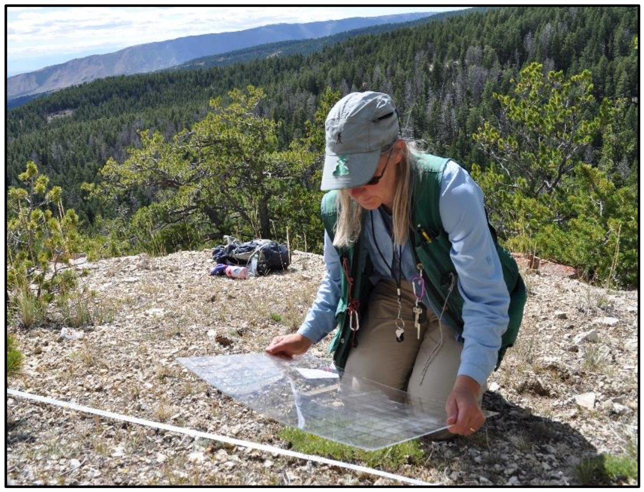
MONITORING *SHOSHONEA PULVINATA* IN THE PRYOR AND BEARTOOTH MOUNTAINS, CARBON COUNTY, MONTANA 1991 – 2015 TREND REPORT



Prepared for:
Bureau of Land Management

Prepared by:
Montana Natural Heritage Program
A program of the
Montana State Library's Natural Resource Information System
that is operated by the University of Montana.

February 2016

MONTANA Natural Heritage Program

MONITORING *SHOSHONEA PULVINATA* IN THE PRYOR AND BEARTOOTH MOUNTAINS, CARBON COUNTY, MONTANA 1991 – 2015 TREND REPORT

Prepared for:
BUREAU OF LAND MANAGEMENT
5001 Southgate Drive
Billings, MT 59101

Agreement # L12AC20330

Prepared by:
ANDREA PIPP
MONTANA NATURAL HERITAGE PROGRAM

P.O. Box 201800 ● 1515 East Sixth Ave ● Helena, MT 59620-1800

This document should be cited as follows:

Pipp, Andrea. 2016. Monitoring *Shoshonea pulvinata* in the Pryor and Beartooth Mountains, Carbon County, Montana: 1991-2015 Trend Report. February. Prepared for the Bureau of Land Management, Billings, Montana. Prepared by the Montana Natural Heritage Program, Helena, Montana.

TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

APPENDICES

EXECUTIVE SUMMARY

Shoshonea pulvinata (Shoshonea) is a plant endemic to the region of northwestern Wyoming and adjoining south-central Montana (Heidel 2011). Globally Shoshonea is ranked as a G3 - vulnerable (NatureServe 2015). In Montana and Wyoming, it is ranked as an S2 and listed as a Species of Concern (MTNHP 2015 and Wyoming Natural Diversity Database 2015). It is listed as Sensitive by the Montana and Wyoming state offices of the Bureau of Land Management (BLM) (BLM 2014 and 2010).

A demographic monitoring study of Shoshonea was started to learn the details of Shoshonea's growth, fecundity, recruitment, mortality, and population trends. Monitoring was initiated by the BLM in 1991 because the plant was relatively "new" to the flora, has a limited distribution, and lives where potential threats (grazing by wild horses and bighorn sheep in the Pryor Mountains and mining, oil, or gas development in the Beartooth Mountains) were recognized (Lesica 1993, Lesica and Achuff 1991). Permanent belt transects were established on land managed by the BLM in Carbon County, Montana. The Grove Creek transect in the Beartooth Mountains is approximately five air-miles south-southeast of Red Lodge. The Mystery Cave Road and Mystery Cave Ridge transects are approximately 32 air-miles southeast of Bridger in the Pryor Mountains. Over a span of 25 years, monitoring data was collected in seven years: 1991, 1992, 1993, 1999, 2012, 2013, and 2015. Individual plants were mapped and information on plant size and reproduction were recorded and tracked over the 25-year timeframe. This trend report evaluates all monitoring data from 1991 to 2015, and expands upon the previous publications (Heidel 2001, Lesica 1993) regarding life history, effects of potential threats, and management information.

From 1991 through 2015, 113, 79, and 39 individual plants have been named and monitored at the Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transects, respectively. Of these 36, 33, and 13 individual plants at the Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transects, respectively, have been monitored in all seven years. As a result, 32%, 42%, and 33% of the Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transect populations, respectively, having lived for at least 25 years.

The Grove Creek transect population appears to be stable, though data on plant area (size) and reproduction indicate uncertainty. No trend in plant numbers (population) was detected from 1991 to 2015. Overall, the Grove Creek transect has consistently maintained the highest population and smallest plant size when compared with the other transects. At Grove Creek, plant area on the transect has declined from 1991 to 2015, and was statistically significant at the transect level (total plant area on transect), but not for individual plant areas. This apparent dichotomy is explained by an interaction between plant number and plant size which may be shifting with time. Consistent with having the highest population it also seems to have the highest mortality and recruitment. Reproductive characteristics may not be as stable at the Grove Creek transect. The transect has produced the least number of flowering plants, but this was not statistically significant when compared with the other transects. At both the pooled transect and individual plant levels, a negative (declining) trend in flower production was found at Grove Creek.

The Mystery Cave Road transect population appears stable, as indicated by plant numbers and reproductive characteristics. No trend in plant numbers (population) was detected from 1991 to 2015. Though not statistically significant, plant area and total inflorescence number has increased from 1991 to 2015. The observed recruitment is slightly higher than mortality.

The Mystery Cave Ridge transect population is apparently stable; however, the declining trend in plant area and inflorescence number coupled with mortality numbers that are higher than recruitment seems to indicate a declining population. The decline in total plant area was statistically significant at the transect level, but not for individual plant areas. Overall, the Mystery Cave Ridge transect has consistently maintained the lowest population and the largest plant size when compared with the other transects. The decline in inflorescence number was statistically significant. Observed mortality is higher and recruitment lower when compared with the other transects.

Potential threats of grazing and energy development continue to exist, but have not been realized in the monitoring that spans 25 years. Details on observations and the potential for impacts from fire and recreation are discussed. Future directions for this demographic monitoring and its relevance for management are also discussed.

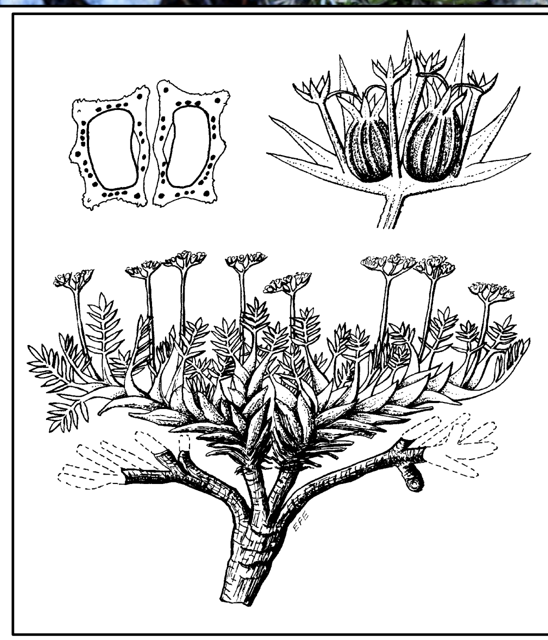
ACKNOWLEDGMENTS

This project was supported by a challenge cost-share agreement between the Bureau of Land Management and the Montana Natural Heritage Program. I appreciate the interest and support by Wendy Velman (Bureau of Land Management) to have continued this monitoring effort.

I am appreciative of Peter Lesica and Peter Achuff, the botanists whose interest to study *Shoshonea pulvinata*'s life history created a monitoring project that was well-thought out, simple to follow, and remained intact over a 25-year span. I am indebted to botanist Bonnie Heidel for her meticulous data collection, synthesis and writing of the 1999 Trend Report, and informative feedback on the draft version of this trend report. Special thanks goes to botanist Scott Mincemoyer who's guidance allowed me to properly collect the latest year (2015) of monitoring data. Thanks goes to biometrician Kevin Podruzny (Montana Fish, Wildlife and Parks) for statistical assistance. Credit belongs to many botanists who have surveyed, studied, and written on *Shoshonea pulvinata*, creating a foundation of information. These botanists include, but are not limited to, Erwin Evert, Lincoln Constance, Peter Lesica, Steve Shelly, Bonnie Heidel, and Scott Mincemoyer. Any errors or omissions in this report are entirely the responsibility of the author.

1.0 INTRODUCTION

Shoshonea pulvinata (Shoshonea) is a plant endemic to the region of northwestern Wyoming and adjoining south-central Montana (Heidel 2011). Shoshonea is a member of the Carrot Family (Apicaeae). It is a mat-forming, herbaceous, long-lived perennial with a woody taproot and branching underground stems (**Figures 1 A-B**). The species was first described in Wyoming in 1981 by Erwin Evert and Lincoln Constance (Evert and Constance 1982). In Montana it was first discovered in the Pryor Mountains by John Pierce in 1984, and in the Beartooth Mountains by Peter Lesica in 1985. Since the mid-1980's numerous surveys have mapped is distribution in Wyoming and Montana (Heidel 2011, Fertig 1997 and 1998, Marriott 1988 and 1992, Lesica and Achuff 1991, Lesica and Shelly 1988).



Figures 1 A-B: *A photograph by Peter Lesica (top) and illustration by Evert and Constance 1982 (bottom) of* Shoshonea pulvinata.

In Montana Shoshonea grows on thin rocky soils of open, exposed limestone outcrops, ridgetops, and canyon rims at elevations from about 6,400 to 7,950 feet above sea level (Lesica and Shelly 1988, Montana Natural Heritage Program [MTNHP] 2015). Globally it is ranked as a G3 indicating it is vulnerable, at moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors (NatureServe 2015). In Montana and Wyoming, it is ranked as an S2 indicating it is at risk due to very limited and/or declining numbers, range, and/or habitat, making it vulnerable to extirpation; it is a Species of Concern (MTNHP 2015 and Wyoming Natural Diversity Database 2015). It is listed as Sensitive by the Montana and Wyoming state offices of the Bureau of Land Management (BLM) (BLM 2014a and 2010). In Montana, Shoshonea is found in 13 sub-populations (referred by the MTNHP as species occurrences [SO]) which occur in three populations (East Slope Beartooth Plateau, East Pryor Mountain, and Big Pryor Mountain) (MTNHP 2015).

While surveys provide information on a species' distribution, population density, and habitat associations, demographic monitoring marks and monitors the fate of individual plants through time to acquire life history information. A demographic monitoring study of *Shoshonea pulvinata* began in 1991 to learn the details of Shoshonea's growth, fecundity, recruitment, mortality, and population trends.

The monitoring was initiated by the BLM to learn about a long-lived, slow-growing species that was relatively "new" to the flora, has a limited distribution, and lives where potential threats (grazing by wild horses and bighorn sheep in the Pryor Mountains and mining, oil, or gas development in the Beartooth Mountains) were recognized (Lesica 1993, Lesica and Achuff 1991). In 1991, permanent belt transects were established in the Pryor and Beartooth Mountains in Carbon County, Montana (Lesica and Achuff 1991). Monitoring results have been analyzed and reported in a 1991-1993 Baseline Report (Lesica 1993) and 1999 Trend Report (Heidel 2001). In 2012 funding from the BLM was made available to conduct three additional years of monitoring and to revise the 1999 Trend Report. Over the past 25 years, seven years (1991, 1992, 1993, 1999, 2012, 2013, and 2015) of monitoring data have been collected. This trend report evaluates all monitoring data from 1991 to 2015, and presents on expanded life history, effects of potential threats, and management information.

2.0 STUDY AREAS

Demographic monitoring for Shoshonea occurs at two of its three Montana populations: Beartooth Plateau and Pryor Mountains. In 1991 permanent belt transects were installed at three locations on land managed by the BLM. The Grove Creek transect is approximately five air-miles south-southeast of Red Lodge. The Grove Creek transect is situated on the east slope of the Beartooth Plateau on a narrow ridge of the Meeteetse Spires. The habitat is of widely scattered, stunted conifers ranging mostly in height from 4-6 feet tall with a diverse and open understory of forbs, grasses, and shrubs growing on limestone pavement (**Table 1**; **Photos 1-2** in **Appendix B**). The Mystery Cave transects are in the Pryor Mountains approximately 32 air-miles southeast of Bridger. They also occur within the Pryor Mountain National Wild Horse Range. The Mystery Cave Road transect (often referred to in report as mcRoad) is situated in an open Douglas-fir (*Pseudotsuga menziesii*) forest with a diverse and open understory of shrubs, forbs, and grasses growing on limestone covered by duff (**Table 1**; **Photo 3** in **Appendix B**). A wild horse trail crosses through and parallels the belt transect (**Photo 14** in **Appendix B**); an old two-track road occurs a short distance upslope of the transect. The Mystery Cave Ridge transect (often referred to in report as mcRidge) is situated on an exposed ridge of limestone pavement that supports sparse forbs and grasses and is adjacent to mature coniferous forest (**Table 1**; **Photo 4** in **Appendix B**).

Table 1. ***Landscape setting for the* Shoshonea pulvinata *monitoring transects.***

Transect	Transect Orientation	Slope Grade & Aspect	Elevation (feet)	Tree Canopy (estimate)	Habitat Description
Grove Creek	353°	5%, northwest	7140	1%	Open, stunted, mixed-conifer forest growing on limestone pavement on exposed ridge. **Photos 1-2** in **Appendix B**
Mystery Cave Road	194°	2%, west	7570	45%	Open Douglas-fir forest, on limestone covered with duff. **Photo 3** in **Appendix B**
Mystery Cave Ridge	213°	2%, west	7587	10%	Exposed rim outcrop adjoining forest, on limestone pavement. **Photo 4** in **Appendix B**

3.0 METHODS

The demographic monitoring goal was to map individuals across years and detect changes in population trends, individuals by size, and reproductive characteristics, and to evaluate recruitment and mortality (Heidel 2001). Over a span of 25 years, three transects were monitored seven times in the years of 1991, 1992, 1993, 1999, 2012, 2013, and 2015. Information from the previous reports (Heidel 2001, Lesica 1993, Lesica and Achuff 1991) were used in the evaluation and writing of this 1991-2015 trend report.

3.1 Field Procedures

Monitoring methods were developed and transects were installed by Lesica and Achuff (1991) with annotations in Lesica (1993) and following standards and assumptions of Lesica (1987). Trend data derived from these subjectively placed transects statistically represents the transect and not the entire Shoshonea population. In 1991 the Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transect ends were marked by rebar and in 2012 their location was recorded with a global positioning system (GPS) unit. Incidentally the rebar has remained intact and strong over the years. The Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transects are each 50 cm wide by approximately 10, 10, and 12 meters long, respectively. All transects are read on the west side, starting from the south end for Grove Creek and starting from the north end for Mystery Cave Ridge and Road. The seven years of monitoring took place from mid-June to early August. It has been observed that: a) leaf petioles elongate slightly over the summer causing a small difference in June and August readings (Heidel 2001), b) seedlings become more apparent in August (Heidel 2001), and c) by the early August of dry summers inflorescences may abort and flowering stems shrivel (Heidel 2015).

At each site the ring of the meter-tape is placed over the rebar and the tape is stretched to the other end and secured. The tape is to be taut and straight. The center coordinates of each Shoshonea plant is recorded to the nearest centimeter using the meter tape and meter stick. As the plant grows, portions of it may also die. Thus, the center coordinates of an individual plant may change over time. It is necessary to use the previous monitoring year's data to aid in determining plant coordinates. It is also sometimes necessary to carefully scrape the soil and determine if 'individuals' are connected underground or truly separated. In measuring the coordinates, it is important to keep the meter stick perpendicular to the meter tape.

After recording the plant's coordinates, the size of the plant is measured. A 50-centimeter by 50-centimeter clear Plexiglas that has been marked with a grid of 4-centimeter by 4-centimeter squares is randomly placed over the plant (**Figure 2**). The number of quarter-squares that are filled by green vegetation is counted and recorded onto the data sheet (**Figure 2**). In the office the number of quarter-squares will be multiplied by four to calculate area in square centimeters. Larger plants tend to die out in the center and this dead region is not counted. The number of inflorescences on each plant is counted and recorded onto the datasheet. If a plant partially occurs within the transect, the location, size, and number of inflorescences that occur within the transect is counted and a comment that it extends outside is recorded. Comments on individual plants should be recorded, especially regarding health, browse, and disturbance.

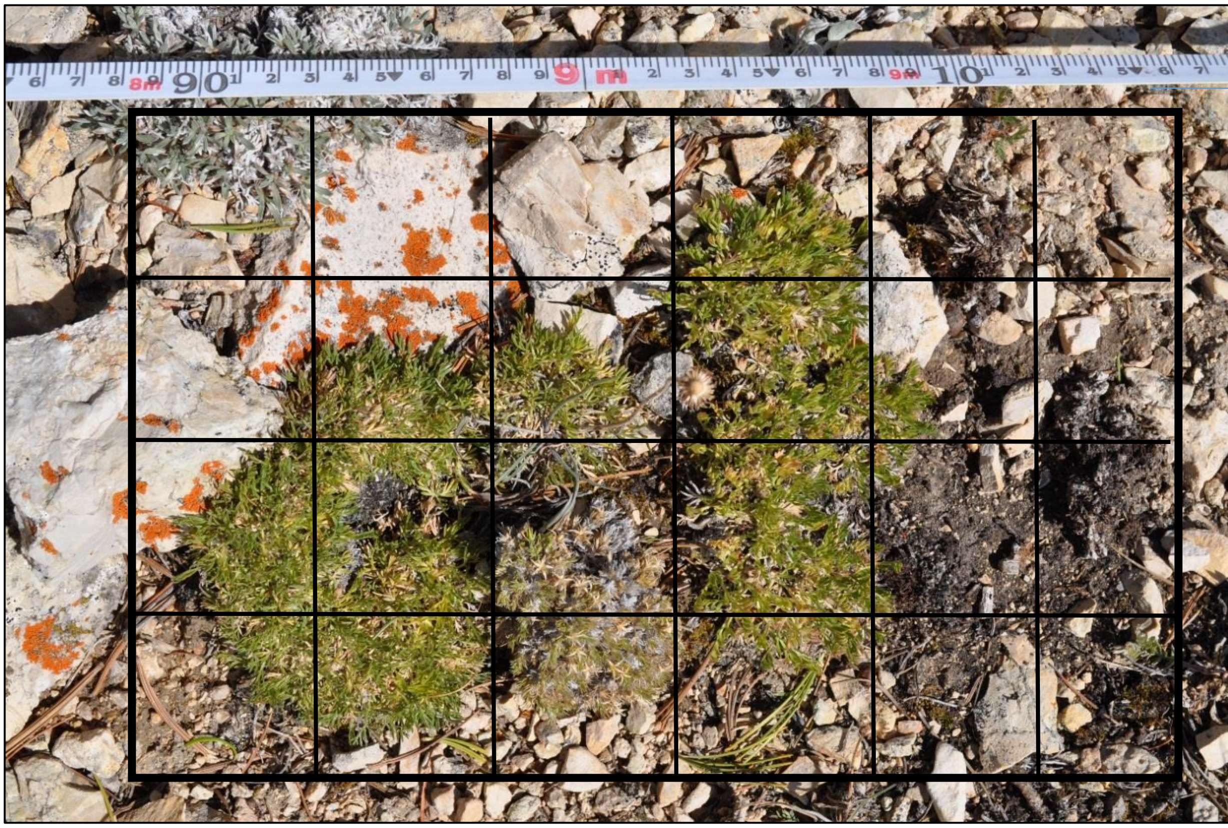


Figure 2. ***The Plexiglas is randomly placed over the plant. From top left to bottom right the number of filled quarter-squares are: 2, 1, 2, 2, 3, 1, 2, 3, 3, 4, 1, 1, 2, 2, 1. Plant area is 30 quarter-squares which equals 120 square-centimeters.***

Each plant on a transect is assigned a unique alpha-numeric code that identifies it. Plants in the first meter of the transect (from 0 to 99 cm) are given the code "1" followed by a letter assigned in alphabetical order. In 1991 six plants were found in the first meter of the transect and were given the codes of 1a, 1b, 1c, 1d, 1e, and 1f. These unique codes remain assigned to the plant at that location for the duration of the study. If a new plant appears in the first meter of this transect in subsequent years, it will be assigned the code of 1g. Assigning a unique alpha-numeric code to each plant allows the fate of each individual to be followed during the course of the study.

Photographs are useful for documenting conditions during each monitoring year. Photographs should be taken from each end of each transect and of plants, habitat, and site conditions.

3.2 Data Analysis

Because of technological advances in computers and software to analyze data, it was necessary to re-evaluate the entire data-set from 1991 to 2015. Data from all data sheets were entered into Microsoft Excel, which was also used to track individual plant coordinates, size, inflorescence number, recruitment and mortality (where applicable), and to conduct basic statistical summaries, transformations, and graphical displays. Statistical tests were performed using R version 3.2.2 (2015-12-10) and the Rcmdr package (R 2015). Due to the re-evaluation of tracking individuals and some past calculation errors, information in this report may differ from past reports.

The previous reports categorized plant ages by using size: juvenile/smallest (less than 15 square centimeters), small mature (16 to 80 square centimeters), and large mature (greater than 80 square centimeters) (Heidel 2001, Lesica 1993, Lesica 1992, and Lesica and Achuff 1991). It was thought that plants smaller than 16 square centimeters were likely to not flower; however, subsequent monitoring has recorded flowers on plants as small as 4 square centimeters. This analysis chose to ignore size as an indicator of maturity and instead categorized plants as flowering or non-flowering.

3.2.1 Transect Level Pooled Data

Data was pooled by year at each transect. The number of established plants (transect population), total plant surface area, total number of flowering plants, and total inflorescence number were not normally distributed; therefore, the most appropriate transformation was used to normalize each data-set. The number of established plants, total plant area, total number of flowering plants, and total number of inflorescences were transformed using the natural log (ln). The monitoring year was transformed so that 1991 and 2015 represented Year 0 and Year 24, respectively.

To test for differences in pooled data among transects, a one-way Analysis of Variance (ANOVA) was used and a pairwise comparison of means was examined. Using consecutive years of monitoring data is better for analyzing population trends. Therefore, a t-test was used to test the null hypothesis of no difference between the early consecutive monitoring years (1991-1993) and the later, nearly consecutive monitoring years (2012-2015). The ANOVA and t-test were applied to the ln established plant number, ln total plant area, ln total number of flowering plants, and ln total inflorescence number. Box plots were used to graphically display the t-test and ANOVA results.

3.2.2 Transect Level Individual Plant Data

Data on all the individual plants were assessed at each transect. A subset of plants present in all seven monitored years was also assessed at each transect. Plant area (cover or surface area) and the number of inflorescences per plant were not normally distributed; therefore, the most appropriate transformation was used to normalize each data-set. The plant area was normalized using the ln transformation. The number of inflorescences per plant was transformed using the equation ln-1. The monitoring year was also transformed using the same method as for the 'transect level pooled data'.

A t-test was used to test the null hypothesis of no difference between the early consecutive (1991-1993) and later, nearly consecutive (2012-2015) years. Box plots were used to graphically display the t-test results. A linear regression was used to statistically test the trend of all (1991, 1992, 1993, 1999, 2012, 2013, and 2015) seven monitored years. The linear regressions were back transformed to display the results graphically. Both tests were applied to the transformed data.

4.0 RESULTS

4.1 Plant Number and Area

Basic summary statistics were generated on plant numbers (transect population) and plant size (area) for each monitored year at each transect (**Table 2**). In each monitored year the transect population at Grove Creek was the largest, Mystery Cave Ridge was the lowest, and Mystery Cave Road was intermediate (**Table 2**; **Figure 3**). However, the total plant area was consistently highest at Mystery Cave Ridge indicating that plants were fewer, but larger (**Table 2**; **Figure 4**). The lowest total plant area was found at Mystery Cave Road for the years monitored through 1999, but switched in 2012-2015 at Grove Creek (**Table 2**; **Figure 4**).

Table 2. ***Summary statistics for* Shoshonea pulvinata *monitoring from 1991 to 2015.***

Site	Year	Established Plants (count)	Total Plant Area (sq cm)	Mean Plant Area (sq cm)	Standard Deviation Plant Area	Min - Max Plant Size (sq cm)
Grove	1991	57	2204	39	80	4 - 532
	1992	69	2368	34	71	4 - 500
	1993	67	2316	35	69	4 - 492
	1999	81	2276	28	68	1 -552
	2012	59	1816	31	69	4 - 524
	2013	59	1757	30	68	1 - 512
	2015	62	1549	25	54	1 - 412
Mystery Cave Road	1991	49	1808	37	28	4 - 132
	1992	49	1872	38	30	4 -140
	1993	50	1968	39	30	4- 140
	1999	60	1699	28	25	1 - 100
	2012	46	1996	43	41	12 - 220
	2013	50	2121	42	43	9 - 232
	2015	51	1868	37	39	4 - 204
Mystery Cave Ridge	1991	31	2638	85	112	4 - 488
	1992	22	2556	116	128	4 - 520
	1993	21	2496	119	132	4 - 524
	1999	19	2464	130	137	4 - 568
	2012	20	2292	115	126	4 - 520
	2013	20	2156	108	121	8 - 496
	2015	19	2096	110	130	4 - 548

Figure 3. ***Number of plants found in monitored years on each transect.***

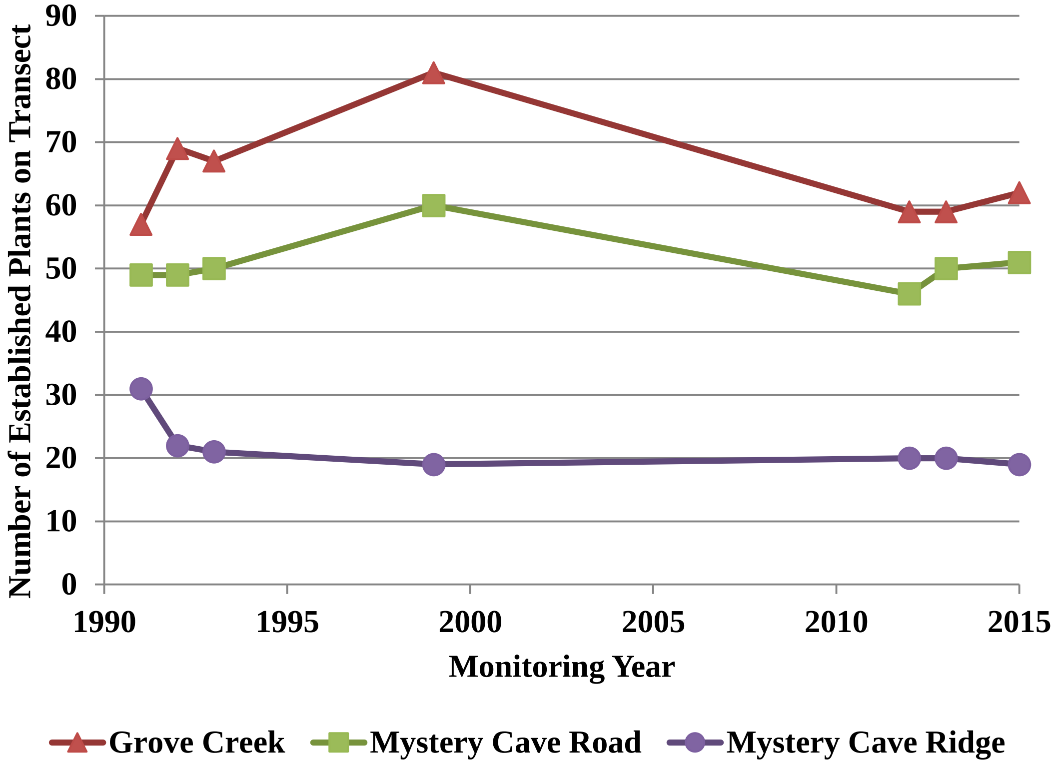
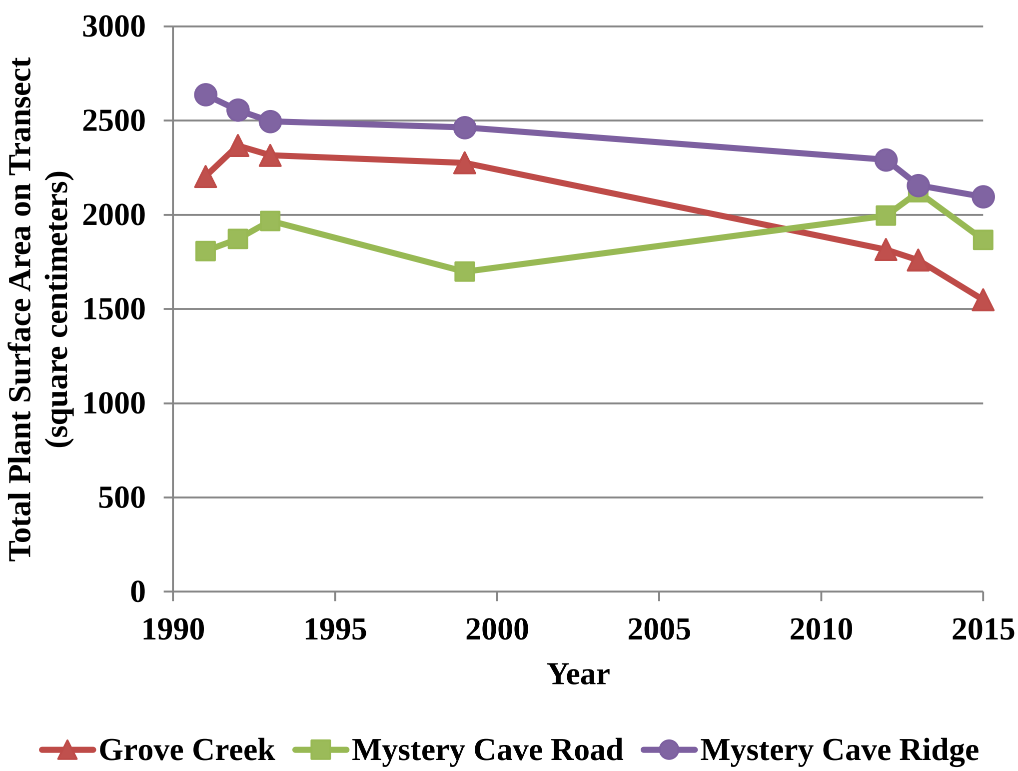


Figure 4. ***Total plant surface area in monitored years on each transect.***



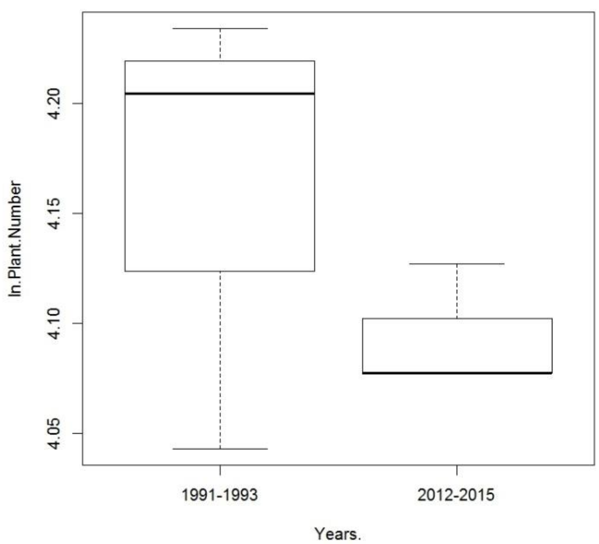
4.1.1 Transect Level Pooled Data

The t-test found no statistically significant difference in the transformed plant number (number of established plants) between the early (1991-1993) and later (2012-2015) years at the Grove Creek (t=1.079, df=2.308, p-value=0.380), mcRoad (t = 0.238, df = 2.181, p-value = 0.831), and mcRidge (t = 1.703, df = 2.077, p-value = 0.225) transects (**Figures 5 A-C**).

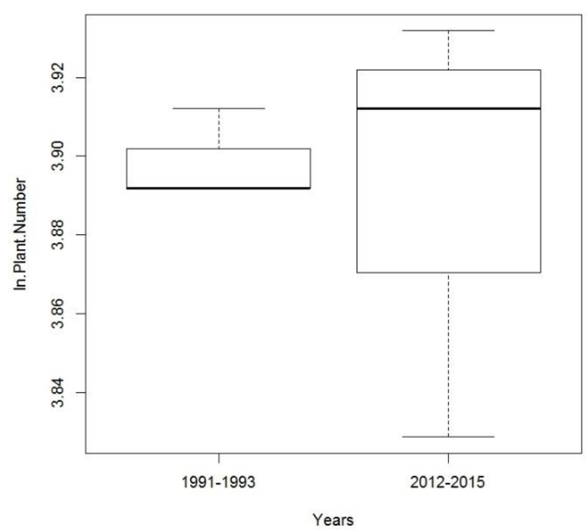
The linear regression of plant numbers from 1991 to 2015 was also not statistically significant at the Grove Creek (slope -0.004, df=5, p-value=0.453), mcRoad (slope -0.001, df=5, p-value=0.776), and mcRidge (slope -0.009, df=5, p-value=0.144) transects. Thus, no trends in plant numbers were found.

Figures 5 A-C. ***Box plots of ln plant number in early (1991-1993) and later (2012-2015) years at Grove Creek, mcRoad, and mcRidge transects. Plant number was not statistically different.***

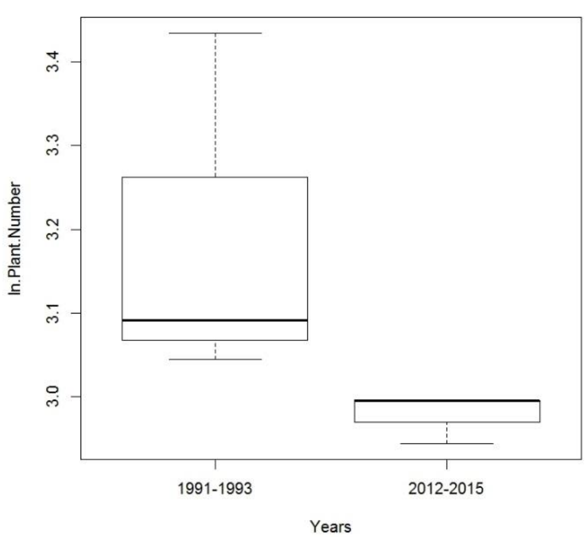
(A) Grove Creek



(B) mcRoad



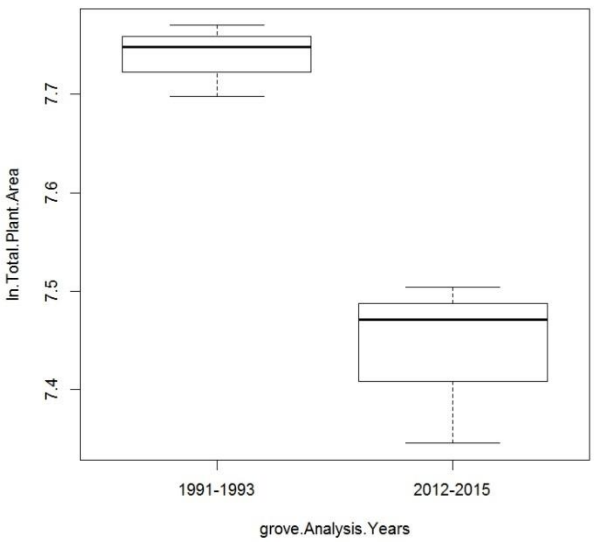
(C) mcRidge



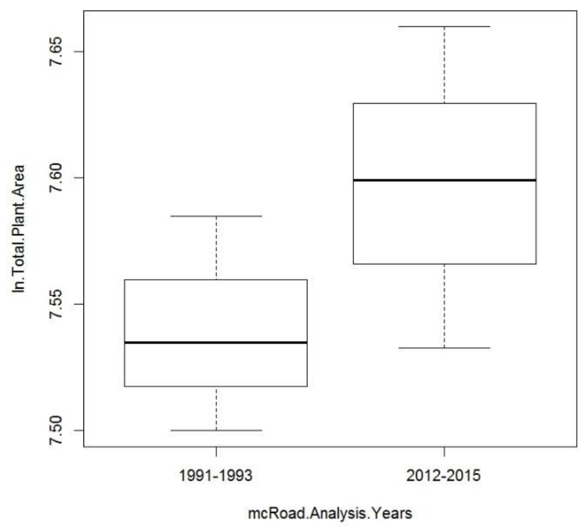
The t-test of the transformed total plant area on the transect was statistically different between the early (1991-1993) and later (2012-2015) years at the Grove Creek (t = 5.636, df = 2.739, p-value = 0.014) and mcRidge (t = 5.241, df = 3.299, p-value = 0.010) transects, but not statistically different at the mcRoad transect (t = -1.295, df = 3.497, p-value = 0.274) (**Figures 6 A-C**).

Figures 6 A-C. ***Box plots of ln total plant area in early (1991-1993) and later (2012-2015) years at Grove Creek, mcRoad, and mcRidge transects. Plant area was statistically significant at the Grove Creek and mcRidge sites.***

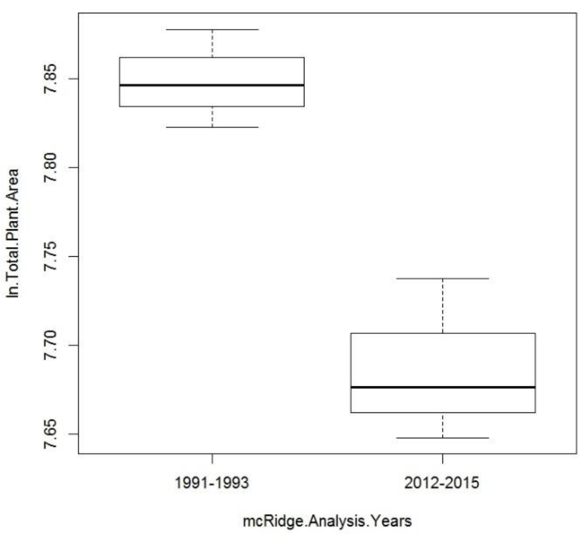
(A) Grove Creek



(B) mcRoad



(C) mcRidge

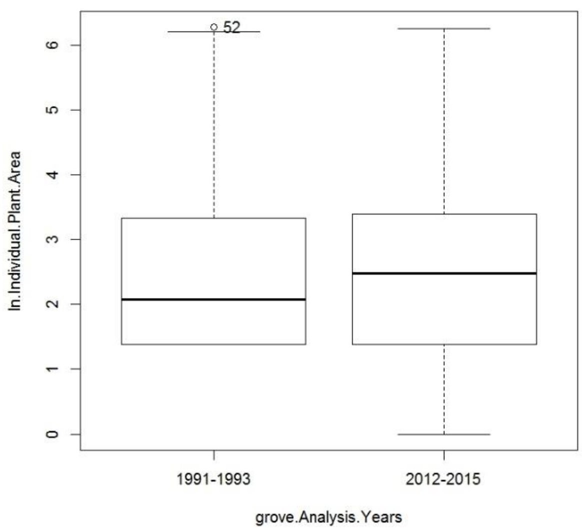


4.1.2 Transect Level Individual Plant Data

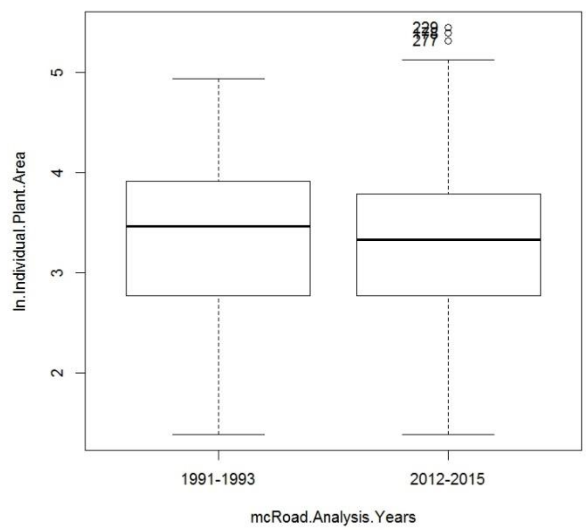
The t-test of the transformed individual plant area found no statistical difference between the early (1991-1993) and later (2012-2015) years at the Grove Creek (t = 0.257, df = 370.83, p-value = 0.797), mcRoad (t = -0.62851, df = 288.47, p-value = 0.5302), and mcRidge (t = -0.305, df = 122.87, p-value = 0.761) transects (**Figures 7 A-C**).

Figures 7 A-C. ***Box plots of ln individual plant area in early (1991-1993) and later (2012-2015) years at Grove Creek, mcRoad, and mcRidge transects. Individual plant area was not statistically significant at each transect.***

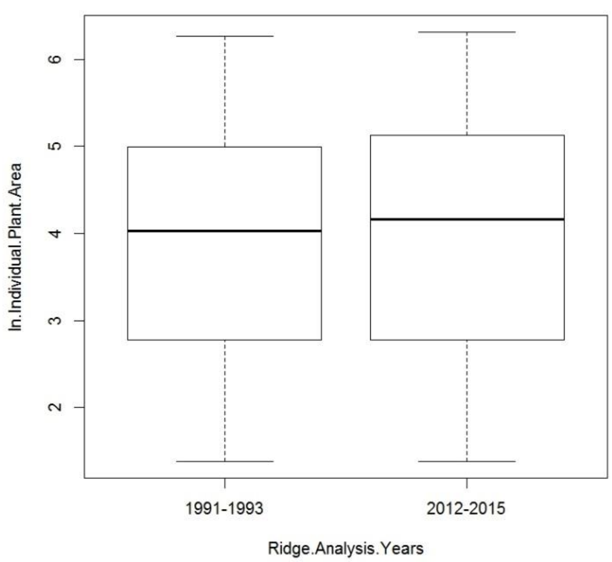
(A) Grove Creek



(B) mcRoad



(C) mcRidge



The regression for the transformed individual plant area from 1991 to 2015 was also not statistically significant at the Grove Creek (slope < 0.001, df = 452, p-value = 0.963), mcRoad (slope = 0.005, df = 353, p-value = 0.281), and mcRidge (slope = 0.003, df = 150, p-value = 0.77) transects. Thus, no trends in plant size for individuals were detected (**Figures C1 A-C** in **Appendix C**).

The trend in plant area was evaluated for a subset of plants that had been present in all seven monitoring years which spans 25 years. This subset lacks individuals that have germinated or died in the study period, and provides another way to study changes in size (i.e., plant cover or area) of individual plants. At Grove, mcRoad, and mcRidge sites 36, 33, and 13 plants have been tracked in all seven monitored years (**Appendix A**). The regression for individual area of plants tracked over the 25-year period found no statistical difference in plant size for Grove Creek (slope -0.005, df = 262, p-value = 0.477), mcRoad (slope = 0.007, df = 247, p-value = 0.133), and mcRidge (slope = -0.015, df = 89, p-value = 0.232). Thus, no trends in individual plant area were detected for the subset of plants tracked in all seven monitored years (**Figures C2 A-C** in **Appendix C**).

4.2 Plant Reproduction

Reproductive characteristics were statistically summarized by year for each transect (**Table 3**). Mystery Cave Road has the most or equal number of flowering plants when compared to the other two sites (**Figure 8**). The one-way ANOVA test found a statistical difference among sites for the number of flowering plants (F = 8.939, df = 2, p-value = 0.002). The pairwise comparison of means found that the number of flowering plants between mcRoad-Grove Creek and mcRoad-mcRidge sites statistically differed from the Gove Creek-mcRidge site. However, plants on the Mystery Cave Ridge transect have collectively produced the most number of inflorescences until it was surpassed in 2013 and 2015 by Mystery Cave Road (**Figure 9**). The one-way ANOVA found a statistical difference among sites for total inflorescence number (F = 7.566, df = 2, p-value = 0.004). The pairwise comparison of means found that the number of inflorescences was significantly different between Grove Creek and mcRidge, but not at the other pairs of sites.

This difference can also be seen by assessing percentages. The highest percentage of flowering plants was found at Mystery Cave Ridge where 59% to 84% of the transect population flowered (**Table 3**). The lowest percentage of flowering plants was found at Grove Creek where flowering plants made up 15% to 30% of the transect population (**Table 3**). Mystery Cave Road was intermediate with 27% to 68% of the plants flowering (**Table 3**).

<u>4.2.1 Transect Level Pooled Data</u>

The t-test found the transformed total inflorescence number between the early (1991-1993) and later years (2012-2015) to be statistically significantly different at the Grove (t = 2.307, df = 323.85, p-value = 0.021) and mcRidge (t = 2.716, df = 2.638, p-value = 0.0837) transects, but not at the mcRoad (t = -1.374, df = 2.1762, p-value = 0.293) transect (**Figures 10 A-C**).

Table 3. ***Reproductive characteristics of*** **Shoshonea pulvinata** ***plants found on each transect from 1991-2015.***

Site	Year	Established Plants (count)	Reproductive Plants (count, %)	Total Inflorescence Number	Mean Inflorescence Number Per Flowering Plant	Standard Deviation Inflor. Number Per Flowering Plant	Min - Max Inflorescence Number
Grove	1991	57	16 (28%)	97	6.1	6.5	1 - 27
	1992	69	13 (19%)	42	3.2	3.7	1 - 15
	1993	67	14 (21%)	92	6.6	7.2	1 - 29
	1999	81	30 (37%)	196	6.5	8.9	1 - 47
	2012	59	13 (22%)	32	2.5	1.9	1 - 7
	2013	59	13 (22%)	30	2.3	1.7	1 - 6
	2015	62	9 (15%)	13	1.4	0.9	1 - 3
Mystery Cave Road	1991	49	29 (59%)	109	3.8	4.4	1 - 20
	1992	49	13 (27%)	44	3.4	3.1	1 - 11
	1993	50	34 (68%)	151	4.4	4.0	1 - 16
	1999	60	30 (50%)	133	4.4	3.3	1 - 13
	2012	46	24 (52%)	139	5.8	7.3	1 - 30
	2013	50	35 (70%)	176	5.0	7.8	1 - 36
	2015	51	34 (61%)	140	4.1	5.2	1 - 20
Mystery Cave Ridge	1991	31	21 (68%)	366	17.4	16.8	1 - 69
	1992	22	13 (59%)	160	12.3	9.5	2 - 32
	1993	21	16 (76%)	339	21.2	19.9	1 - 59
	1999	19	14 (74%)	374	26.7	22.4	3 - 82
	2012	20	12 (60%)	149	12.4	8.7	1 - 30
	2013	20	14 (70%)	127	9.1	11.5	1 - 40
	2015	19	16 (84%)	103	6.4	8.6	1 - 29

Figure 8. ***The number of flowering plants found on each transect during monitored years.***

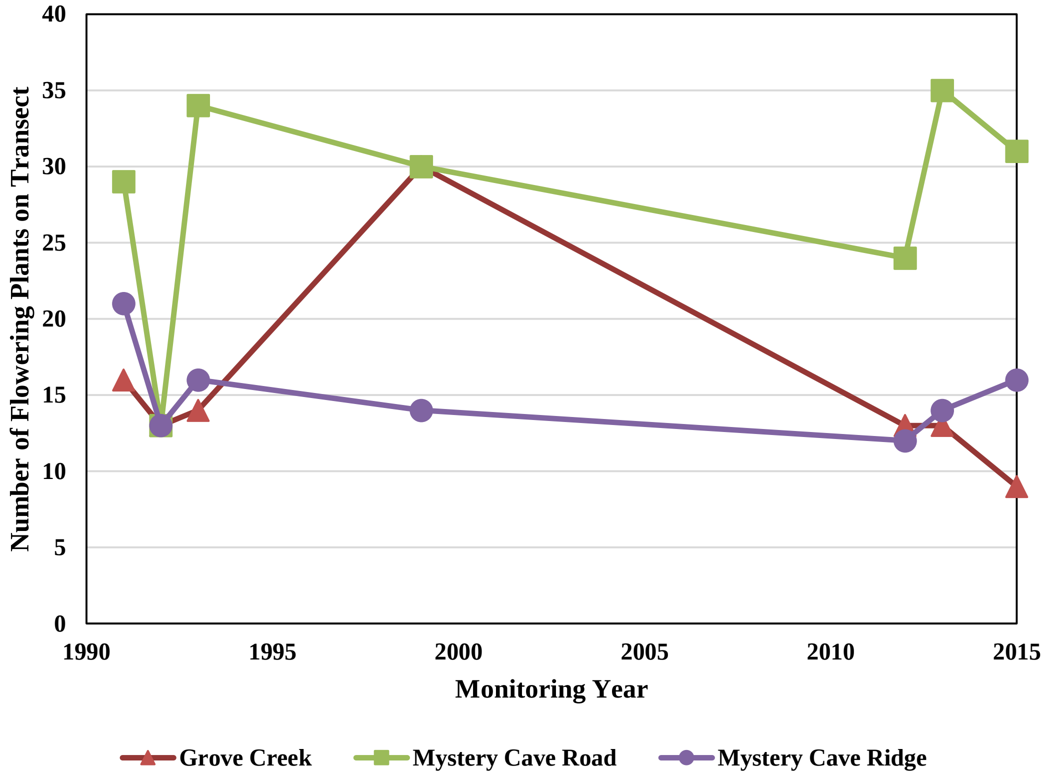
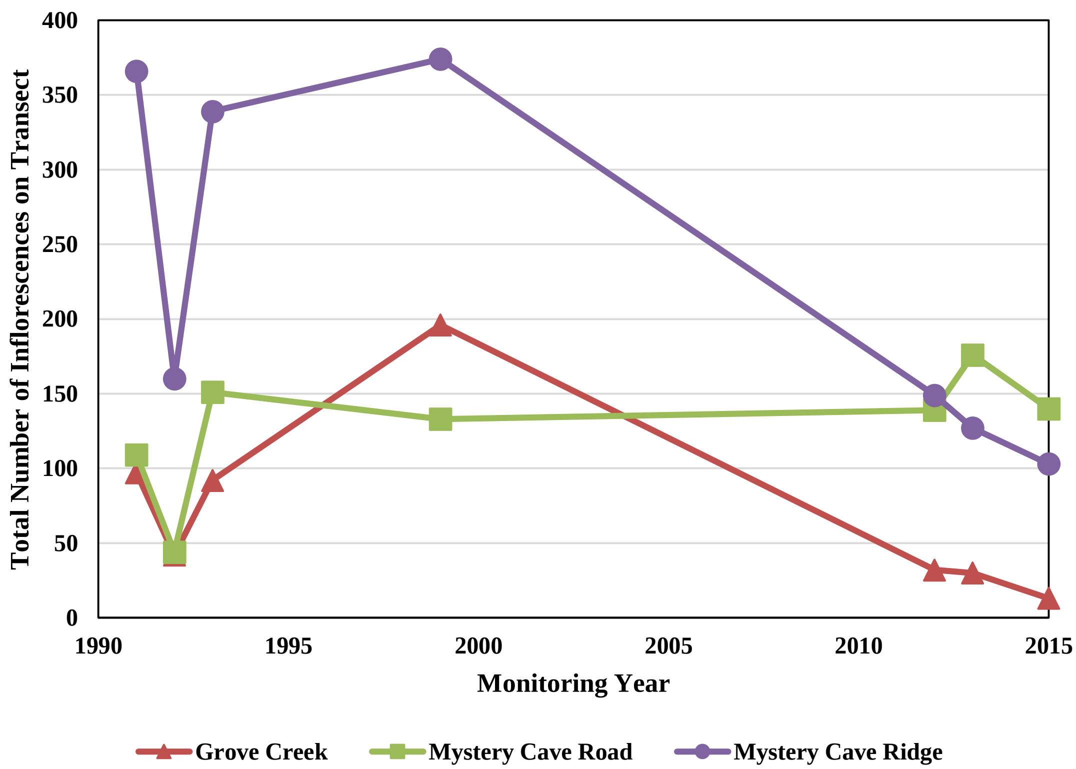
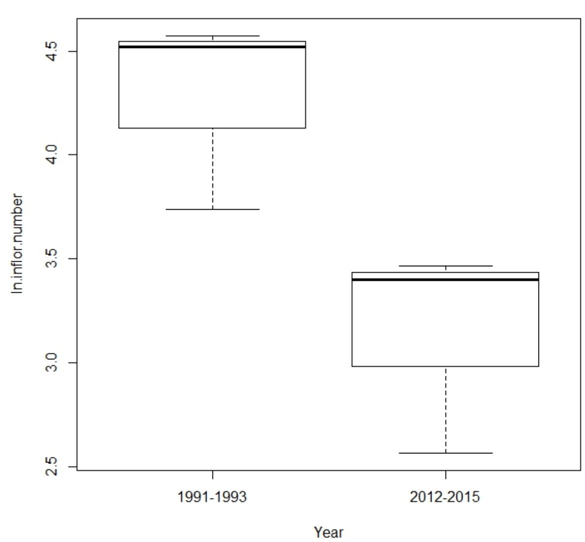


Figure 9. ***The total number of inflorescences found on each transect during monitored years.***

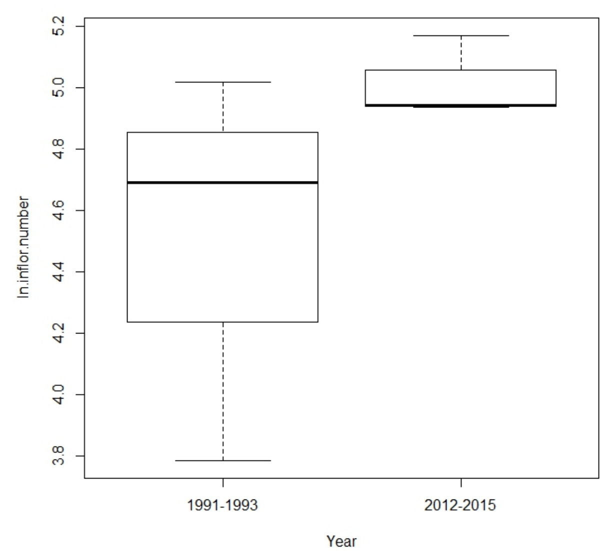


Figures 10 A-C. ***Box plots of ln total inflorescence number found in early (1991-1993) and later (2012-2015) years at Grove Creek, mcRoad, and mcRidge transects. Total inflorescence number was statistically significant at the Grove Creek and mcRidge transects, but not at the mcRoad (B) transect.***

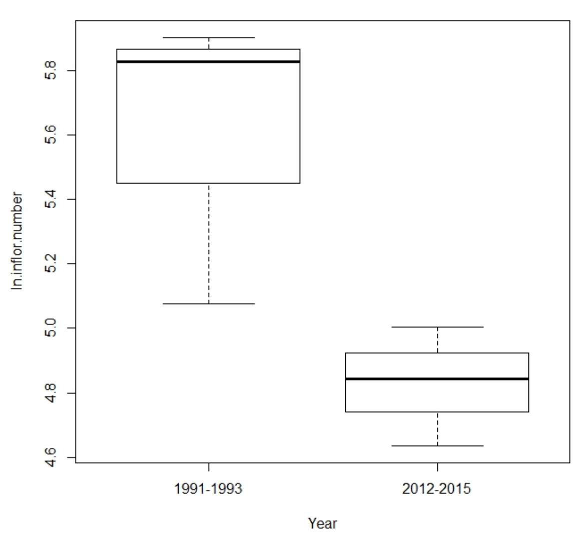
(A) Grove Creek



(B) mcRoad



(C) mcRidge



4.2.2 Transect Level Individual Plant Data

The regression for the transformed individual plant inflorescence number (number of inflorescences per plant) from 1991 to 2015 was statistically significant at the Grove Creek (slope = -0.044, df = 452, p-value = 0.010) and mcRidge (slope = -0.017, df = 150, p-value = 0.106) transects, but not at the mcRoad (slope = 0.007, df = 353, p-value = 0.113) transect. Thus, the Grove Creek and mcRidge sites exhibited a negative trend in total inflorescence number while no trend could be detected at the mcRoad site (**Figures 11 A-C**).

The trend in the transformed individual plant inflorescence number was evaluated for a subset of plants that were present in all seven monitoring years that spans 25 years. This subset lacks individuals that have germinated or died during the study period, and provides another way to evaluate changes in inflorescence number. At Grove, mcRoad, and mcRidge transects 36, 33, and 13 plants have been monitored in all seven years (**Appendix A**). The regression for the transformed number of inflorescences on plants tracked over the 25-year period was statistically significant at Grove Creek (slope -0.015, df = 264, p-value = 0.001), mcRoad (slope = 0.009, df = 247, p-value = 0.103), and mcRidge (slope = -0.038, df = 89, p-value = 0.006). Thus, a negative trend in inflorescence number for the plants tracked over a 25-year period was found at the Grove Creek and mcRidge transects. A positive trend in inflorescence number for the plants tracked over a 25-year period was found at the mcRoad transect (**Figures 12 A-C**).

Figures 11 A-C. ***Back transformed graphs showing the linear regression with 95% confidence intervals of the individual plant inflorescence number for the Grove Creek, mcRoad, and mcRidge transects. The trend was statistically significant at Grove Creek and mcRidge transects, but not at the mcRoad transect.***

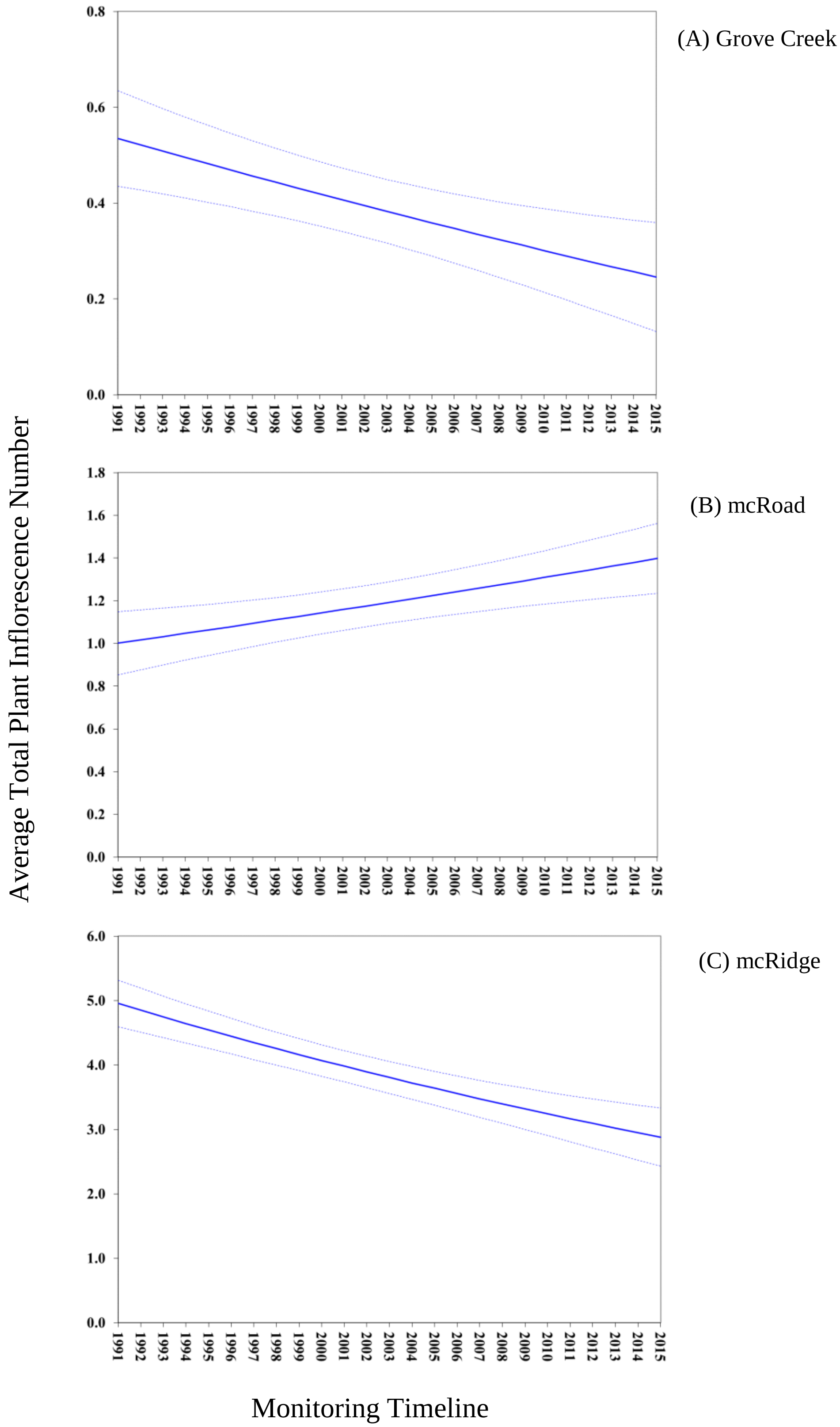
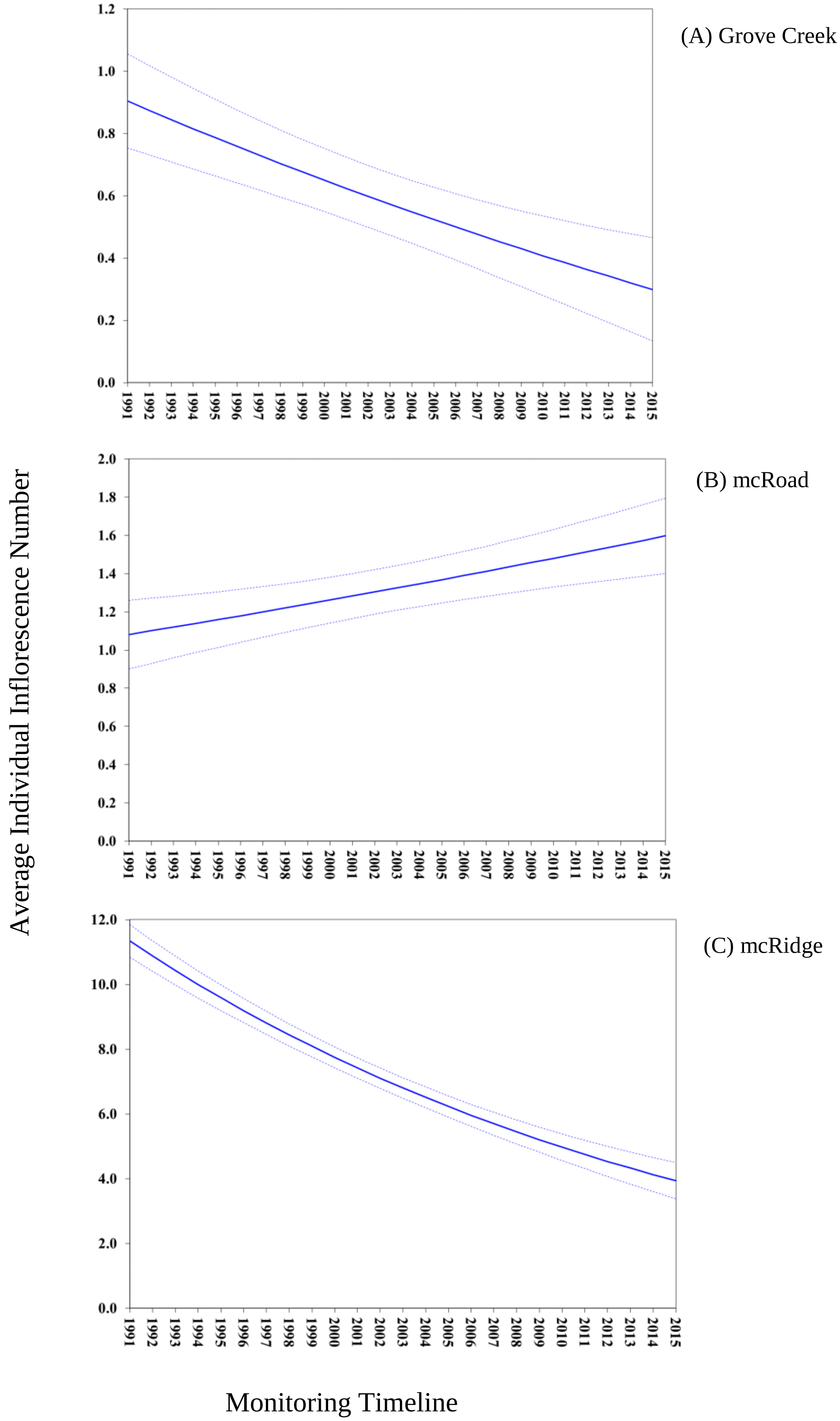


Figure 12 A-C. ***Back transformed graphs showing the linear regression with 95% confidence intervals of individual inflorescence number for plants tracked in all 7 monitored years at the Grove Creek, mcRoad, and mcRidge transects. All trends were significant.***

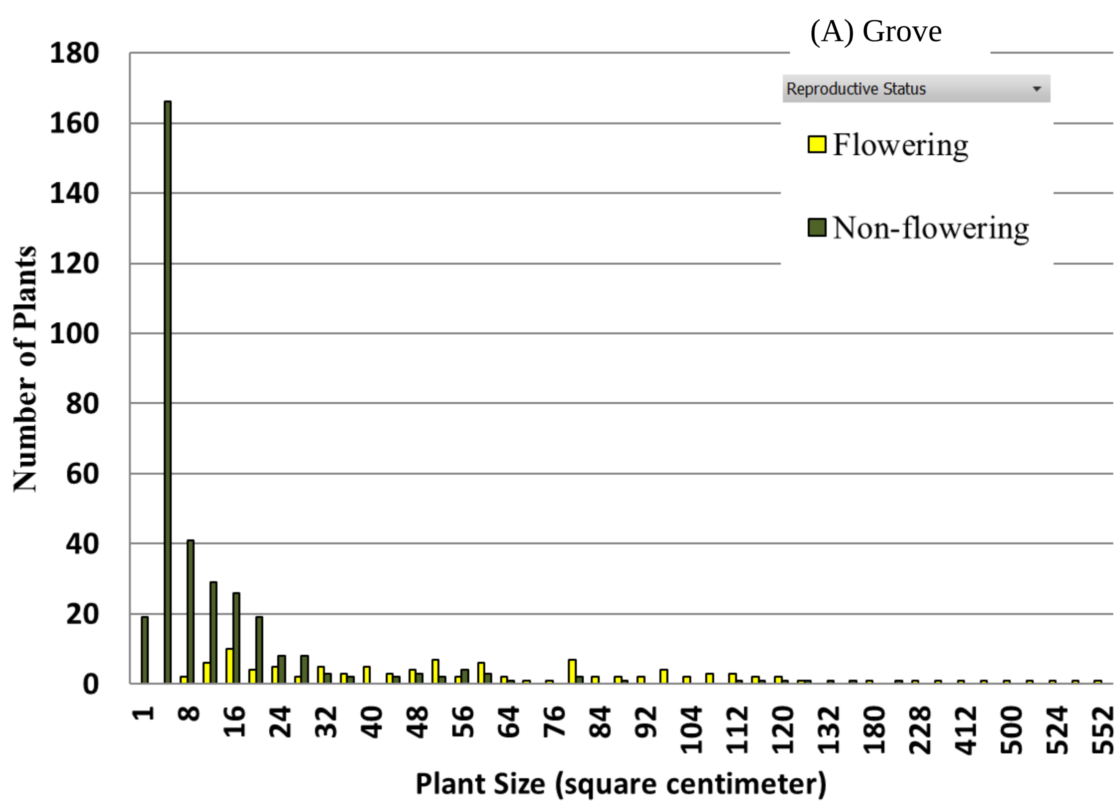


4.3 Reproduction and Plant Size

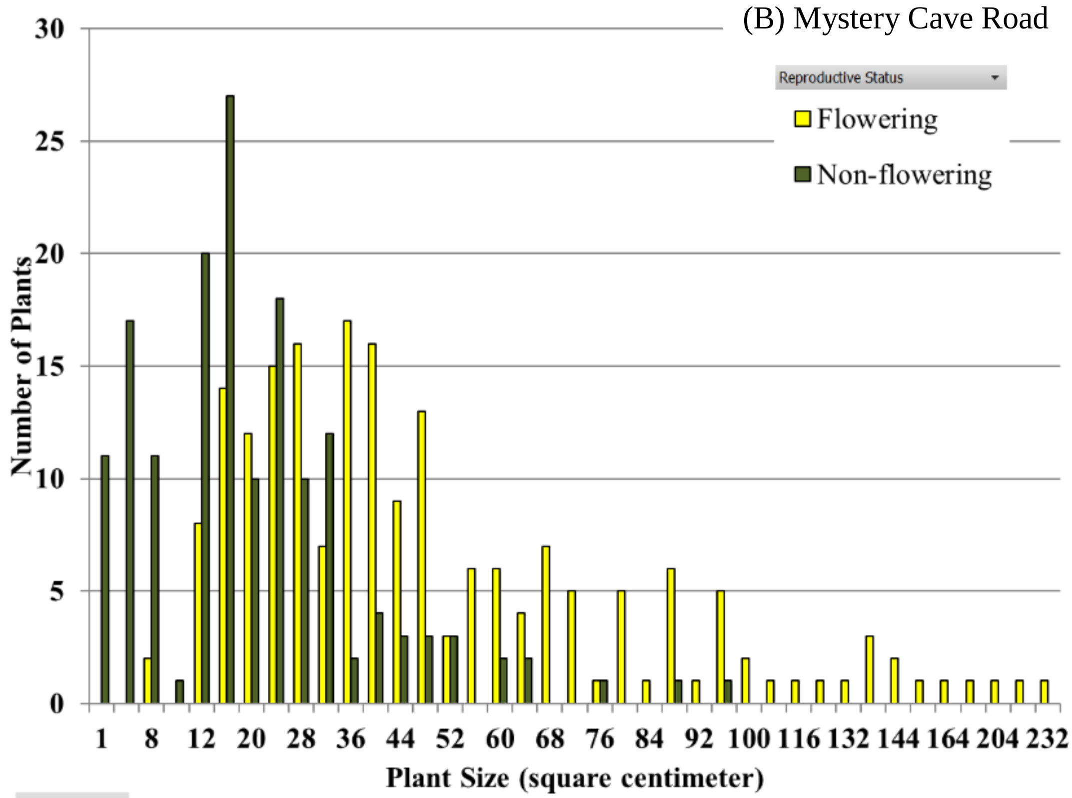
The size of flowering and non-flowering plants at each transect was graphed (**Figures 13 A-C**). Combined transect data showed that flowering plants can be as small as 4 square centimeters, which is not typical, and as large as 568 square centimeters. In general, flowering plants tend to be larger while non-flowering plants tend to be smaller, but with a great deal of overlap. For Grove Creek, Mystery Cave Road, and Mystery Cave Ridge, the average size for flowering plants was 88, 51, and 140 square centimeters respectively, when all years of data are combined. For Grove Creek, Mystery Cave Road, and Mystery Cave Ridge, the average size for non-flowering plants was 14, 39, and 21 square centimeters, respectively, when all years of data are combined.

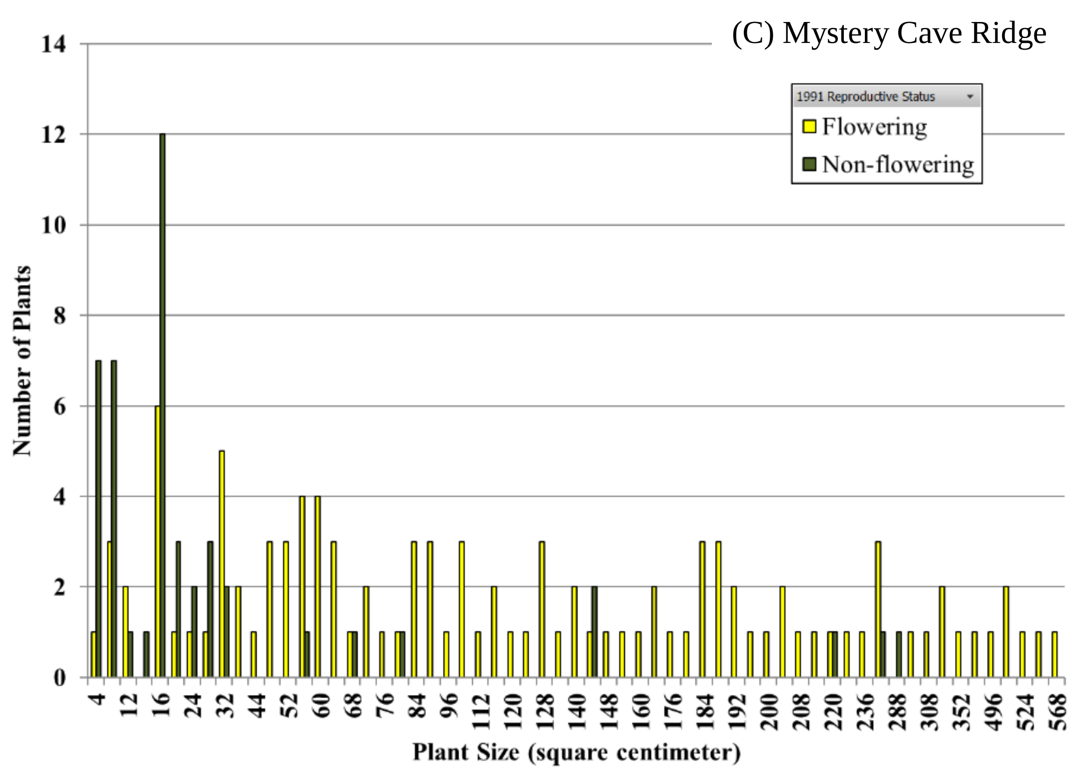
In general, the Grove Creek and Mystery Cave Road transects show that the number of flowers produced tends to increase with plant size, but then levels off or declines as plants get very large (**Figures 13 A-B**). This was less apparent at the Mystery Cave Ridge transect where a greater number of large plants produce flowers (**Figure 13 C**).

Figures 13 A-C. ***The number of flowering and non-flowering plants by size for all years combined at the Grove Creek (A), Mystery Cave Road (B), and Mystery Cave Ridge (C) transects.***



Figures 13 A-C (continued). ***The number of flowering and non-flowering plants by size for all years combined at the Grove Creek (A), Mystery Cave Road (B), and Mystery Cave Ridge (C) transects.***





4.4 Longevity, Mortality, and Recruitment

4.4.1 Longevity

From 1991 through 2015, 113, 79, and 39 individual plants have been named and monitored at the Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transects, respectively (**Table 4**). Of these 36, 33, and 13 individual plants at the Grove, Mystery Cave Road, and Mystery Cave Ridge transects, respectively, have been monitored in all seven years (**Appendix A**). That results in 32%, 42%, and 33% of the Grove Creek, Mystery Cave Road, and Mystery Cave Ridge transect populations, respectively, having lived for at least 25 years. Given that size was not measured each year during the 25-year period and that portions of the plant will grow and die asymmetrically, it is not possible to determine a growth rate (**Appendix A**). It is interesting that plant size increases greatly for some individuals, stays stagnant for others, and fluctuates for some plants (**Appendix A**). The data does demonstrate that Shoshonea plants are long-lived.

4.4.2 Mortality and Recruitment

Mortality and recruitment data are unknown for 1991 since that was the first year of data collection. On the Grove Creek transect 49 individuals died and 55 individuals emerged over the 24-year period (**Table 4**). On the Mystery Cave Road transect, 25 individuals died and 30 individuals emerged over the 24-year period (**Table 4**). On the Mystery Cave Ridge transect, 14 individuals died and 1 individual emerged over the 24-year period (**Table 4**). The monitoring data shows that mortality and recruitment rates vary each year. Annual rates could only be determined for the years of 1992, 1993, and 2013 where data was collected in consecutive years. The 2013 annual rate was generally within the range exhibited in 1992 and 1993 (except for the mortality rate at Mystery Cave Road and Ridge); although, sample sizes are too low to really make inferences. The best time to study recruitment would be in August when germinated plants are easier to detect; however, most monitoring was conducted earlier in the summer (Heidel 2001). Based on the information collected, mortality and recruitment numbers vary by site. At Grove Creek, mortality removed from 0 to 7 plants each year while recruitment brought in 2 to 15 plants each year (**Table 4**). At Mystery Cave Road, mortality removed fewer plants, ranging from 0-3 plants each year, and recruitment brought in 2-5 plants each year (**Table 4**). At Mystery Cave Ridge, mortality removed from 0 to 7 plants each year while recruitment brought in 1 plant (**Table 4**).

Table 4. ***Summary of population, mortality, and recruitment numbers for the three*** **Shoshonea pulvinata** ***transects.***

Site	Year	Established Plants (count)	Mortality (count)	Mortality Rate per Time[1]	Recruitment (count)	Recruitment Rate per Time[2]
Grove	1991	57	--	--	--	--
	1992	69	3	5% / 1 year	15	26% / 1 year
	1993	67	7	10% / 1 year	5	7% / 1 year
	1999	81	4	6% / 6 years	16	24% / 6 years
	2012	59	29	36% / 13 years	15	19% / 13 years
	2013	59	6	10% / 1 year	2	3% / 1 year
	2015	62	0	0% / 2 years	2	3% / 2 years
Total Individuals		**113**	**49**		**55**	
Mystery Cave Road	1991	49	--	--	--	--
	1992	49	3	6% / 1 year	4	8% / 1 year
	1993	50	1	2% / 1 year	2	4% / 1 year
	1999	60	2	4% / 6 years	14	28% / 6 years
	2012	46	17	28% / 13 years	5	8% / 13 year
	2013	50	0	0% / 1 year	3	6.5% / 1 year
	2015	51	2	4% / 2 years	2	4% / 2 years
Total Individuals		**79**	**25**		**30**	
Mystery Cave Ridge	1991	31	--	--	--	--
	1992	22	7	23% / 1 year	0	0% / 1 year
	1993	21	1	4.5% / 1 year	1	4.5% / 1 year
	1999	19	3	14% / 6 years	0	0% / 6 years
	2012	20	2	10.5% / 13 years	0	0% / 13 years
	2013	20	0	0% / 1 year	0	0% / 1 year
	2015	19	1	5% / 2 years	0	0% / 2 years
Total Individuals		**39**	**14**		**1**	

[1] Mortality rate is the number of dead plants in year t/number of established plants in year t-1 multiplied by 100.
[2] Recruitment rate is the number of new plants in year t/number of established plants in year t-1 multiplied by 100.

5.0 DISCUSSION

5.1 Beartooth Plateau

The Grove Creek transect occurs in a sub-population that is representative of the other sub-populations in the Beartooth Mountains. The Grove Creek transect population grows on limestone pavement on an exposed ridge where coniferous trees are primarily shorter than 6 feet (**Photos 1, 2,** and **5-9** in **Appendix B**). It is a naturally harsh site, that is basically flat, and thus receives full sun and exposure to the elements. In 2015 the cohort of 4-6-foot tall conifers on the ridge had mostly died. The cause is unknown, but a possible explanation is that the site might not be capable of supporting forest.

5.1.1 Grove Creek Transect

The Grove Creek transect population appears to be stable, though data on plant area (size) and reproduction indicate uncertainty. The transect population was not statistically different between early (1991-1993) and later (2012-2015) years and no positive or negative trend (1991-2015) was detected (**Table 2**; **Figures 3** and **5A**). It can be inferred that the population appears stable. The decline in total plant area from 6,888 square centimeters (1991-1993) to 5,122 square centimeters (2012-2015) was statistically significant, but not when analyzing the change in individual size across all years (**Figures 4, 6A**, and **C1A**). This apparent dichotomy is explained by an interaction between plant number and plant size which may be shifting. Overall, the Grove Creek transect has consistently maintained the highest population, and the smalles plant size when compared with the other transects. Consistent with having the highest population it also seems to have the highest mortality and recruitment (**Table 4**).

Reproductive characteristics may not be as stable at the Grove Creek transect. The transect has produced the least number of flowering plants, but this was not statistically significant when compared with the other transects. Approximately 15% to 37% of the Grove Creek transect population is reproductive in any given year (**Table 3**). At both the pooled transect and individual plant levels, a negative (declining) trend in flower production was found at Grove Creek. The total number of inflorescences (flower production) significantly declined from 231 flowers (1991-1993) to 75 flowers (2012-2015) (**Table 3**; **Figures 10A** and **11A**). In each monitored year recruitment has been observed and in 1999 seedlings were documented (Heidel 2001). Overall recruitment is higher than mortality, which provides a positive, but not statistically tested, indicator for the population (**Table 4**).

Competition between Shoshonea and other vascular plants seems to be stronger on the Grove Creek transect when compared with the Mystery Cave sites. In several monitoring years, it was noted that other vascular plants were growing through the foliage of some Shoshonea plants. In 2015, 11 Shoshonea plants had other vascular plants growing through their canopy, and several of these plants exhibited lower plant cover and increased decadence. Coniferous trees growing on the transect exhibit a growth form that is wide and shrubby, which indicates a harsh environment. This sprawling growth by an evergreen plant could slowly smother the neighboring Shoshonea plants. For a long-lived plant, a harsh environment and strong competition from other vascular plants could reduce the availability of nutrients and water necessary for the transect population to maintain growth and flower production.

5.1.2 Potential Population Threats

Monitoring at the Grove Creek site was partially initiated by concerns that energy development could impact the Beartooth Plateau population. The potential for energy development (mining, oil, gas, wind, or solar) in the vicinity might always be possible. Direct impacts would be less likely as the Shoshonea populations grow on ridges in rugged terrain. Energy development would more likely occur in the valleys at lower elevations where a network of roads and flatter topography provides easier access. Thus, indirect impacts from energy development, such as changes in air quality and potential spread of invasive species, could affect Shoshonea populations.

The Beartooth Plateau populations occupy ridge tops at higher elevations where access is difficult because of very steep slopes and rock spires. Recreationalists do access the Meeteetse Spires area through a system of trails, but these do not seem to be adjacent to Shoshonea sub-populations. In 1992 a hoof print was observed at plant 4H, but no other observations of animal use have been noted on the datasheets. Soil was eroded on the downhill side of plant 8A, which was present from 1991 to 1999. No impacts from recreationalists have been noted on sub-populations in or near the Grove Creek transect.

5.2 Pryor Mountains

Mystery Cave Road and Mystery Cave Ridge transects represent different sub-populations in contrasting settings of the same population in the Pryor Mountains. The Mystery Cave Road plants grow in an open-canopied forest on the upper slope that faces west. This site is more sheltered, where plants are shaded more by the forest and grow on limestone covered with duff (**Photos 3** and **10-14** in **Appendix B**). The Mystery Cave Ridge plants grow on an exposed ridge of limestone pavement. It is a naturally harsh site that faces west, receives full, afternoon sun, but is capable of supporting tall limber pine and Douglas-fir trees (**Photos 4** and **15-19** in **Appendix B**).

5.2.1 Mystery Cave Road Transect

The Mystery Cave Road transect population appears stable, as indicated by plant numbers and reproductive characteristics. The transect population has fluctuated very little from 1991 to 2015, and no trend (increasing or decreasing) was detected which implies stability (**Table 2**; **Figures 3** and **5B**). Though not statistically significant, the increase in total plant area from 5,648 square centimeters (1991-1993) to 5,985 square centimeters (2012-2015) is a positive indicator (**Table 2**; **Figures 4, 6B,** and **C1-B**). While not statistically significant, the increase in total inflorescence number from 304 flowers (1991-1993) to 455 flowers (2012-2015) coupled with maintaining a large number and intermediate percentage (27%-70%) of flowering plants and an observed recruitment that is slightly higher than mortality are positive signs that the transect population is maintaining viability (**Tables 3** and **4**; **Figure 7B**). Further the 1999 field work documented seedlings indicating that germination can occur on the transect (Heidel 2001).

5.2.2 Mystery Cave Ridge Transect

The Mystery Cave Ridge transect population is apparently stable; however, the declining trend in plant area and inflorescence number coupled with mortality that is higher than recruitment seems to indicate a declining population. A stable population is inferred by the finding of no statistical difference in population size between the early (1991-1993) and later (2012-2015) years and across all years (**Table 2**; **Figure 5C**). The decline in total plant area from 7,690 square centimeters (1991-1993) to 6,544 square centimeters (2012-2015) was statistically significant, but not when analyzing the change in individual plant size across all years (**Table 2**; **Figures 6C**, 7**C**, and **C1-C**). This apparent dichotomy is explained by an interaction between plant number and plant size which may be shifting. Overall, the Mystery Cave Ridge transect has consistently maintained the lowest population and the largest plant size when compared with the other transects.

It is interesting that most of the Mystery Cave Ridge plants flower, produce the highest number of inflorescences, and yet no seedlings and only one new plant has been documented in the seven years of monitoring (**Table 3**). It is important to keep in mind that germination and mortality could have occurred on the transect in the years between monitoring. It is likely that the population is stressed, which may cause a response to reproduce. As suggested by Heidel (2001), it is plausible that either seed production or seed viability is low, which will prevent germination. This report agrees with the suggestion by Heidel (2001) that seed production should be examined. This would entail documenting staminate versus perfect flowers, fruit abortion, and fruit viability at the Mystery Cave Ridge transect (Heidel 2001). Seed viability and germination can differ between sub-populations that have different landscape settings (Heidel 2001).

Mortality may be affecting the population stability at Mystery Cave Ridge. In 1992 mortality was high, affecting mature plants of 4 to 28 square centimeter sizes within a 2-meter segment of the transect. This concentrated mortality points to a localized mortality factor (Heidel 2001). In 1999 this was the only transect where seedlings were absent (Heidel 2001) and the infrequency of recruitment affects a population's trend. If recruitment is episodic (e.g., is dependent upon wet springs) then targeted monitoring might be conducted in such years. This is also the only transect where a rust has been observed, but observers in 1999 and 2015 could not determine that it was causing harm (Heidel 2001) (**Photo 5** in **Appendix B**). The rust is likely a species of *Puccinia*, and several of these species occur in Montana and Wyoming and have infected species of *Lomatium* and *Musineon* (a relative of Shoshonea) (Stone 2015). The rust was found on Plant 8A, which has been monitored in all seven years which spans 25 years. However, it is not known how long this rust has been on this particular plant. Future monitoring should specifically look for and note individuals that have this rust (and any other disease). Future monitoring could also include an assessment of disease and pathogens on neighboring sub-populations. Sub-populations support each other in terms of genetic exchange and sharing pollinators, and the health of one sub-population may affect the health of others.

5.2.3 Animal Use

Monitoring at the Mystery Cave site was partially initiated by concerns that wild horse and native ungulate populations could negatively impact the Pryor Mountain population. The transects occur within the Pryor Mountain National Wild Horse Range, which is managed by the BLM. The free-roaming wild horse population is approximately 158, which exceeds the established Appropriate Management Level (AML) set at 90-120 horses (BLM 2014b). The National Wild Horse Range is used by a variety of native ungulates, and domestic livestock are not provided access (BLM 2014b). This area is also greatly used by recreationalists who hike, camp, and/or drive off-road vehicles.

A trail used by wild horses and likely by game animals crosses through and parallels the Mystery Cave Road transect (**Photo 14** in **Appendix B**). This provides a good setting to observe the effects of animal use on Shoshonea plants as the trail has been present since at least 1991. Herbivory, soil compaction, and soil surface disturbance have not been observed on the transect during the seven years of monitoring. This indicates that in the span of 25 years, Shoshonea plants at this site are not negatively impacted by wild horses or native ungulates.

The Mystery Cave Road transect is also very near to a two-track road. This road provides access for recreationalists and is used by hikers and off-road vehicles. In the seven years of monitoring that spans 25 years, no negative impacts have been observed on or around the sub-population.

5.2.4 Fire Management

The 1999 trend report recognized that the BLM's fire management policy could directly have an impact on Shoshonea plants and the many other regionally endemic plants that occur in the Pryor Mountains (Heidel 2001). It is recommended that a fire management policy (for wildfires and prescribed burns) and related vegetation management address Shoshonea and the other regionally endemic plants as protection targets and to maintain early- to mid- successional conditions on suitable ridge settings without destabilizing the habitat. Further management of Shoshonea should include collaboration among the agencies (e.g., BLM, Bighorn Canyon National Recreation Area, USFS, and tribal lands) that manage the occupied range of this plant in Montana and Wyoming.

5.2.5 Demographic Monitoring

Demographic monitoring tracks the fate of individual plants through time. When implemented correctly, this labor intensive method of monitoring provides information on age structure, plant growth, recruitment, mortality, fecundity, and more. Long-term data-sets can be the foundation for guiding management. The demographic monitoring of *Shoshonea pulvinata* has been able to successfully track individuals over a 25-year period and provide insights into population, flowering, and growth trends. However, significant challenges with tracking individuals is becoming apparent with the existing method and frequency of monitoring.

First, *Shoshonea pulvinata* is a weak mat-forming plant. Mat-forming plants are not recommended for demographic monitoring because it is difficult to consistently distinguish individuals (Elzinga et al. 1998). This monitoring project has been successful, in part because both plant coordinates and cover are used together to determine individuals. Shoshonea plants can remain as discrete individuals for years, or individuals can grow together into a large mat. Often the center of a mat-forming individual will die while the outer portions grow, but death and growth is not usually symmetric. The result is that portions of the same plant can appear separate. To determine if plants are connected only requires one to scrape a little soil away and look for an underground stem. Plants are mapped in their center, but as the center changes so do the coordinates. This has become a bit of a challenge, especially when long intervals pass between monitoring years.

Second, consecutive years of monitoring is necessary for identifying typical versus unusual data. The value found in demographic monitoring gets lost when data collection occurs infrequently or sporadically. For example, statistical inferences on recruitment and mortality of Shoshonea plants is not possible because monitoring has occurred too infrequently. To maintain the power that demographic monitoring brings requires consecutive years of monitoring or at the very least very frequent and consistent monitoring.

Although Shoshonea plants are long-lived and appear stable at three Montana locations, negative trends in flower production and/or plant size are being observed at the Grove Creek and Mystery Ridge sites. To better understand the causes behind these trends would require additional studies of germination, seed viability, and climate change. The transects have remained in place for 25-years, and their stability allows for monitoring activities to continue and to build on the current transect data-sets. On one hand this data-set has acquired a lot of information, some of which has yet to be analyzed. It provides a great foundation for building upon to investigate germination, seed viability, and effects of climate change on the sub-populations. Specifically, the influence of temperature and precipitation on flowering, plant numbers, mortality, and recruitment could be evaluated using local weather station data. The Grove Creek transect data-set could be re-evaluated with monthly temperature and precipitation data, collected since 1894, from the Red Lodge, Montana weather station. The Mystery Cave transect data-sets could be re-evaluated with monthly temperature and precipitation data, collected since 1909, from the Bridger, Montana weather station. On the other hand, these sub-populations (and hence, the populations) are not experiencing threats from wild horses, native ungulates, energy development, or recreation. Given a limit in funding and labor resources, demographic monitoring of the appropriate species (those possessing characteristics that make demographic monitoring possible) should be prioritized for places where long-term data-sets will provide the most benefit to BLM managers.

6.0 REFERENCES

Bureau of Land Management (BLM). 2010. BLM Wyoming Sensitive Species Policy and List. March 31, 2010. Accessed on February 24, 2016. URL <http://www.blm.gov/style/medialib/blm/wy/resources/efoia/IMs/2010.Par.41285.File.dat/wy2010-027atch2.pdf>

Bureau of Land Management (BLM). 2014a. 2014 Montana/Dakotas Special Status Species List. August 1, 2014. Memorandum from State Director to Field Managers, Montana State Office, Billings, Montana.

Bureau of Land Management (BLM). 2014b. Pryor Mountain Wild Horse Range Quick Facts. Updated August. Obtained on February 2, 2016 at <http://www.blm.gov/mt/st/en/fo/billings_field_office/wildhorses.html>

Elzinga, C., D. Salzer, and J. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1. Bureau of Land Management, National Business Center, Denver, Colorado.

Evert, E.F. and L. Constance. 1982. *Shoshonea pulvinata*, a new genus and species of Umbelliferae from Wyoming. Systematic Botany 7:471-475.

Heidel, B. 2015. Botanist, Wyoming Natural Diversity Database, Laramie, Wyoming. February. Personal communications.

Heidel, B. 2011. Status of *Shoshonea pulvinata* (Shoshonea), Park County, Wyoming. Prepared for the Bureau of Land Management, Cody Field Office. Prepared by Wyoming Natural Diversity Database, Laramie, Wyoming.

Heidel, B. 2001. Monitoring *Shoshonea pulvinata* in the Pryor and Beartooth Mountains, Carbon County, Montana. 1999 trend report prepared for the B Bureau of Land Management, Billings, Montana. Montana Natural Heritage Program, Helena, Montana. 11 pp. plus appendices.

Lesica, P. 1993. Monitoring Population of *Shoshonea pulvinata* in the Pryor and Beartooth Mountains, Carbon County, Montana. 1991-1993 baseline report prepared for the Bureau of Land Management, Billings, Montana. Montana Natural Heritage Program, Helena, Montana. 10 pp. plus appendices.

Lesica, P. and P.L. Achuff. 1991. Monitoring Populations of S*hoshonea pulvinata* in the Pryor and Beartooth Mountains, Carbon County, Montana. Report prepared for the Bureau of Land Management, Billings, Montana. Montana Natural Heritage Program, Helena, Montana. 18 pp. plus appendices.

Lesica, P. and J.S. Shelly. 1988. Report on the Conservation Status of *Shoshonea pulvinata*, a candidate threated species. Report to the U.S. Fish and Wildlife Service, Office of Endangered Species, Denver, Colorado.

Lesica, P. 1987. A technique for monitoring non-rhizomatous, perennial plant species in permanent belt transects. Natural Areas Journal 7(2): 65-68.

Montana Natural Heritage Program (MTNHP). 2015. Queries of the Botany Observation Database. Helena, Montana.

NatureServe. 2015. Profile of *Shoshonea pulvinata*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Accessed on February 24, 2016. URL <http://explorer.natureserve.org>

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/.

Rcmdr Package. 2015. A platform-independent basic-statistics graphical user interface for R, based on the tcltk package. URL <http://www.r-project.org> and <http://socserv.socsci.mcmaster.ca/jfox/Misc/Rcmdr/>

Stone, J. 2015. Senior Research Professor, Agricultural Botany and Plant Pathology, Oregon State University, Corvallis, Oregon. July 27- 31, 2015 electronic mail correspondence on *Puccinia*.

Wyoming Natural Diversity Database (WNDD). 2015. Species of Concern 2012 List. University of Wyoming, Laramie, Wyoming. Accessed on January 21, 2016. URL <http://www.uwyo.edu/wyndd/species-of-concern/>

Appendix A

Raw Transect Monitoring Data:

Table A-1: Grove Creek
Table A-2: Mystery Cave Road
Table A-3: Mystery Cave Ridge

Appendix B

Monitoring Photographs

Monitoring Shoshonea pulvinata *in the Pryor and Beartooth Mountains, Carbon County, Montana: 1991-2015 Trend Report*

Appendix C

Linear Regression Graphs

Monitoring Shoshonea pulvinata *in the Pryor and Beartooth Mountains, Carbon County, Montana: 1991-2015 Trend Report*