Conservation Agreement and Strategy for Graham's Beardtongue (*Penstemon grahamii*) and White River Beardtongue (*P. scariosus* var. *albifluvis*)

POPULATION MONITORING PLAN

Prepared by the Penstemon Conservation Team

State of Utah School and Institutional Trust Lands Administration
Uintah County, Utah
Utah Public Lands Policy Coordination Office
Utah Division of Wildlife Resources
Rio Blanco County, Colorado
Bureau of Land Management
U.S. Fish and Wildlife Service

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CONSERVATION AGREEMENT AND STRATEGY FOR GRAHAM'S BEARDTONGUE (*PENSTEMON GRAHAMII*) AND WHITE RIVER BEARDTONGUE (*P. SCARIOSUS* VAR. *ALBIFLUVIS*):

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PREFACE

This monitoring plan supersedes the 2017 Demographic Monitoring Plan for Graham's beardtongue (*Penstemon grahamii*) and White River beardtongue (*Penstemon scariosus var. albifluvis*) (PCT 2017). The purpose of this updated monitoring plan is to improve monitoring outcomes and streamline data collection by incorporating information obtained during the first three years of the monitoring program, and to allow feasible implementation with limited staffing and resources. This updated range-wide population trend monitoring study design consists of twenty permanent, long-term, trend monitoring sites (two monitoring sites per beardtongue species per conservation area) to document population trends of both species range-wide. In addition to population trend, supplemental information gathered at each study site - including the frequency of invasive weeds, vegetation composition, and evidence of disturbance - will be used to evaluate relative habitat condition. The purpose of the supplemental data collection is to meet monitoring objectives stated in the 2015 Weed Management and Livestock Grazing Management Plans (PCT 2015b, 2015c). Demographic monitoring will occur at a subset of the twenty monitoring sites. Adding to five previously established monitoring sites, ten new sites were established by the Penstemon Conservation Team (PCT) in May 2020. Five additional sites are to be added to the study system during the 2021 field season. Throughout the life of the plan, changes in the strategy will be made when necessary (new information, etc.) and as approved by the PCT using principles of adaptive management. If any problems are identified during monitoring, more intensive monitoring may be implemented in those areas.

INTRODUCTION

The 2014 Conservation Agreement and Strategy for Graham's beardtongue (*Penstemon grahamii*) and White River beardtongue (*Penstemon scariosus* var. *albifluvis*) includes a requirement that a long-term population monitoring plan be developed and implemented (Penstemon Conservation Team [PCT] 2014). Specifically, the Agreement calls for the development and implementation of "a species monitoring plan to determine trends in plant populations across their ranges and to identify significant threats to the species" (PCT 2014). A deliberative process beginning in 2016 resulted in the issuing of a Demographic Monitoring Plan for the two species the following year (PCT 2017). This monitoring plan employed a two-phase sample design at 25 randomly generated sample points per species. At the center of each sample point was a 1-meter square demography plot with three 25-meter transect lines radiating from the center. Along each of the three transect lines, nested frequency plots were measured at 5-meter intervals to quantify the change in *Penstemon* frequency (%) from year to year. Based on pilot data collected in 2017, 2018, and partial data collected in 2019, it was determined that the monitoring methods should be amended to alleviate issues related to insufficient sample size and staffing resources associated with the original study design.

Pursuant to Section 6.5 of the Conservation Agreement – Monitoring and Adaptive Management, in 2019 the PCT began a process of exploring options for adapting and improving the Demographic Monitoring Plan. Over the course of several meetings occurring between November 2019 and February 2020 the study design and updated range-wide population trend monitoring plan was developed and approved by consensus of the PCT for implementation beginning during the 2020 field season. The updated methods, summarized here, will help to streamline data collection and strengthen results – ensuring that monitoring is both efficient and robust. This range-wide Population Monitoring Plan supersedes the 2017 Demographic Monitoring Plan. The 2014 Agreement does not contain an explicit requirement for demographic monitoring. Nevertheless, recent demographic studies of both species (McCaffery et al.

2014) meet current needs for understanding population processes. Limited demographic monitoring is ongoing at a limited number of sites across both species ranges. Additional demographic monitoring may be implemented on an as needed basis as determined by the Penstemon Conservation Team.

The updated monitoring plan employs a series of permanent macroplots (i.e., large rectangular study sites) located at discrete *Penstemon* occurrences that are stratified by species (Graham's & White River) and conservation unit, in order to obtain a representative range-wide sample. Each *Penstemon* trend monitoring macroplot is sampled via a series of permanent 1m wide belt transects positioned at randomly selected locations within the plot. Population trend is determined by the change in mean plant density (*Penstemon* plants/m^2) from year to year. Invasive weed and disturbance monitoring is assessed at each site within a series of 30 to 50 $1m^2$ frequency quadrats nested within the belt transects at each plot (5 quadrats per transect to a maximum of 50 quadrats per macroplot). These additional monitoring components will help support the implementation of the Livestock Grazing and Weed Management Plans (PCT 2015b, 2015c). Demographic monitoring will occur at a subset of sites where all individual *Penstemon* plants occurring in the transect lines will be tagged and followed from year to year to quantify survivorship and recruitment rates.

The rationale for using permanent macroplots, rather than randomly selected sample points is based, in part, on precedent. Previous trend monitoring studies of the two *Penstemon* species have utilized macroplots rather than randomly placed transects. BLM Colorado has maintained a single long-term demographic monitoring macroplot of Graham's beardtongue at Mormon Gap in the White River Field Office since 2005 (BLM 2019). Since 2016, three additional demographic monitoring macroplots have been established at White River beardtongue populations in Colorado. Similar demographic monitoring studies using macroplots have been conducted on both *Penstemon* species in Utah by Red Butte Garden and Arboretum (McCaffrey 2014; Barlow and Pavlik 2020). Subjectively placed macroplots also ensure monitoring is efficient by eliminating sample size shortcomings based in the uncertainty of plant detection associated with a random selection of monitoring locations. Additionally, this new study design will allow for an assessment of populations relative to management objectives outlined by the Conservation Agreement and provide for a consistency in approach with previously established methods.

MANAGEMENT OBJECTIVES

This plan consists of three management objectives and three associated sampling objectives. The primary intent of the Agreement is to promote the long-term persistence of the two *Penstemon* species. Objective 3, as defined by the Conservation Agreement at pg. 3, is to "promote stable or increasing populations within identified conservation areas and across the range of the two species" (PCT 2014). Supplemental to this goal are two additional objectives that relate to the frequency of invasive plant species and disturbance at each monitoring site. The management and sampling objectives associated with this plan are:

Management Objective 1:

Maintain stable or increasing density *of Penstemon grahamii* and *Penstemon scariosus* var. *albifluvis* within the six conservation units designated by the Penstemon Conservation Agreement for the duration of the agreement (2020 – 2034).

Sampling Objective 1:

To be 80% confident of detecting at least a 20% change in mean *Penstemon grahamii* and *Penstemon scariosus* var. *albifluvis* density while maintaining the possibility of observing a false change or missed change error at ≤ 20%.

Management Objective 2:

Minimize the frequency of invasive weeds within occupied *Penstemon grahamii* and *Penstemon scariosus* var. *albifluvis* habitats. Monitoring will help detect invasive weed species incursions into, or increased weed frequency within, monitored *Penstemon* habitats for the duration of the agreement (2020-2034).

Sampling Objective 2:

To be 80% confident of detecting at least a 20% change in mean invasive weed species frequency while maintaining the possibility of observing a false change or missed change error at ≤ 20%.

Management Objective 3:

Minimize the frequency of domestic livestock related impacts to *Penstemon grahamii* and *Penstemon scariosus* var. *albifluvis* plants and occupied habitats. Monitoring will quantify the frequency of livestock trampling and other forms of disturbance and any changes in disturbance frequency within monitored penstemon habitats for the duration of the agreement (2020-2034).

Sampling Objective 3:

To be 80% confident of detecting at least a 20% change in mean disturbance frequency while maintaining the possibility of observing a false change or missed change error at ≤ 20%.

METHODS

The monitoring methods described here were adapted from the BLM technical references: *Measuring and Monitoring Plant Populations* (Elzinga et al. 1998) and the *Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems* (Herrick et al. 2005). Population trend monitoring is designed to assess whether *Penstemon* populations are increasing, decreasing, or stable by comparing differences in mean plant density across years. Understanding the trend of monitored populations can then be used to inform land management decisions / interventions aimed at reducing or eliminating threats to the species and minimize the likelihood of, and need for, their listing under the Endangered Species Act (BLM 2008).

Study Design

Monitoring will occur at a series of twenty permanent macroplots established at occurrences of both *Penstemon* species across their respective ranges (Figure 1). Conservation Units 2 (Seep Ridge), 3 (Evacuation), 4 (White River), and 5 (Raven Ridge) include occurrences of both *Penstemon* species and will each have four study sites – two per species. Units 1 (Sand Wash) and 6 (Book Cliffs) include just one species – *Penstemon grahamii* in Unit 1 and *Penstemon scariosus* var. *albifluvis* in Unit 6 – each of these units will have two study sites.

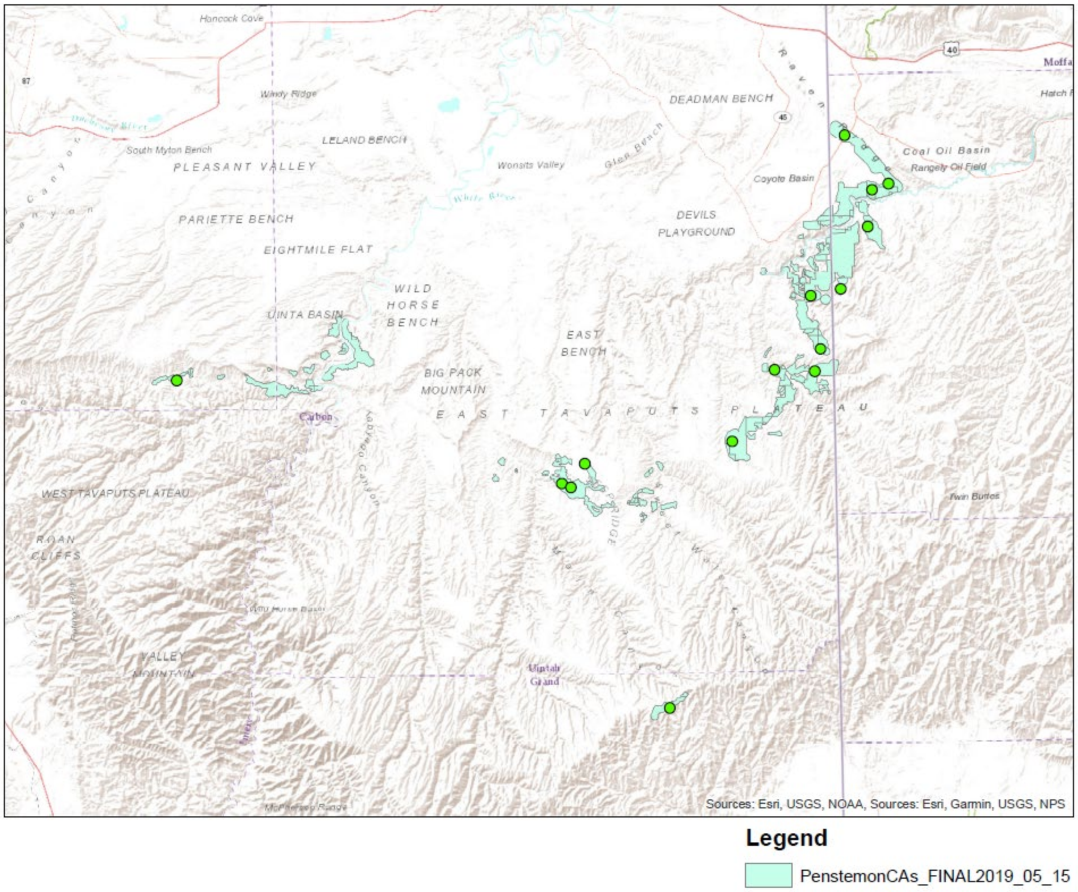

Figure 1. Distribution of *Penstemon* monitoring sites within the 6 Conservation Units as of February 2021.

Populations were selected for trend monitoring from PCT aggregated spatial occurrence data. Consideration related to the spatial distribution of study populations and variation in habitat and other bioclimatic variables of occupied sites were taken into account when selecting study sites. Populations were identified for sampling based on BLM surface management responsibility, the relative importance of the population for the conservation of the species overall, and in areas where certain management questions can be assessed. One *Penstemon scariosus* var. *albifluvis* study site established in 2020 is located on conservation area private land held by Enefit American Oil ("Enefit").

It is important to note, that since the macroplots were subjectively located the extent to which inferences can be drawn to the larger landscape from our study sites ultimately represents a subjective assessment (Karl 2014).

Study Site Establishment

A permanent rectangular macroplot is established at each occurrence selected for sampling. Each macroplot is oriented to capture a portion of the target population considered to be representative of the site. Macroplot dimensions vary among sites based on population size and structure at location of occurrence. Plot corners are monumented with rebar and marked with GPS to aid in relocation.

Within each macroplot permanent sampling units (1m wide belt transects) are established. In order to limit observer bias, transect locations are selected using a restricted random method (Elzinga et al. 1998). Ten-inch steel stakes are placed in the middle and at both ends of each transect. When transect length exceeds 25 meters, quarter points are established to aid in the accuracy of data collection.

Data Collection Procedure

Monitoring data will be collected during the spring (approximating peak phenology) as a collaborative effort organized by the PCT monitoring sub-committee. After at least two sampling intervals at each monitoring site, monitoring intensity may be decreased to biannually. A decision to decrease sampling interval frequency will be subject to the discretion of the PCT and based on observed stable to increasing trends and available resources.

Population Trend Monitoring

Population trend monitoring data is collected on site-specific paper field data forms. At each monitoring site a group of observers establishes the macroplot perimeter and then strings the series of transect lines within the macroplot using 50m survey tapes attached at either end to the permanent nails marking the transect locations. Using a metal carpenters tape measure, the researcher walks the length of the transect recording the number of *Penstemon* plants occurring in the 1m wide transect belt on their data sheet. The resulting data consists of a total number of plants/m^2 for each transect. The average of all the transects are taken to calculate the mean density of the entire macroplot. Population estimates can be extrapolated for each plot by multiplying the average density by the area of the macroplot.

For both species, the researcher will document whether each plant detected was in a reproductive or vegetative stage at the time of sampling. Plants are classified as reproductive if they possess sampling year reproductive structures (either flowers or fruits), vegetative individuals either lack reproductive structures or possess a previous year's flowers or fruits. Additional information gathered for each detected *Penstemon grahamii* plant consists of the number of rosettes per individual plant. For White River beardtongue the number of flowering stems per reproductive individual is recorded. Notes will also be taken indicating evidence of browsing or herbivory and the general condition of the plant.

Individual plants are usually discrete and easily identifiable on sparse shale barrens. Though, in situations where plants occur in dense clumps (more frequently observed in *Penstemon scariosus* var. *albifluvis*) a general rule is that if a mature clump is separated from another by >10cm of soil it is considered a separate individual. In situations where there are many seedlings (or very young plants) occupying a small space, the 10cm rule does not apply and each is counted individually.

Disturbance and Invasive Plant Species Monitoring

Disturbance and invasive plant species frequency data will be collected on site-specific paper field data forms. At each macroplot, researchers will place a one-meter square quadrat frame at five randomly selected intervals along the transect lines for a minimum of 30 and maximum of 50 quadrats per macroplot. At each quadrat, the observer records the presence (frequency) of all native plant species, invasive plant species, ground cover, and any disturbance by type (hoof print, tire track, erosion, etc.). The resulting data is nested frequency of all plant cover, ground cover, and disturbance, where the total frequency of species by functional groups, invasive species, ground cover, or disturbance across all quadrates divided by the total number of quadrats sampled provides a mean frequency value for the entire macroplot. The nested frequency quadrat locations will be selected annually using a random number generator prior to monitoring.

Demographic monitoring

In order to address questions related to the life history and vitality of population's, demographic metrics will be recorded at a subset of monitoring sites. At demographic monitoring sites, plants detected in each 1m wide transect belt will be tagged with an 8" nail and individually numbered aluminum tag. Tags will be placed ca. 5-10cm from the plant in the direction of the macroplot origin. In order to relocate individuals from year to year, X / Y coordinates are recorded for each nail in order to assist with relocation. Demographic metrics include but are not limited to: reproduction, recruitment, and longevity of individuals. In addition to the stage of each plant (reproductive or vegetative), for each detected *Penstemon grahamii* plant the number of rosettes per individual plant is recorded. For *Penstemon scariosus* var. *albifluvis* the number of flowering stems per reproductive individual is recorded.

Survivorship and transition rates:

Raw data from our tagged sample can be easily transformed to determine survival and transition rates for various life stages (*e.g.,* seedlings, vegetative adults, reproductive adults). McCaffrey 2014 describes the procedure for performing naïve survival analysis from raw data. Survivorship is determined by the proportion of plants in a certain life stage that survive to the following year. [(# of plants alive in year t+1)-(new plants marked in year t+1)]/# of plants alive in year t).

Reproduction and recruitment:

A commonly used method of quantifying plant reproduction is to calculate the ratio of the number of seedlings counted in year $t + 1$ to the number of flowering plants in year t. (# of new plants in year t+1 / the number of reproductive plants in year t). This method assumes that all new seedlings present in year $t + 1$ were a product of the previous year's flowering individuals. This method does not account for the effect of a soil seedbank, plant dormancy, or imperfect detection. This method has been used previously in demographic studies of the two *Penstemon* species and eliminates the need to visit each monitoring site on two different occasions per monitoring season. Allowing for easy interpretation of reproductive success.

Climate monitoring

Interactions between climate (precipitation and temperature) and population trend will be evaluated using spatially explicit climate data. Data sources will comprise the PRISM database (PRISM 2021) or other available climate datasets.

Power Analysis

Population trend:

Two years of data are required to perform sample size calculations. If necessary, the number of sampling units within the macroplot will be adjusted following the second sampling interval to accommodate the necessary number of samples required to obtain statistically meaningful results. The calculation used to determine the necessary number of samples to detect a specified amount of change in plant density between two time periods using permanent sample units is:

$$n = \frac{(s)^2(Z_\alpha + Z_\beta)^2}{(MDC)^2}$$

Where n is the necessary number of transects needed to detect a specified amount of change between two samples according to a specified power (Elzinga et al., 1998; Sample Size Equation 3). Calculations are performed to meet a sampling objective that maximizes statistical power (≥ 0.8) of detecting at least a 20% change in mean plant density, while maintaining the possibility of committing either a type 1 or 2 error at ≤ 20%.

A finite population correction factor (fpc) is applied when sampling > 5% of the within-plot population:

$$n' = \frac{n}{(1 + \left(\frac{n}{N}\right))}$$

Disturbance and invasive plant species:

A similar sample size estimation approach will be used to determine the minimum number of nested quadrats needed at each monitoring location (Elzinga et al. 1998, 2001; Sample Size Equation 5). The number of nested quadrats will be adjusted following the second sampling interval using the following sample size equation (equation 5, Elzinga et al. 2001):

$$n = \frac{\left[Z_\alpha + Z_\beta\right]^2 [p_1 q_1 + p_2 q_2]}{[p_2 - p_1]^2}$$

Preliminary sample size estimations based on the 2020 data indicate that our sampling approach is more than adequate to capture interannual changes in nested disturbance frequency.

Statistical analysis

Population trend:

Each transects sampling results are compared from year to year using a two-tailed paired t-test analysis to determine the significance ($p \leq 0.05$) of changes in mean density over time. As with determining sample size, if more that 5% of a population has been sampled you must apply the fpc to the results of the significance test (Elzinga et al., 1998).

Range-wide trends are determined by assessing the mean change in plant density across all monitoring plots between years.

All statistical transformations can be completed using Microsoft Excel.

Disturbance and invasive plant species:

Nested quadrat-level frequency of invasive species and disturbance will be compiled for each monitoring macroplot. Average frequency of invasive species or disturbance (by type) will be analyzed using chisquare test for between-year or between-site analyses and McNemar's test for within-site analyses (Elzinga et al. 2001).

Reporting

Monitoring results will be summarized in the PCT annual reports and as part of regular progress reports.

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