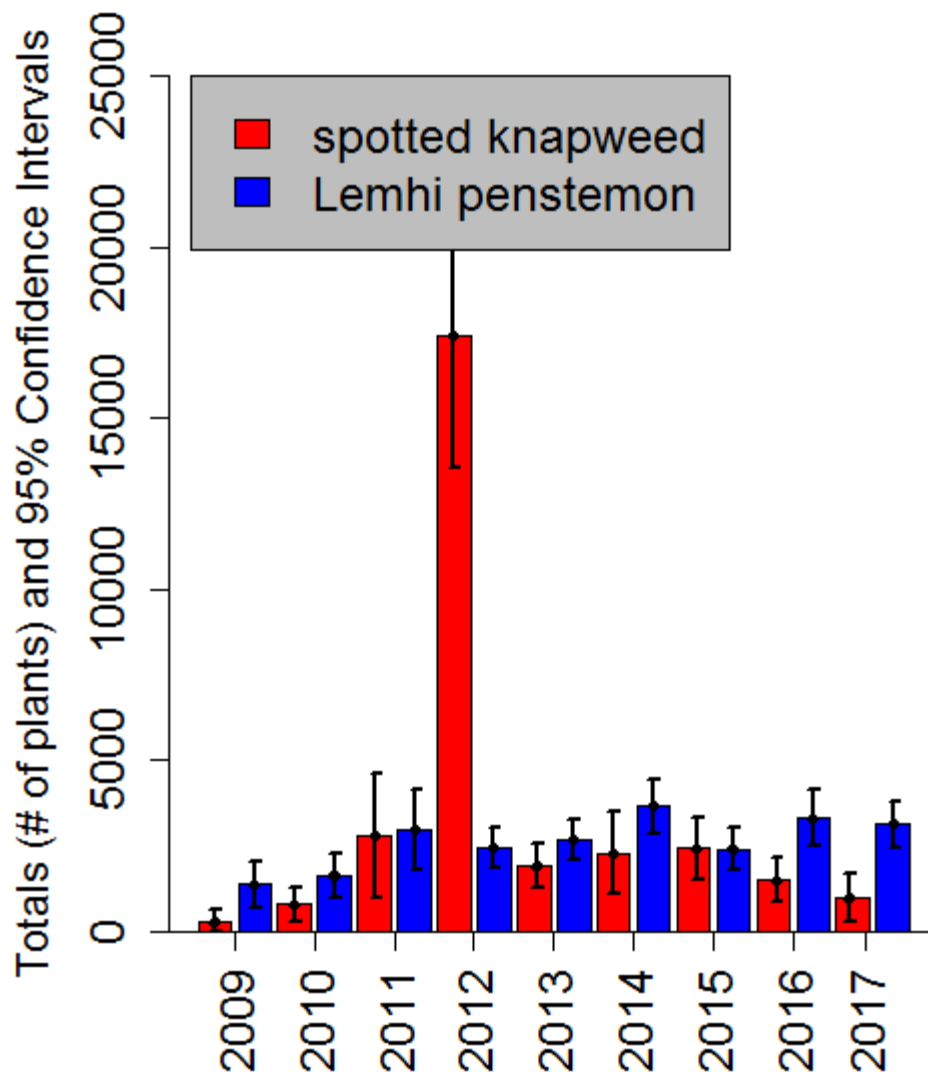


Figure 10. Annual status estimates for Lemhi penstemon and spotted knapweed populations in BIHO, 2009-2017.

Trend Analysis

Trend analyses will be conducted on a periodic basis as data become available. We demonstrate trends in population abundance (λ) using the 2009-2014 extensive plot data; trends in fecundity (γ) using the 2012-2014 intensive plot data; and trend in survivorship (Φ) using 2012-2017 intensive plot data in SOP 7. Rodhouse (2016) also provides a more thorough example for trend modeling using extensive and intensive plot data through 2014. We include covariates that illustrate how management-relevant hypotheses will be tested and used to guide decision-making. We estimate population change over time and changes in fecundity using generalized linear mixed models with a negative binomial link function appropriate for the overdispersed counts of plants in plots. We use a

mixed-effect Cox proportional hazards model to estimate differences in survivorship between cohorts of burned and unburned plants. The mixed-modeling strategies allow us to estimate random effects for repeated observations made within the intensive permanent plots over time and account for the serial correlation that is induced from repeated measures.

Figure 11 shows the similarity between the distribution of counts of established Lemhi penstemon plants and simulated data from a negative binomial distribution with the same mean and dispersion parameter as that estimated from the observed data. Spotted knapweed is also highly overdispersed and will be modeled using the same approach (SOP 7). Following the parameterization recommended by Hilbe (2011) for negative binomial regression, we define the (vector of) counts of plants as $Y_i \sim \text{Negative-binomial}(\mu, \alpha)$, with mean $\mu = e^{X'\beta}$ and variance $\mu + \alpha\mu^2$, and overdispersion α . The regression predictors $X'\beta$ (e.g., year and slope) are linearly related to the mean on the log scale via the negative binomial link function such that exponentiated regression coefficients are interpreted in terms of a multiplicative change in the growth rate, λ , for each unit change in a given predictor (holding all other predictors included in the model constant). This modeling strategy provides a natural connection to the monitoring and sampling hypotheses and objectives, illustrated in Figure 6. It provides flexibility for addressing questions about the influence of prescribed fire, and environmental factors such as slope and aspect because they also can be included as regression covariates. This same approach will be used to model change in the seedling rate (γ) from seedling counts obtained from the intensive plots and in the annual mortality rate ($1-\Phi$) obtained from counts of live-to-dead transitions observed for tagged mature plants. The *glmmADMB* function in the *glmmADMB* library (Fournier et al. 2012, Skaug et al. 2014) in R provides one way to construct and fit these models (SOP 7).

An alternative approach for estimating mortality rate ($1-\Phi$) is to directly estimate survivorship (probability of survival) of tagged plants with mixed-effects proportional hazards models (i.e., a “frailty” model, similar to Cox proportional hazards model; Cox [1972], McGilchrist and Aisbett [1991]). This approach also provides a direct link to the hypotheses of interest related to survival of established plants (Φ) over time, and among different groups of plants (e.g., plants in burned or unburned blocks or in different microsites). Specifically, this model links survival at time t , $\Phi(t)$, to a baseline hazard function (proportional to a survival curve) $\Phi(t)$ adjusted by fixed effects and random effects in a multiplicative link as $e^{X'\beta + Zb}$, β is the vector of fixed-effect coefficients and b is the vector of random effects coefficients. We demonstrate this with 2012-2017 intensive plots data in SOP 7, using the *coxme* function in the *coxme* library in R (Therneau 2015).

Lemhi penstemon count distribution

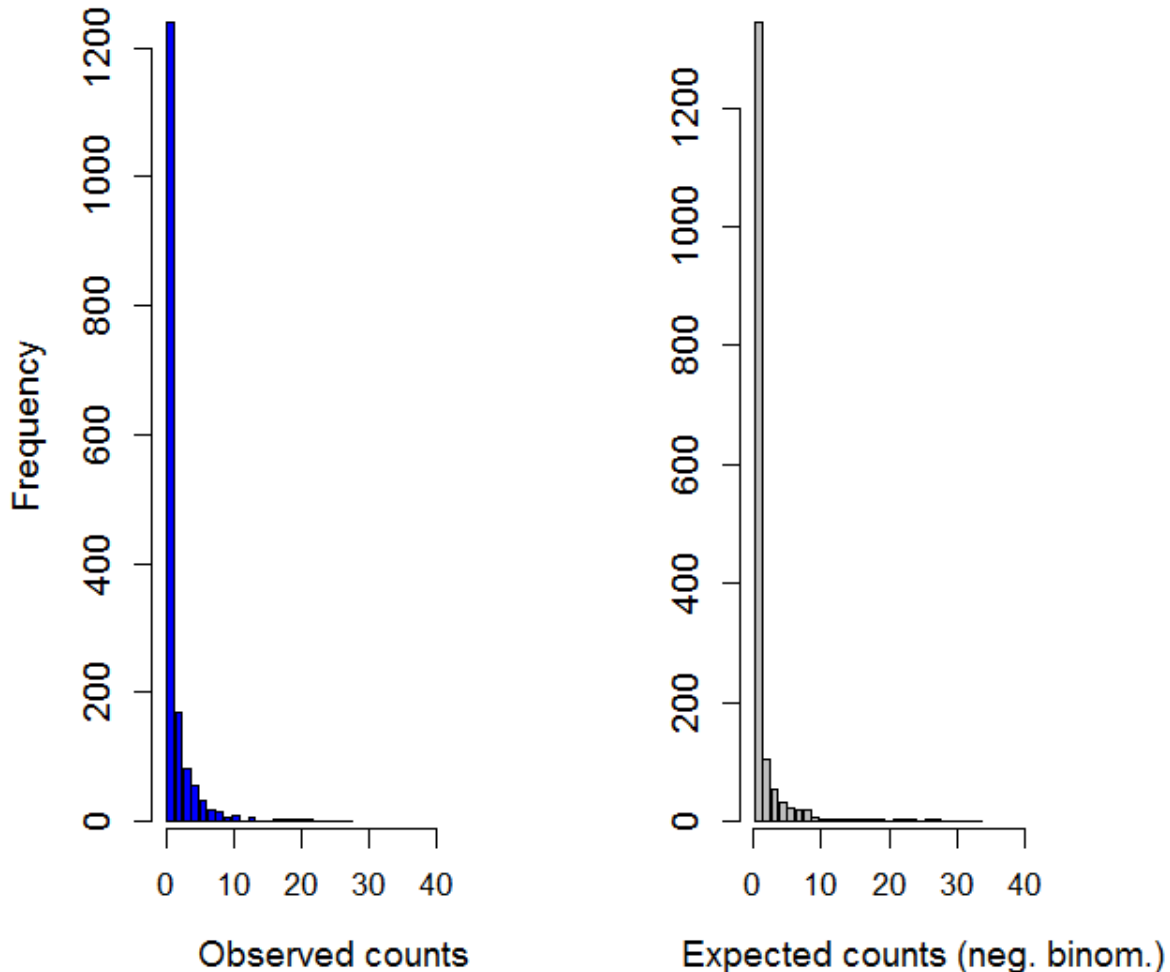


Figure 11. Lemhi penstemon count distributions from observed data (blue, left panel) and a negative binomial model (gray, right panel).

Fire Effects Hypothesis Testing

The mixed-effects models described in the preceding section provide an intuitive conceptual and statistical linkage to directly estimate fire and weed management effects. We will use these models as in a fixed-effects analysis of covariance (ANCOVA) context in which counts of plants and seedlings, or rates of individual plant survival, are related to discrete and continuous fixed effects, including burn and weed treatments, via models. Random effects will be used to account for the repeated measures on permanent intensive plots. Models will be developed separately for the extensive plots and the intensive plots, providing separate lines of evidence. We demonstrate such an approach using pilot data and simulation in SOP 7.

Auxiliary Information Used to Characterize Microsites and Influential Climatic and Management Events

Integrating auxiliary information that represents management actions and microsite conditions is a critical component of this protocol. Fire and weed management activities will be retrieved from Battlefield (or proxy, e.g., Glacier Fire Management officers) on an annual, or in the case of infrequent fire, after each event (e.g., Appendix A). Weed management actions undertaken by Battlefield and Exotic Plant Management Teams is reported annually to NISIMS, and NISIMS reports, available to NPS users via the Information Resources Management Applications (IRMA) portal, will be used at the time of data analysis to construct binary indicator variables representing sprayed/not sprayed indicator variables in regression models (SOP 7). Appendix A provides all necessary information for constructing burned/unburned binary indicator variables and also quantitative burn severity covariates from the September 2014 Rx burn of block 1. Similar information will be provided by Battlefield staff or Glacier Fire Management staff if future blocks are burned. Climate and weather information will be extracted from the Climate Analyzer web portal (<http://www.climateanalyzer.org/>) at the time of analysis (SOP 7). Microsite characteristics will be constructed from slope, aspect, and ground cover measurements (SOP 6 and SOP 7). Extensive plot analysis will benefit from other measures of ground cover, for example normalized difference vegetation indices (NDVI) developed from high-resolution near-infrared aerial photography produced and archived by the National Agricultural Imagery Project (<https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/>). Rodhouse (2016) provides a thorough example of how this auxiliary information can be integrated into trend analyses.

Reporting

An annual summary report will be produced after each year of data collection, with a more detailed report produced approximately every five years. The annual report will:

- Provide a summary of results.
- Provide summary status statistics and interpretation of the results relative to management and monitoring hypotheses and objectives.
- Evaluate data quality and identify any data quality concerns and/or deviations from protocols that affect data quality and interpretation.
- Evaluate and identify suggested or required changes to the protocol.

Annual reports have been produced following the 2009, 2012, 2013, and 2014 surveys and can be used as templates to guide future reports (Stucki and Rodhouse 2009, Rodhouse 2016, Rodhouse and Stucki 2013a, 2013b). A one-page resource brief will also be prepared from this annual report that will be provided to superintendents, park interpretive staff, and resource managers. Resource briefs have also been produced for each year from 2009-2017 and are available on the UCBN website (<http://science.nature.nps.gov/im/units/ucbn/>). Information from the annual summary report will also

be provided to parks in time for park reporting and for informing and evaluating park resource stewardship strategies and State of the Parks reports.

A more in-depth trend report will be produced approximately every five years (e.g., Rodhouse 2016). This report will provide greater analytical and interpretive detail, and will evaluate the relevance of findings to long-term management goals. In particular, these trend reports will evaluate findings from both intensive and extensive plot surveys in the context of management and monitoring hypotheses and objectives, including fire effects, if prescribed fire plans are carried out. The report will also evaluate operational aspects of the monitoring program and recommend necessary protocol updates.

Annual reports and trend reports will use the NPS Natural Resource Publications templates, pre-formatted Microsoft Word template documents based on current NPS formatting standards. Template guidelines and documentation of the NPS publication standards are available at the following address: <http://www.nature.nps.gov/publications/NRPM/index.cfm>. Additionally, publication of particularly interesting findings relevant to the broader scientific community-at-large will also be occasionally pursued, in a manner similar to Stucki et al. (2013).

Current versions of the protocol, resource briefs, reports, and journal publications will be made available on the UCBN website (<http://science.nature.nps.gov/im/units/UCBN/index.cfm>), from the national Natural Resources Publications Management (NRPM) website (<http://www.nature.nps.gov/publications/NRPM/index.cfm>), and on the NPS Integrated Resource Management Applications (IRMA) portal (<http://irma.nps.gov>).

Data Archival Procedures

Upon certification, data and reports will be archived on the UCBN Network Attached Storage (NAS) unit and on the NEPE and BIHO servers, posted to the UCBN website, and posted to the national web-accessible secure database hosted by the NPS Washington Areas Support Office or National I&M program and accessible through the NPS IRMA portal (<https://irma.nps.gov>).

Protocol Testing and Revision

Pilot data were collected at BIHO during 2009-2017, and reported by Stucki and Rodhouse (2009), Stucki et al. (2013), Rodhouse and Stucki (2013a), Rodhouse and Stucki (2013b), and Rodhouse 2016. These pilot efforts were instrumental in helping the UCBN and BIHO develop and test this protocol. In 2010, we compared a strip adaptive cluster sampling (SACS) design with the GRTS design, and presented these findings at the 2011 George Wright Society biennial meeting and Stucki et al. (2013) also briefly discussed this work. The GRTS design provided a more precise population estimate than the one obtained from the SACS design, and was easier to implement in the field and required a simpler data entry and management scheme. We have learned that on the Battlefield hillslopes, Lemhi penstemon typically grows in very small discrete clusters of one to few plants, and therefore adaptive sampling does not provide a benefit relative to the added design and implementation complexity. Likewise, for spotted knapweed, dense weed patches make it impractical to tag and track individual plants; moreover these plants are actively being sprayed with herbicide and program objectives are met with simple plant counts.

Over time, revisions to both the protocol narrative and specific SOPs are expected. Careful documentation of any changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate summary analyses. The database for each monitoring component will contain a field that identifies which version of the protocol was used when the data were collected. The protocol narrative is a general overview of the protocol that gives the history and justification for doing the work and an overview of the sampling methods, but that does not provide the methodological details. The protocol narrative will only be revised if major changes are made to the protocol. The SOPs, in contrast, are specific, step-by-step instructions for performing tasks. They are expected to be revised more frequently. It will only rarely be necessary to revise the protocol narrative to reflect specific changes in an SOP. All versions of the protocol and SOPs will be archived in a project digital library on the UCBN Network Attached Storage (NAS) server and on the BIHO server. Current versions will be served off of the UCBN website and the national I&M protocol database, as well as from the IRMA portal.

The steps for changing the protocol (either the narrative or an SOP) are given in SOP 8, “Revising the Protocol”. Each SOP contains a change log that must be filled out each time an SOP is revised to explain why the change was made and to assign a new version number to the revised SOP. The new version of the SOP or Protocol Narrative will be archived in the project library under the appropriate folder. A revision history log in SOP 8 will also document revisions over time.

Personnel Requirements and Training

Personnel Requirements and Roles and Responsibilities

The UCBN project lead will ensure that adequate qualified field personnel are assembled and prepared prior to each field survey event. Six people are required to complete both extensive and intensive plot surveys within a 1-week period. Since 2009, staff from the UCBN, NEPE, and BIHO have completed surveys during the same week that camas lily monitoring is conducted in BIHO, taking advantage of the co-location of these two efforts and leveraging staff time. Table 2 outlines details of the roles and responsibilities of staff from the UCBN, NEPE, and BIHO. Note that NEPE staff is heavily involved because of their larger natural resource program capacity and their on-going administrative and programmatic support for BIHO.

Qualifications, Training and Calibration

Although this protocol does not require highly advanced plant identification skills among all team members, at least three well-trained and experienced people are required to lead the three, two-person field teams. Training can then be carried out as a group at the start of the survey and in “real time” in team settings throughout the survey. The most important qualification is that of the project lead, who must be well-trained in botany and field ecology, and must have first-hand knowledge of the Battlefield hillslope steppe ecosystem. The UCBN staffing plan (Garrett et al. 2007) also provides for a well-trained botanist to serve as field crew lead and this person typically will accumulate as much, if not more, first-hand field experience than the project lead over time. Either the project lead or the UCBN field crew lead, or both, will participate in field surveys, unless extenuating circumstances prevent that and a well-experienced replacement, perhaps from the NEPE resource staff, is available to lead and provide training. Several staff members from NEPE and BIHO have become very well versed with the program and adept at field leadership and training over the pilot study period. These individuals can be relied upon to lead crews, although in the event of staff turnover, the UCBN will assume responsibility to ensure that a sufficient, adequately skilled crew is assembled each season. Note that intensive plot surveys require participation from the most experienced personnel (e.g., the project lead and field crew lead), although these staff can be paired with inexperienced staff who are dedicated data recorders.

Table 2. Roles and responsibilities for implementing the Lemhi penstemon and spotted knapweed monitoring program in BIHO.

Role	Responsibilities	Name/Position
Project Leader	Project oversight and administration. Track project objectives, budget, requirements, and progress toward meeting objectives. Facilitate communications between NPS and cooperator(s). Coordinate and ratify changes to protocol. Acquire and maintain field equipment. Assist in training field teams. Perform data summaries and analyses. Maintain and archive project records. Oversee project operations and implementation. Certify each season's data for quality and completeness. Query park staff for management actions and update project database with annual updates. Complete reports, metadata, and other products according to schedule.	UCBN Ecologist
Field Leader	Direct training and safety of field teams. Plan and execute field visits. Oversee data collection and entry; verify accurate data transcription into database. Complete a field season report.	UCBN Ecologist or designated field crew lead
Field Technicians (6)	Collect, record, enter and verify data.	UCBN, Park, university employees (via cooperative agreements), or interns (e.g., Student Conservation Association)
Data Manager	Consultant on data management activities. Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule. Maintain and update database application. Provide database training as needed. Consultant on GPS use and data collection tools. Work with Project Lead to analyze spatial data and develop metadata for spatial data products. Primary steward of Access database and GIS data and products.	Network Data Manager

Table 2 (continued). Roles and responsibilities for implementing the Lemhi penstemon and spotted knapweed monitoring program in BIHO.

Role	Responsibilities	Name/Position
Program Manager	Project leader oversight. Administration and budget. Consultant on all phases of protocol review and implementation. Review of annual and comprehensive reports.	Network Program Manager
Park Resource Managers	Consultant on all phases of protocol implementation. Facilitate logistics planning and coordination. Communicate management and restoration plans and associated information to Project Lead. Assist with field data collection when feasible. Review reports, data and other project deliverables.	Park Resource Manager or representative

Operational Requirements

Annual Workload and Field Schedule

The ideal phenological window for Lemhi penstemon and spotted knapweed monitoring is in late June when the penstemon plants are blooming or nearly in bloom, and while knapweed plants are still in visible rosette stage but not yet flowering (creating an opportunity for us to direct efficient weed management prior to seed production). Monitoring should be delayed until after the Lemhi penstemon plants have begun to develop inflorescences, as this is one of the measured response variables. Communication with BIHO can help ensure appropriate timing each year. Sampling can be accomplished within the span of one week provided ample field personnel (at least three teams of two observers each) are available. This period of time includes training of field personnel at BIHO prior to the start of sampling. Additional time outside of sampling period will be required from the project lead, data manager, and field leaders for field preparation, data entry and validation, analysis of data, and reporting. Table 3 details the annual workload and schedule.

Table 3. Annual schedule of major tasks and events for the Lemhi penstemon and spotted knapweed monitoring protocol.

Month	Administration	Field Preparation/Fieldwork	Data Management/Reporting
January	Network annual report and work plan for upcoming season complete.	Begin process for hiring seasonal staff and scheduling travel to BIHO, housing, and vehicles	Query park staff for updated prescribed fire information and, if applicable, compile reference information as in Appendix A.
February	—	—	—
March	—	Draw and organize sample sites; prepare maps and field data sheets	—
April	—	Prepare field and GPS equipment and training manuals.	—
May	—	—	—
June	—	Train field crews and complete sampling.	—
July	—	—	—
August	—	—	—
September	Close-out of fiscal year.	—	Data entry and verification; complete annual report, annual resource brief prepared for network meetings, compile extensive plot slope and aspect data.

Table 3 (continued). Annual schedule of major tasks and events for the Lemhi penstemon and spotted knapweed monitoring protocol.

Month	Administration	Field Preparation/Fieldwork	Data Management/Reporting
October	Prepare & submit budget estimate for fiscal year; draft annual work plan.	Clean and store equipment	Metadata production, quality review; data certification complete; data archival and posting
November-January	—	—	Prepare and publish longer reports and manuscripts as appropriate

Facilities and Equipment Needs

A list of necessary and recommended field sampling equipment is given in SOP 1. Day trips out into the Battlefield are required for this protocol. June weather can be challenging in BIHO, with very hot days interspersed with very cold and rainy days. Mosquitoes can be a nuisance. Personal protective equipment will include adequate clothing that can be layered in order to enable quick response to changing weather and that can provide protection from mosquitoes. Hats, sunscreen, insect repellent, and water bottles are essential items. Lunches are typically taken out on the hillslopes and must be packed in daypacks. A vehicle is required to transport crew from BIHO housing down to the trailhead for accessing the hillslopes. The visitor center subpopulation can be accessed by hiking directly from the housing area or visitor center. Park housing is not a requirement for this protocol, but may be offered to outside personnel traveling to assist with surveys, and is very helpful to expedite implementation of field work. Camping is available near the Battlefield at May Creek Campground on US Forest Service lands. Lodging is also available in the town of Wisdom. The Project Lead and NEPE and BIHO staff will coordinate equipment and housing logistics well in advance of the beginning of the field season.

Budget

Table 4 details the annual operating budget for this protocol, reflecting current costs.

Table 4. Annual budget for monitoring Lemhi penstemon and spotted knapweed in BIHO.

Monitoring Budget	Time allotted	% of time spent on DM*	Cost in dollars DM*	Cost in dollars (2017)
Expenditures	–	–	–	–
Permanent NPS Personnel	–	–	–	–
UCBN Project Lead (GS-12)	2 weeks field season prep and logistics; 1 week field survey; 4 weeks QA/QC, data archiving, annual analysis and reporting, close-out.	50%	\$5487	\$10973
NEPE Natural Resources Chief (GS-12)	1 week pre-season preparation review and logistics/consultation; 1 week post-season review and report editing; As available, 1 week field survey	75%	\$3528	\$4704
UCBN Program Manager (GS-13)	1 week pre-trip plan and post-trip report reviews and consultation with Project Lead	100%	\$1810	\$1810
UCBN Data Manager (GS-11)	1 week field season prep; 1 week QA/QC, data archiving and close-out	100%	\$2460	\$2460
UCBN Field Crew Lead (GS-9)	1 week field season prep; 1 week field survey; 1 week QA/QC, data archiving and close-out; 2 weeks analysis and reporting	50%	\$2464	\$4928
UCBN Field Crew Co-Lead (GS-7)	1 week field season prep; 1 week field survey; 1 week QA/QC, data archiving and close-out; 1 weeks analysis and reporting	50%	\$1611	3222
Seasonal Personnel	–	–	–	–
BioTechs or other supporting personnel (GS-5) × 3	1 week training and preparation; 1 week field survey; 1 week post-season data entry, QA/QC, close-out	50%	\$2926	\$5853
Operations/Equipment	–	–	–	\$250
Housing (6 persons)	–	–	–	NA
Travel – UCBN vehicle	–	–	–	\$500
Travel – NEPE vehicle	–	–	–	\$500
Other (contingency)	–	–	–	\$1000
TOTAL	–	–	\$20,286**	\$36,200

* DM = data management

** More than 50% of the monitoring protocol budget is dedicated to data management, analysis, and reporting activities.

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Appendix A. Prescribed Fire Results for Burn Block 1 Conducted in September 2014

Prescribed Fire Experimental Design

A prescribed fire plan was developed for the Battlefield that is integrated into the long-term monitoring program (Harris 2013). The plan which was written by the Glacier National Park fire management team with substantial input from park and Network I&M staff outlines 4 consecutive fire treatments to be applied to each half of the two hillslopes during consecutive years (Figure A-1). The first treatment was applied to the southeast half of the Howitzer Hill (burn block 1) in September 2014 (Figure A-1). This was originally planned for 2012 but was delayed two years until it was evident that spotted knapweed infestations could be controlled (Harris 2013). The experimental design is a replicated asymmetrical before-after-control-impact (“beyond BACI” design; Green 1979, Overton 1994). This design supports strong causal inference to fire effects on Lemhi penstemon and spotted knapweed because of the highly-replicated structure in which each block is subjected to experimental treatment sequentially and treated and control plots are well replicated within each block. Importantly, the sequential asymmetry will enable climate and weather effects to be accounted for. Subsequent replicate burns in blocks 2-4 have not been conducted because of lack of financial and logistical resources available during fall wildfire fighting seasons, but over time it is anticipated that burn block 4 on the north end of the Horse Pasture will be completed first, and then blocks 2 and 3 will be completed subsequently.

Results of Rx Fire in Burn Block 1

Figure A-2 shows ignition activity and fire behavior. Figure A-3 shows results of fuel moisture measurements taken from vegetation clipped in the block during burn preparations. Figure A-4 shows the temperature at ~20 mm below ground as the fire raced through mid-slope block 1 over two temperature sensors. Figure A-5 shows the burn perimeter and the 9 intensive plots that were burned within that perimeter. Table A-1 shows the relative burn severity of those 9 plots, ranked by average changes in bare ground cover and qualitative inspection of pre- and post-burn conditions. Post-burn plot conditions were evaluated in October, 2014, one month after the burn. Figure A-6 shows burn severity of the entire block as measured coarsely using the normalized burn ratio (dNBR) from pre- and post-burn 30-m resolution Landsat imagery. Although coarse, this image generally aligns with the plot-level assessments made after the burn. Figure A-7 shows pre- and post-burn photos of the most severely burned plot.

**BIHO Pasture Rx Plan
BURN BLOCK MAP**

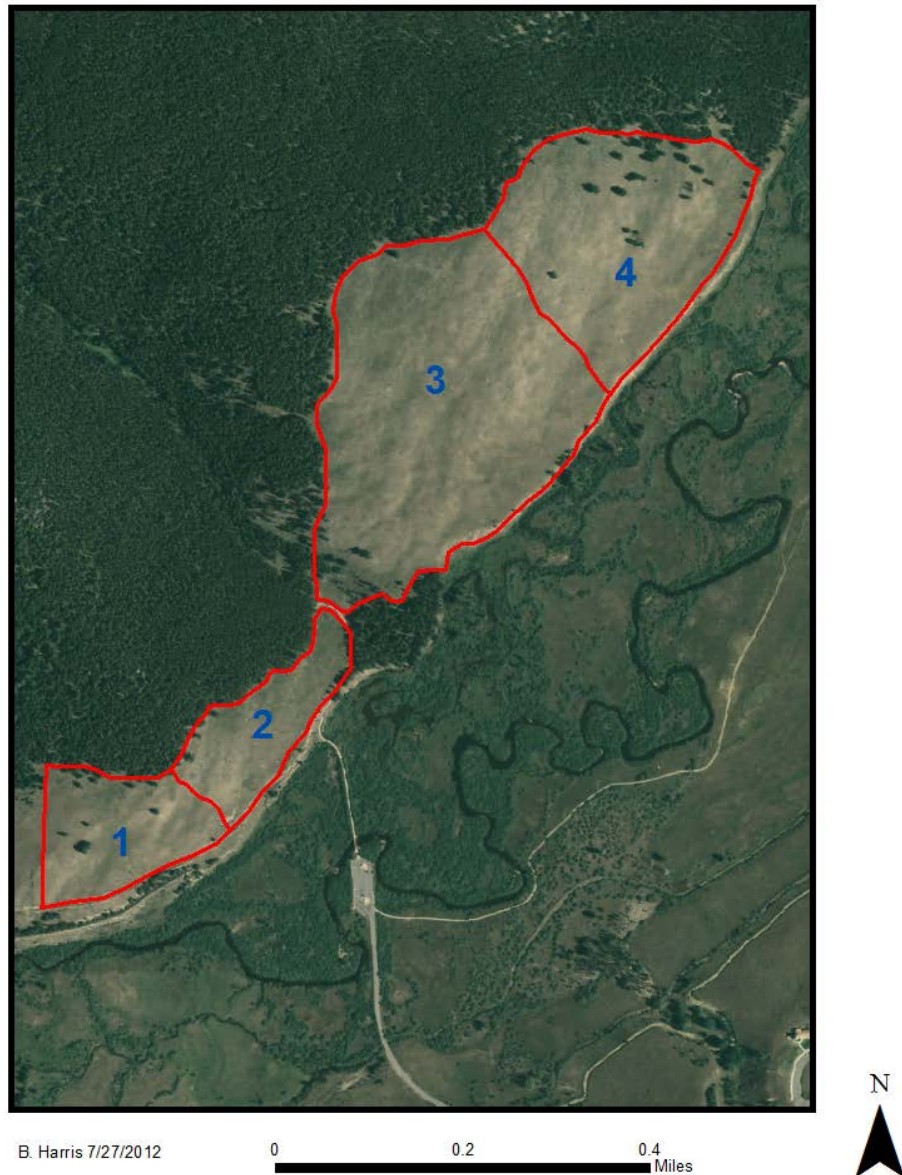


Figure A-1. The 4 proposed experimental burn blocks superimposed on to the Howitzer Hill and Horse Pasture long-term Lemhi penstemon and spotted knapweed monitoring study areas.



Figure A-2. Ignition of the prescribed burn in block 1, September 2014.

FUEL MOISTURE DATA SHEET

UNIT/LOCATION Pasture RX - BIHO North E Soil Sensor

COMMENTS Last Rain = 9-10-2014 0.01" Temp. = 46 RH = 48

DATE/TIME COLLECTED 09-13-2014 1000 hrs TIME IN /OUT OF OVEN 20 hrs

SAMPLERS Fire Effects Crew % FUEL MOISTURE = $\frac{\text{WET WT} - \text{DRY WT}}{\text{DRY WT} - \text{TARE WT}} \times 100$

SPECIES	CAN #	WET WT	DRY WT	TARE	W-D	D-T	%	COMMENTS
Soil Sample	40	242.0	236.0	108.0			4.7%	
Soil Sample	20	306.0	302.0	107.0			2.1%	
Soil Sample	4	251.0	249.0	108.0			1.4%	
Soil Sample	1	331.0	327.0	108.0			1.8%	
Soil Sample	15	341.0	338.0	105.0			1.3%	
							2.3%	

Figure A-3. Fuel moisture characteristics influencing the prescribed burn.

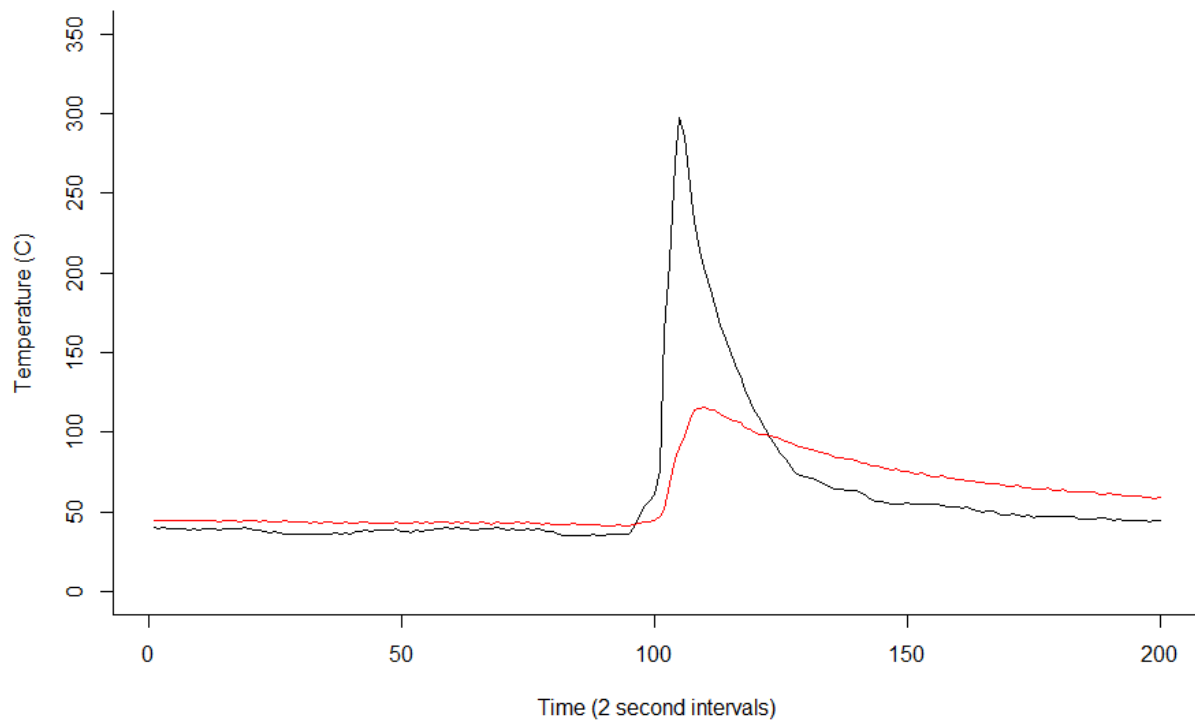


Figure A-4. Burn temperature profiles at two soil temperature data loggers, buried approximately 20 mm below surface. Note that the spike in temperature lasted approximately 1 minute as the fire raced uphill through dry fine fuels. Soil organic matter is low on the study area.



Figure A-5. The actual black-line perimeter of the first experimental burn in block 1, completed in September 2014. Nine intensive study plots were included in the perimeter. Plot 5 was excluded because firing technicians walked above the roadcut, unaware of the marked plot below them in the roadcut itself.

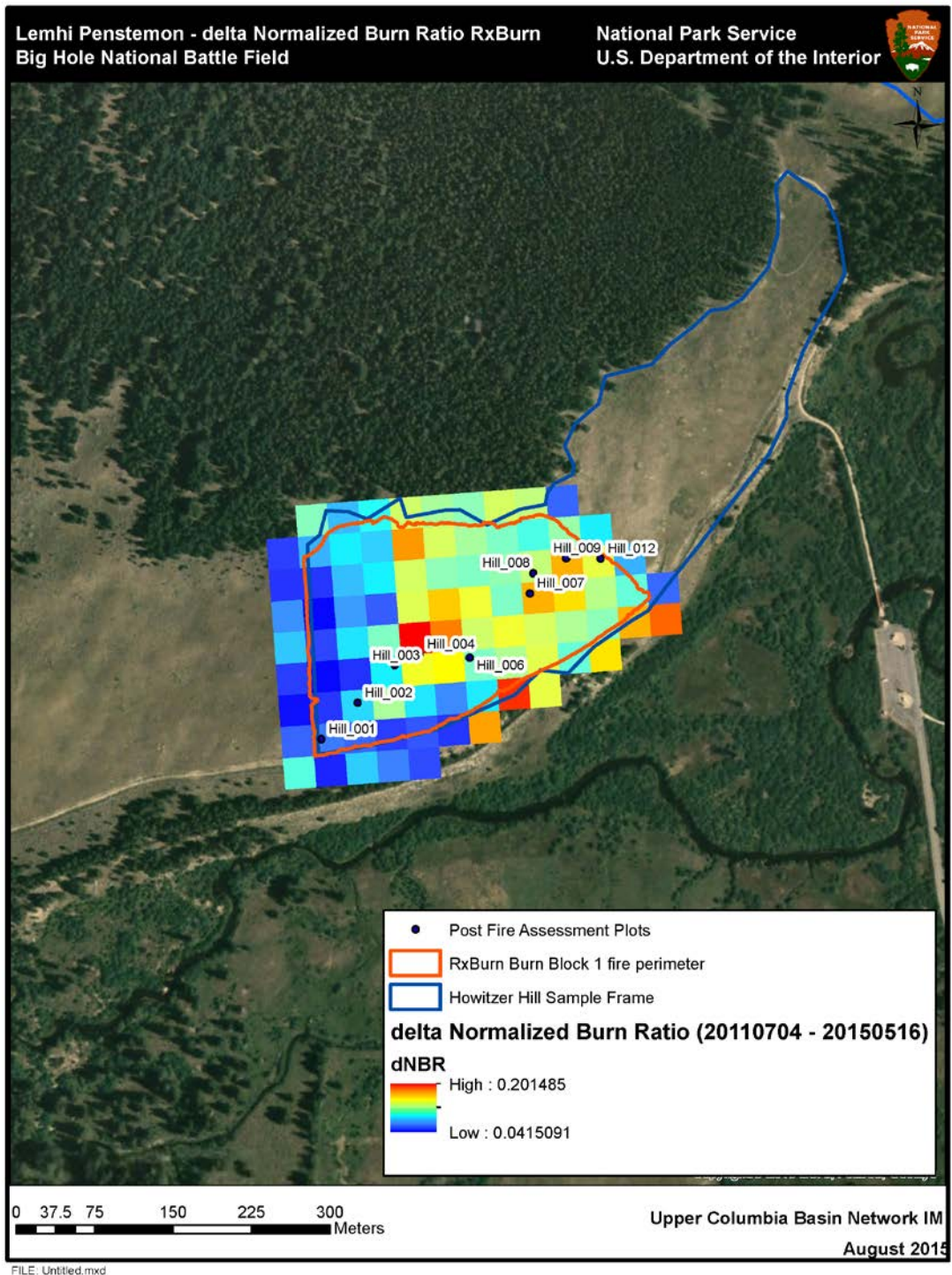
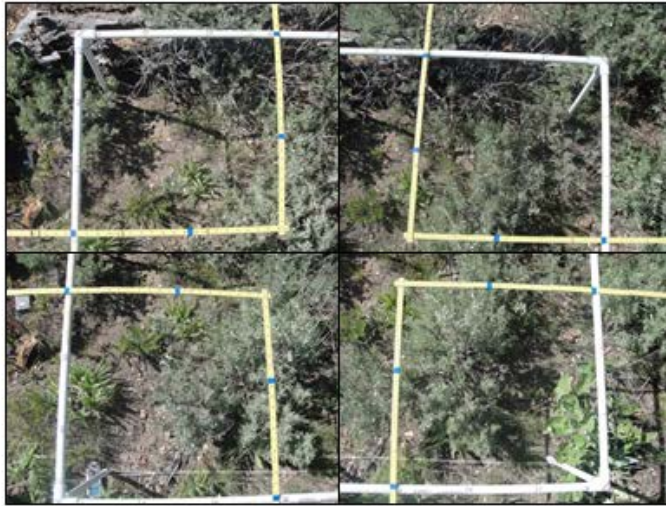


Figure A-6. Burn severity of burn block 1 following the September 2014 prescribed burn, measured using the normalized burn ratio computed from a pre-burn Landsat image dated July 4 2011 and a post-burn image dated May 16 2015. Although coarse, this severity map corresponds generally with plot-level assessments made by I&M staff in October 2014.

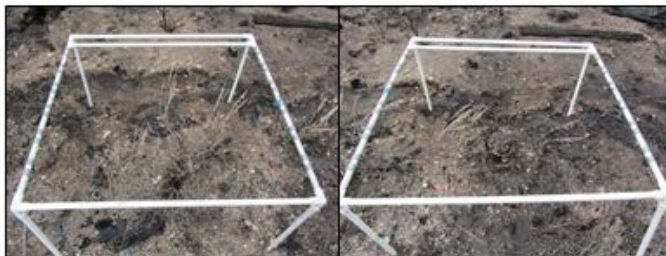
Table A-1. A ranking of burn severity of the 9 intensive plots within the burn block 1 perimeter. Rankings were based on change in bare ground and vegetation cover between June 2014 and October 2014, and with qualitative inspections of pre- and post-burn plot photographs (e.g., Figure A-7). Plots 6-8 increased in cover over the growing season, reflecting no loss of cover resulting from fire, although were still considered to have had some heat stress and, in general, non-zero fire impact.

Plot	Avg. Change Bare Ground	Rank
Hill_001	0.23	Low
Hill_002	0.16	Low
Hill_003	0.17	Low
Hill_004	0.42	High
Hill_006	-0.05	Very Low
Hill_007	-0.10	Very Low
Hill_008	-0.19	Very Low
Hill_009	0.24	Moderate
Hill_012	0.19	Moderate

Pre-burn June 2012



Post-burn October 2014



Post-burn June 2015



Figure A-7. Comparative photos of intensive plot 4, the most severely-burned plot among the 9 plots (see Table A-1). These and other photos taken before and after the Rx burn block 1 are stored at the UCBN offices.

Big Hole National Park Prescribed Fire Monitor Report from the Glacier National Park Fire Management Office

Pasture RX

9/13/2014

Burn Unit/Name: Pasture RX

Acres Burned: 12.95 acres

Dates Burned: 9/13/ 2014

Fuel Model(s): Mostly FM1 with some FM2

Personnel on Burn:

Burn Boss: Brad Harris (NPS)

Holding Crew: 11 (Anaconda Job Corps)

Holding: Cody Montgomery (USFS)

6 Forest Service – 2 engines

Ignition: Dennis Divoky (NPS)

Ignition Crew: 4 (NPS)

Monitors: Scott Lang/Katie Weidman (T) (NPS)

Background

The slopes of the NPS Big Hole Battlefield area were treated with fire in 1985?, 1988?, 1991 and 1997 by Forest Service Fire Management crews to assist the Park Service with tree encroachment and increasing sage on the steep slopes North of the visitor center. Lemhi penstemon is known to be growing on the disturbed slopes of the Battlefield and seems to be somewhat connected to disturbance including fire. The area that the Lemhi penstemon prefers is steep and southern facing consisting of mostly Idaho Fescue, Bluebunch Wheatgrass, Balsamroot, Rabbitbrush, Goldenrod, Sulphur Buckwheat, and Sagebrush. This earlier treatment was done in the spring and had good results. A fall burn period was picked for this treatment to try to match natural fire regimes in the area and the plant ecology of Lemhi penstemon.

Fire Behavior Observation

A test fire was conducted at 1103 hrs at the Northwest corner of the unit near the weather station. This test fire was favorable so black lining was started at 1130hrs on the upslope NW corner burning to the north and then to the East. Once black lining was completed strip firing was started at 1330hrs on the NW corner from the top of the Unit and continued toward the bottom of the Unit using a West to East and then East to West burn strip. Firing was completed at 1430hrs and the Unit smoldered and smoked in spots for a few hours into the evening. The Unit had a large patch on the West side of the Unit that did not burn that well due to low fuel in sparse vegetation, but the rest of the unit burned well due to good fuel loads, lowering humidity, and increasing winds. Sagebrush and rabbitbrush burned well but sagebrush could have been at a lower fuel moisture to create more mortality on the Unit. A cold front created a cloud mass that hung over part of the unit at about 1230 hrs which kept the RH up more than we would have liked but the Unit still burned well, mostly due to good winds. Average flame length was from 4"-5" during the test fire to averages of 1'-2' with highs of 10' at

times during the strip firing. The RH bottomed out at 19% at the end of firing at the bottom of the Unit. Winds averaged 4-5 mph with gusts as high as 12 mph during the burning period. Smoke monitoring observations showed good dispersal and light to moderate smoke volume for short periods during active burning. Rate of spread was estimated at 40 +/- chains per hour on the steep slopes of the Unit.

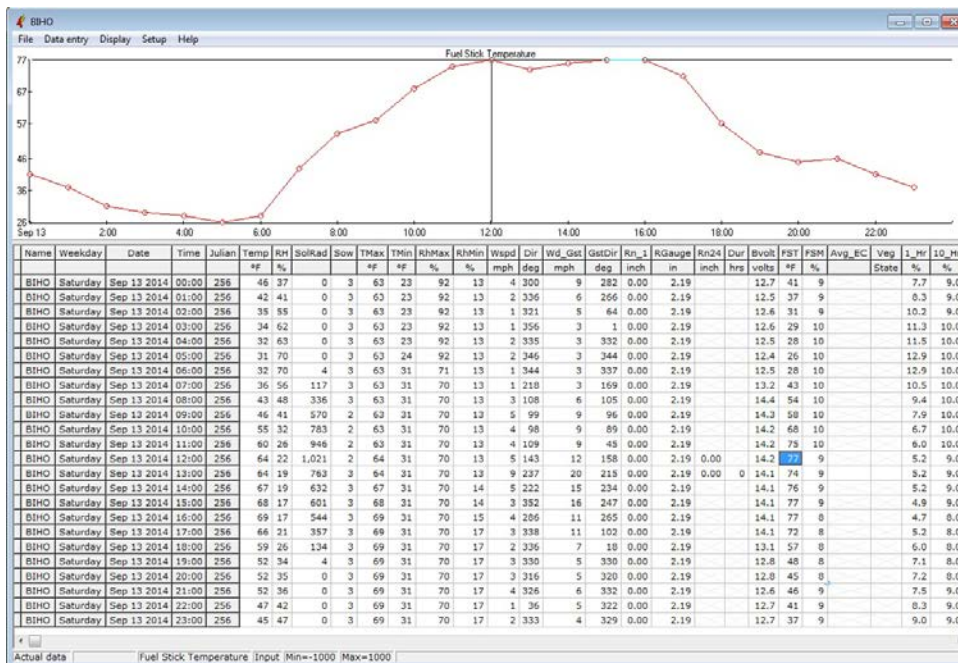
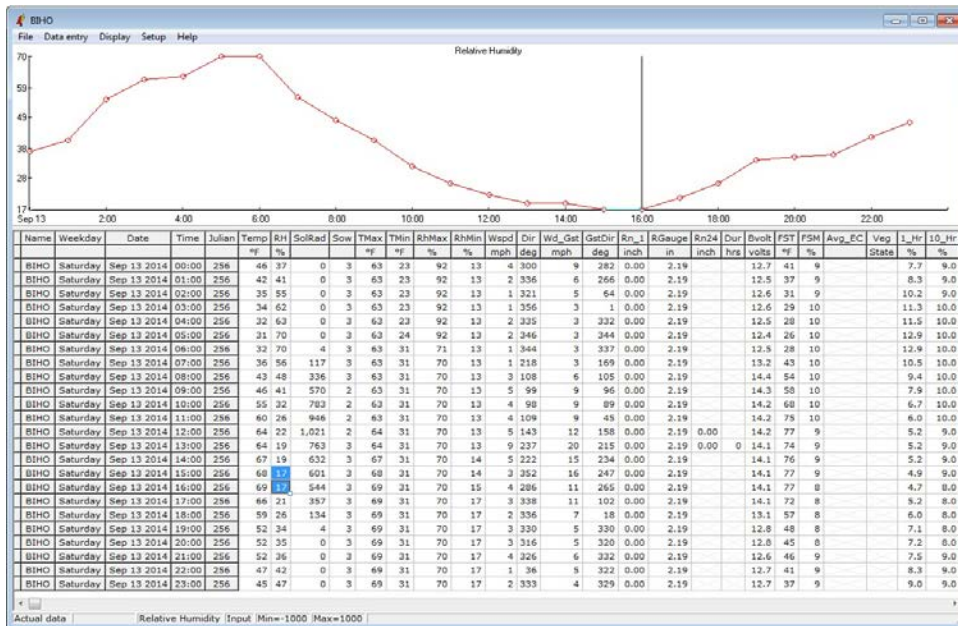
*5% to 50% slope; 6500 ft elevation; S-SE aspect

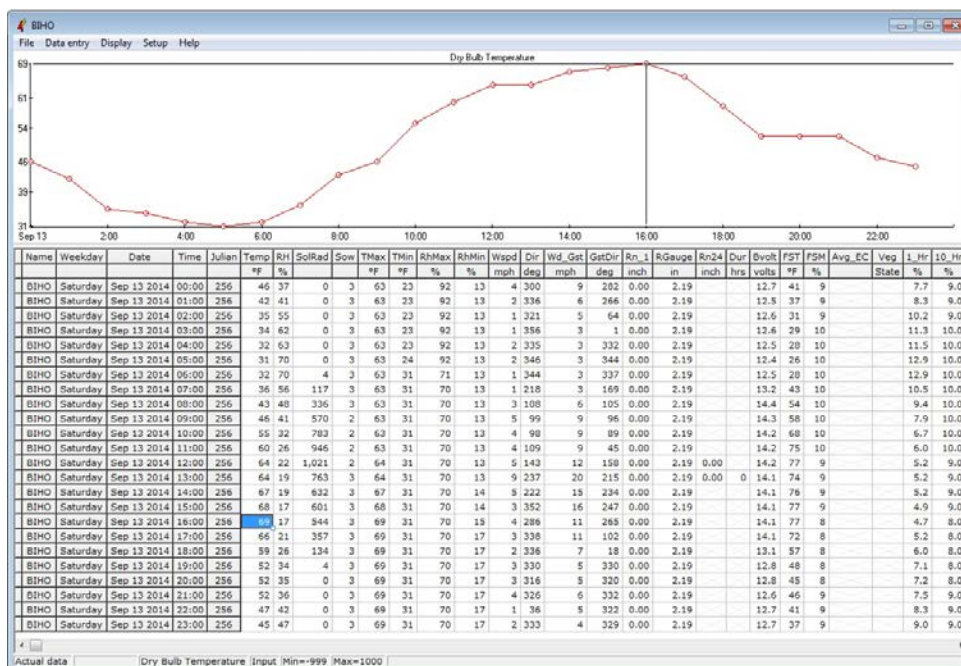
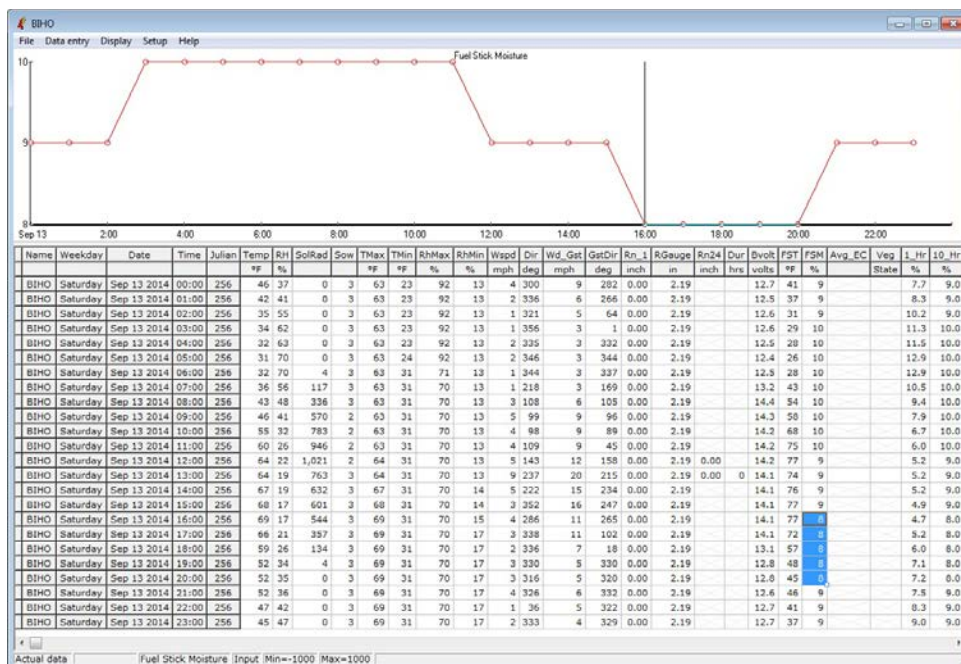
Pasture Rx Fire Weather (Sling)

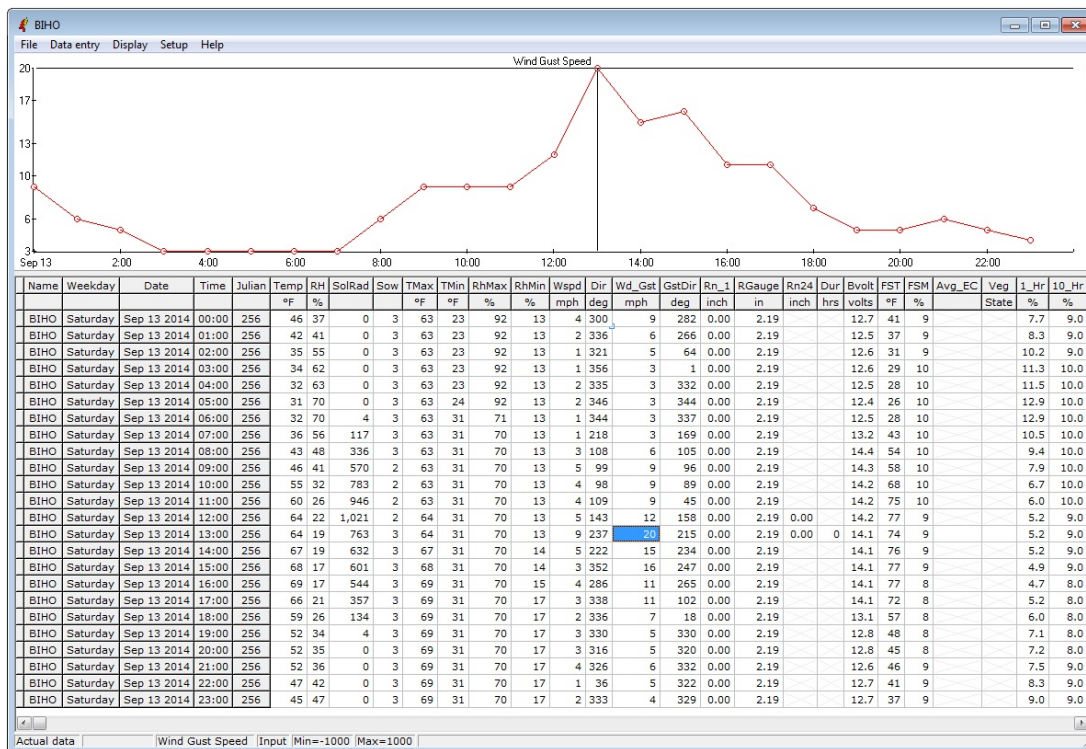
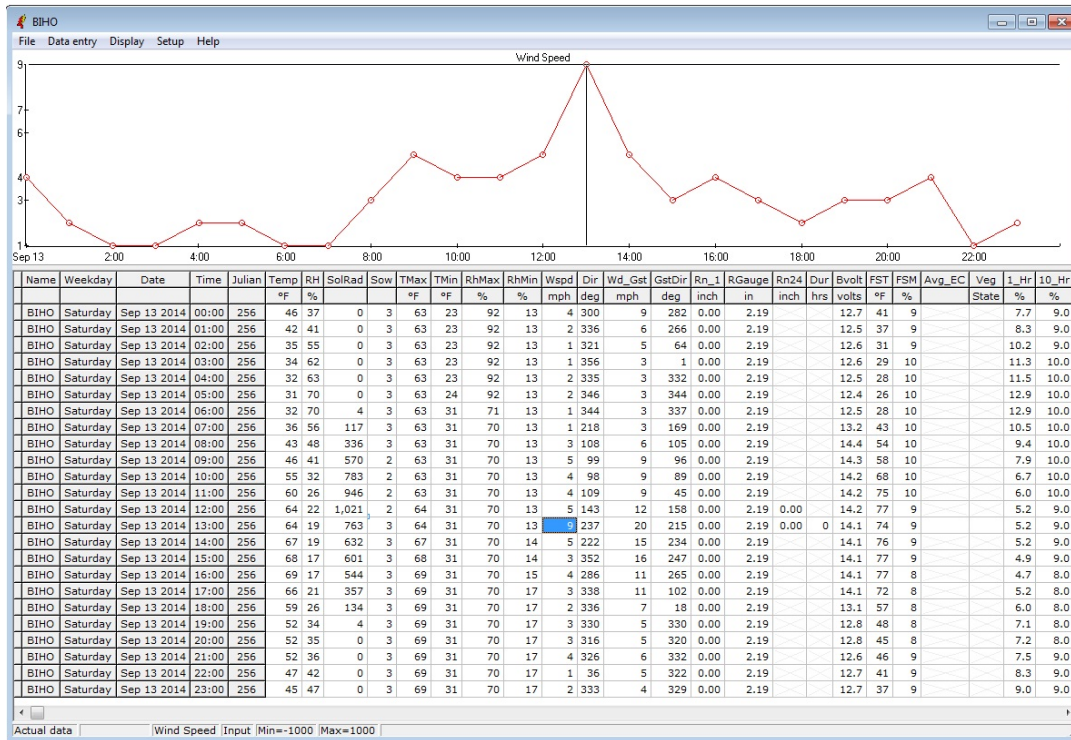
Date	Time	Dry	Wet	RH	Wind	Dir	FDFM	PIG	Comments
09-13-14	1100	46	36	41	2-6G7	E	8	40	–
09-13-14	1200	54	41	35	5G7	NE	7	40	Clds from North
09-13-14	1300	60	44	29	3-4G9.5	ENE	7	50	Still Clds from N
09-13-14	1400	64	46	26	7G11	SW	7	50	Clearing of Clds
09-13-14	1500	68	48	24	2-4G7	W-N	7	50	H. Clds & Low Smoke

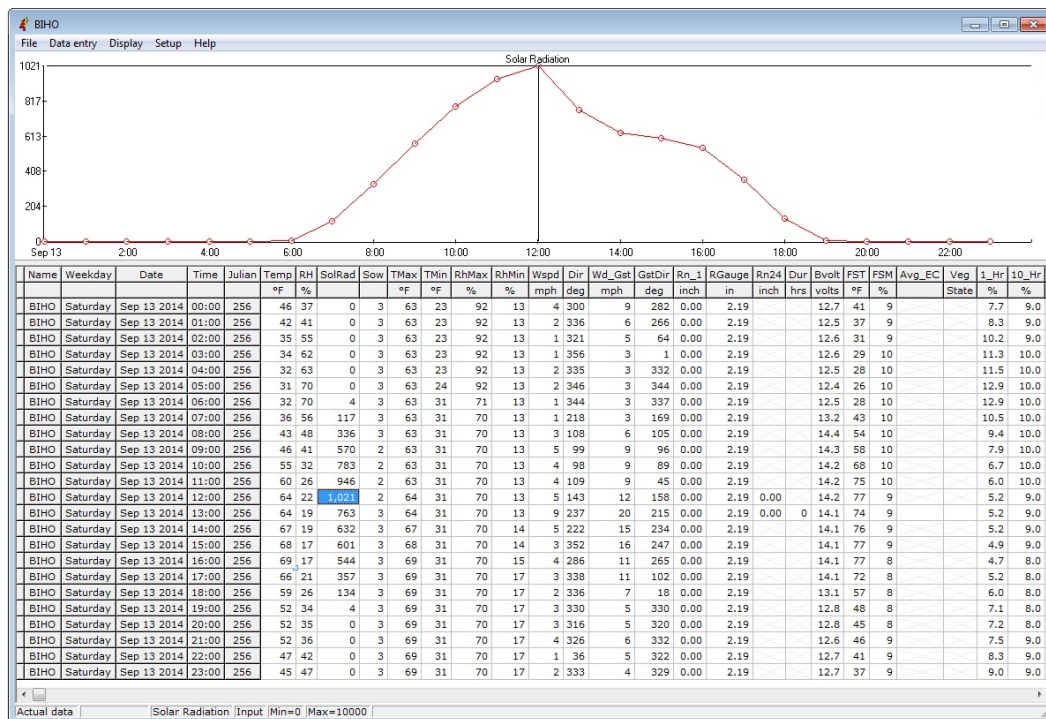
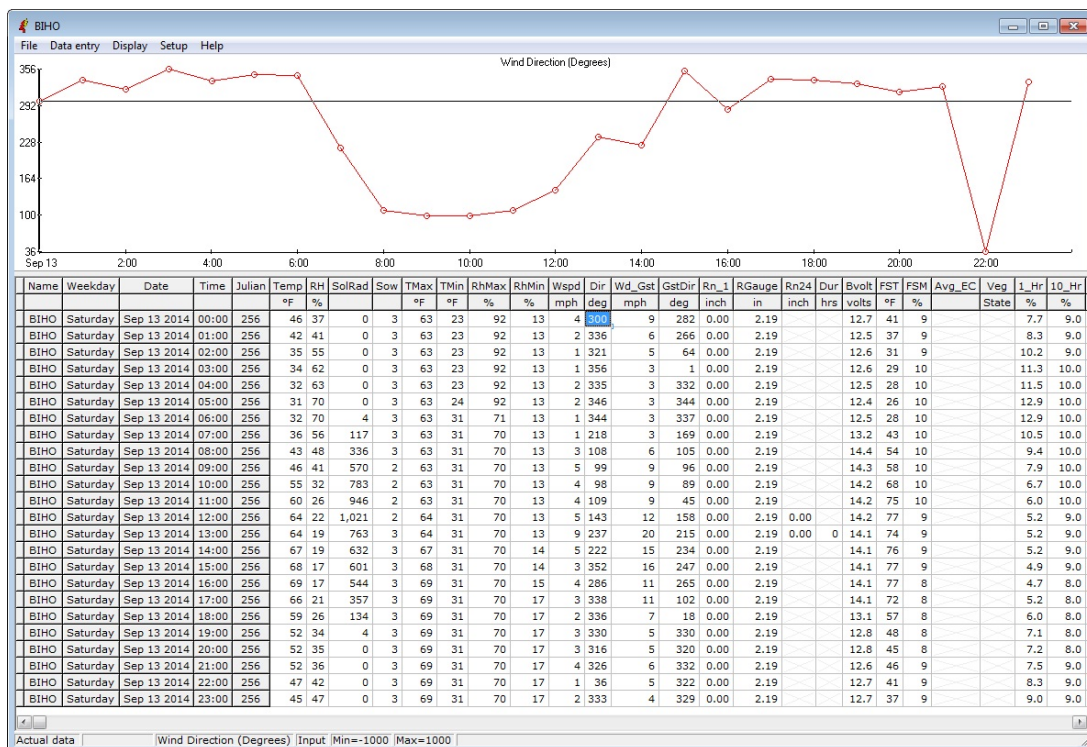
Pasture Rx Fire Weather (Kestrel)

Date	Time	Dry	RH	Wind	Dir	Cloud Cover
09-12-14	1730	64	12	10G15	W	0%
09-13-14	1130	55	31	1G7	E	0%
09-13-14	1230	60	29	3G8	E-NE	3%
09-13-14	1330	63	25	3-6	E	45%
09-13-14	1430	70	70	2-4	SW	5%









Burn Objectives:

Burn objectives were to restore fire as a natural fire regime disturbance on the open slopes of the Battlefield to increase Lemhi penstemon habitat while at the same time maintaining the historical landscape view of the Big Hole Battlefield. Removing conifer encroachment and setting back sagebrush was the main method to be used in restoring the historical landscape view at the Battlefield. Another objective was to not increase the non-native populations, mostly Knapweed, in the prairie ecosystem at the Battlefield while treating the area with fire.

Recommendations:

The use of the portable remote weather station was very useful and should be used again in the future if possible. Slightly lower humidities, slightly higher winds, and lower needle and sage fuel moisture might make the burn have higher mortality rates. Taking some fuel moistures preburn might help dial this burn unit in better in the future. This year has been a wet year and fuels may have been higher than typically found at this site during this season. Weed monitoring and eradication before and after the burn would be a good idea considering some knapweed is in the area.

Positives

- RX plan and logistics was well prepared and implemented.
- Trainee assignments for various firefighters both USFS, Job Corps, and NPS.
- Fire allowed to continue its role in natural processes at the Big Hole Battlefield.
- Decreased sage and tree encroachment on area meadow ecosystems.
- Lemhi penstemon resource management/ monitoring project treatment completed. (NPS Upper Columbia Basin Network I&M Program)
- No injuries

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 341/145030, May 2018

National Park Service
U.S. Department of the Interior



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