Fritillaria gentneri population monitoring at Pickett Creek, Josephine County, Oregon

2013

Report to the Bureau of Land Management, Medford District

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Institute for Applied Ecology

PREFACE

This report is the result of a cooperative project between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization dedicated to natural resource conservation, restoration, research, and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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ACKNOWLEDGEMENTS
The authors gratefully acknowledge the cooperation and support of Susan Carter, Rachel Showalter and Bryan Wender, of the Medford District BLM, and Mark Mousseaux from the state BLM office. We also recognize IAE staff members and interns, Michelle Allen, Sarah Bois, Kelsey Copes-Gerbitz, Andrew Heaston, Charlotte Trowbridge, Tobin Weatherson, and Shell Whittington, for their assistance with fieldwork, administration, and data management in 2013.

Cover photograph: Gentner's fritillary (*Fritillaria gentneri*).

Suggested Citation

Giles-Johnson D.E.L., E.C. Gray, and T.N. Kaye, 2013. *Fritillaria gentneri* population monitoring at Pickett Creek, Josephine County, Oregon. Institute for Applied Ecology, Corvallis, Oregon and USDI Bureau of Land Management, Medford District. iii + 23 pp

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EXECUTIVE SUMMARY

Over the twelve years of this study we have noted a startling drop in the number of flowering individuals of *Fritillaria gentneri* at the Pickett Creek population in the Medford District of Oregon. At the initiation of the study, in 2002, the population numbered above 400 reproductive plants with an estimated population size of 13,294 vegetative. The number of reproductive plants has declined over the years to a low of 46 in 2012 and only 68 in 2013; however, the number of vegetative plants has remained relatively stable. Population monitoring has been identified as a key recovery task in the species' federal recovery plan (USFWS 2003)

While *F. gentneri* primarily reproduces vegetatively, recent work by the Oregon Department of Agriculture has shown that *F. gentneri* can produce viable fruits, and it has been well documented that mother bulbs can reproduce vegetatively creating hundreds of bulblets. Despite this, we have not seen any increases in the vegetative or reproductive populations over the twelve years of this study, and in fact have seen a shift towards smaller size classes and fewer flowering individuals.

The length of this study allows us to capture expected interannual variability driven by climate, and even allows for basic climate models to be created considering temperature and precipitation. We have been able to determine that the Pickett Creek population tends to thrive under warmer/drier fall and winter conditions which have not been experienced in recent years. However the fall and winter of 2013 look to be drier and warmer than previous years thus in 2014, we predict an increase in the number of vegetative and flowering individuals. While climate models can suggest potential influences on the population, they also suggest that *the decrease in the reproductive population is not explained by climate drivers alone and thus it is likely that other environmental or biological variables are driving the alarming decrease in the number of flowering individuals*.

We recommend that action be taken to preserve the Pickett Creek population of this sensitive species. The 2003 Recovery Plan includes both habitat manipulation (including prescribed fire) and reintroductions as potential management actions.

Fritillaria gentneri population monitoring at Pickett Creek, Josephine County, Oregon

REPORT TO THE BUREAU OF LAND MANAGEMENT, MEDFORD DISTRICT

INTRODUCTION

Project Overview

The purpose of this multi-year project is to monitor one of the largest known populations of *Fritillaria gentneri* Gilkey (Gentner's fritillary; Figure 1), a rare member of the lily family (Liliaceae), which is listed as endangered by the U.S. Fish and Wildlife Service (Federal Register 1999) and the State of Oregon (ONHP 2001). This population, consisting of multiple patches, is located on a steep, rocky, poison oak-covered slope overlooking the scenic Pickett Creek drainage in Josephine County, an area managed by the Medford District BLM. Data gathered during this long-term study provides important information on the status, dynamics, and trends of the *F. gentneri* population at Pickett Creek. This information can serve as a useful demographic baseline for evaluating population responses to habitat changes caused by natural forces and/or prescribed land management actions. In 2011-13, we were able to use the long-term monitoring data to model population trends using climatic predictors; these models enable us to understand population trends of this rare species in relation to environmental stochasticity. The monitoring protocols developed at Pickett Creek will also provide the BLM and other land management agencies a useful template for monitoring *F. gentneri* at other locations. Population monitoring has been identified as a key recovery task in the species' federal recovery plan (USFWS 2003).

Figure 1. Three closely related Fritillaria species. *Fritillaria affinis* (left) and *F. recurva* (right) are the putative parents of *F. gentneri* (center).

Species Description and Systematics

Fritillaria gentneri is a perennial member of the lily family (Liliaceae) with grayish-green stems and bell-shaped, blood red flowers (Figure 1). There are several key morphological traits that are helpful in distinguishing *F. gentneri* from its relative, *F. recurva*, though in some individuals these traits can be variable and subtle. Flowers of *F. gentneri* are generally broadly campanulate with deep blood-red perianth segments, whereas those of *F. recurva* are generally less broad, pale red to orange in color, and exhibit more strongly recurved tips (Figure 1). In *F. gentneri*, style branches are usually cleft nearly half the length of the style and are widely spread, while those of *F. recurva* are typically shorter and cleft approximately one-third to one-quarter the length of the style. Glands at the base of *F. gentneri* petals usually extend half the length of the segment and form a conspicuous keel on the dorsal side (Gilkey 1951). In contrast, glands of *F. recurva* are usually less pronounced. In small populations, such as that at Pickett Creek, *F. gentneri* is not known to produce viable seeds, but reproduces asexually by shedding numerous rice-grain sized bulblets below ground (Guerrant 1991; Figure 2).

There are several hypotheses about the evolutionary origin of *F. gentneri*. The prevailing hypothesis suggests that *F. gentneri* is a stabilized hybrid between *F. recurva* and *F. affinis* (= *F. lanceolata*) (see Figure 1). Both hypothesized parents overlap in geographic range with *F. gentneri* (and both are present at the Pickett Creek site) and share several morphological, genetic and physiological traits with *F. gentneri* (Guerrant 1991, Knight 1991, Cary and Jessup 2004). Molecular tests using randomly amplified polymorphic DNA (RAPDs) revealed high interpopulation variability, making conclusions about historical introgression between the three species difficult (Cary and Jessup 2004). However, superimposed nucleotide additivity patterns (SNAPs) in the nuclear ribosomal internal transcribed spacer (ITS) sequences indicate that *F. gentneri* is a hybrid of *F. affinis* and *F. recurva*, with *F. recurva* as the maternal plant (Meyers et al. 2006). In addition, both nuclear and chloroplast sequences suggest that separate hybridization events have occurred on multiple occasions (Meyers *et al.* 2006). A controlled pollination study found that *F. gentneri* had an inability to produce seed from conspecific pollinators corroborating the evidence for a hybrid origin (Amsberry and Meinke 2006). When pollinated by either *F. affinis* or *F. recurva*, *F. gentneri* consistently produced fertile seeds. Preliminary work by the Oregon Department of Agriculture shows that it may be possible for viable seeds to be produced by crossing *F. gentneri* between populations (Amsberry personal communication).

Figure 2. Densely clustered leaves from fragmented bulbs and rice grain bulblets of *F.* gentneri. In this photograph, over 100 *F.* gentneri leaves emerged from a palm-sized area.

Habitat and Geographic Range

Fritillaria gentneri is endemic to southwestern Oregon and northern California. In Oregon, it is known only in Jackson and Josephine Counties; in California, it is only known in Siskiyou County. Most populations are small, containing fewer than 100 individuals, and are within open oak woodland and chaparral shrub communities along the lower slopes of the Rogue Valley basin. The geographic ranges of both *F. affinis* and *F. recurva* are quite broad with *F. affinis* found along the west coast of North America from Vancouver Island to San Jose. *F. recurva* is found from Southern Oregon to just north of San Francisco. Known populations of *F. gentneri* are found in an area where the geographic ranges of *F. affinis* and *F. recurva* overlap (Meyers *et al.* 2006; Figure 3).

The Pickett Creek site is characterized by a steep, south-facing slope, with serpentine influenced bedrock underlying shallow, rocky soils. The subpopulations of *F. gentneri* at Pickett Creek are found in both the whiteleaf manzanita/mixed annual grass chaparral and white oak/poison oak/annual grass woodland habitat types. Shrub and tree species commonly associated with the chaparral habitat type include *Rhus diversiloba, Arctostaphylos viscida, Quercus garryana, Garrya buxifolia, Ceanothus integerrimus,* and *Pinus jeffreyi*. Native grasses are less common in the chaparral habitat where annual invasive grasses including *Cynosurus echinatus, Bromus tectorum, B. hordeaceus*, and *Aira caryophyllea* are more common (Voz 1999). In the woodland habitat co-dominants include the natives *Quercus garryana*, *Pseudotsuga menziesii, Rhus diversiloba, Garrya buxifolia, Ceanothus integerrimus, Ranunculus occidentalis*, and *Sanicula crassicaulis* and invasives *Cynosurus echinatus and Bromus tectorum* (Voz 1999).

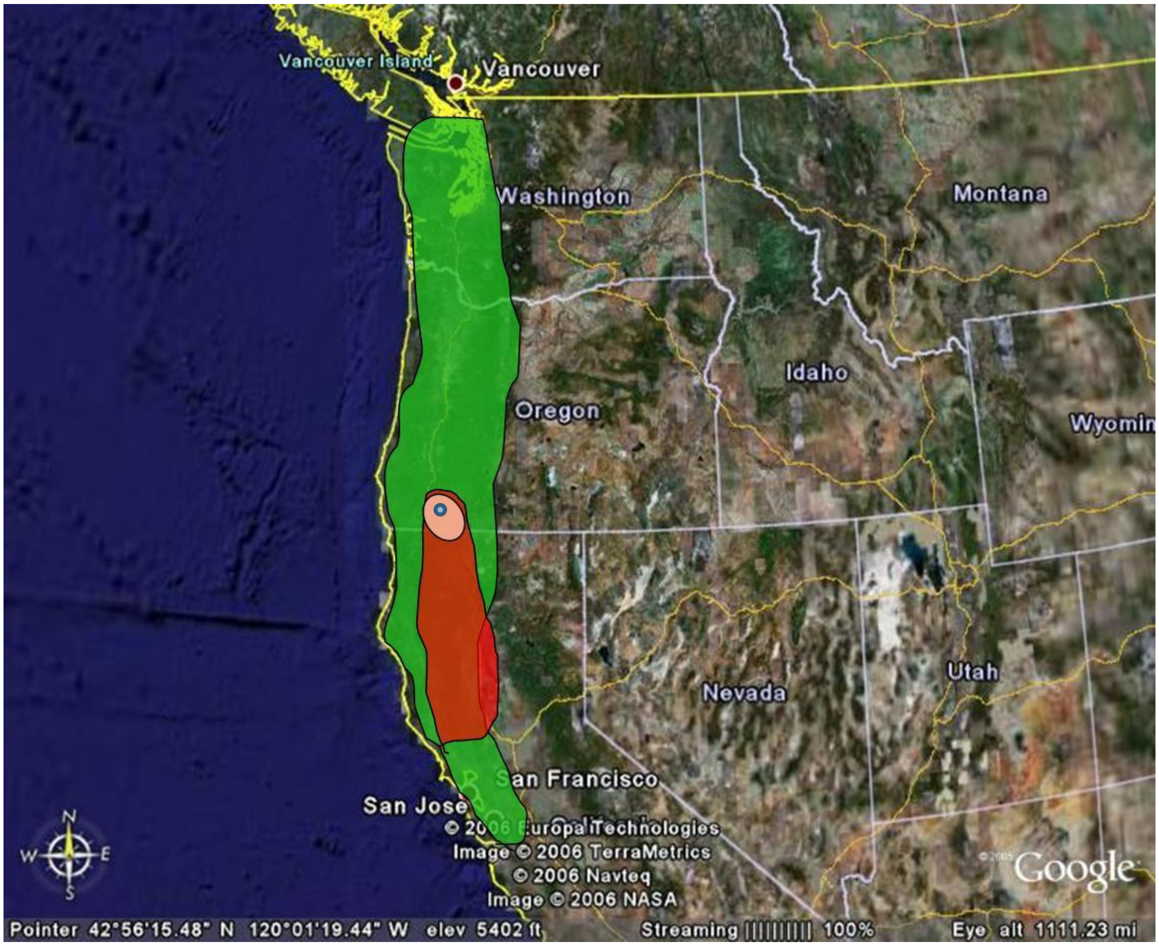


Figure 3. Known range of *Fritillaria recurva* (red), *F. affinis* (green), and *F. gentneri* (pink), from Meyers et al. 2006. Blue dot represents the Pickett Creek Population

METHODS

General Monitoring Approach

Population monitoring at Pickett Creek is conducted annually at two levels of intensity:

1. Complete censusing of all flowering plants
2. Monitoring of density plots

Complete censusing of flowering plants is conducted on an annual basis to provide an accurate count of mature, "reproductive" plants in the entire Pickett Creek population. Since this species is not known to produce viable seeds, flowers are not a true indication of reproductive status. While this monitoring method provides a straightforward and easily repeatable means of evaluating annual fluctuations in flowering individuals, this method omits information on non-flowering plants that comprise the majority of the population. A complete census of non-flowering individuals would however be impractical due to their sheer number, abundance, small size (very young plants produce tiny, solitary leaves resembling blades of grass; Figure 2 and Figure 4) and similar morphology in the vegetative state to other sympatric *Fritillaria* species.

Monitoring of density plots involves counting plants of all sizes, both flowering and vegetative, in randomly selected plots to provide information on the density of the plants and relative number of individuals in various size/life-history classes. Using this monitoring method, typically performed on hands and knees, even grass-like vegetative plants can be located and counted due to the manageable size of sampling plots. As flowering individuals of other *Fritillaria* species have never been observed within these density plots, all *Fritillaria* leaves are attributed to *F. gentneri*.

Collectively, these two levels of monitoring intensity allow us to determine the total number of flowering plants in the population and estimate the population size and relative number (frequency) of individuals in all life-history stages.

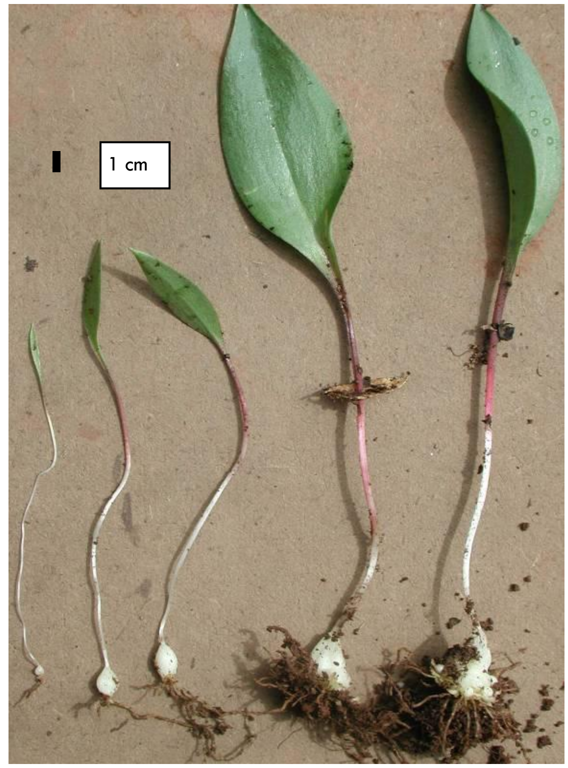


Figure 4. Range of leaf and bulb sizes typically encountered among vegetative plants in populations of *F. gentneri*. Larger bulbs produce offsets that result in asexual reproduction.

Flowering Plant Census

A census of flowering plants has been conducted annually from 2002 through 2013 for the entire Pickett Creek population. Data were collected separately for the four subpopulations: up-slope, mid-slope, roadside, and below road (Appendix A). Each census was performed by traversing the entire area and counting all flowering *F. gentneri* individuals. In dense areas, individuals were temporarily marked to prevent re-counting. Each plant was categorized based on the number of its flowers (plants with one flower are categorized as R1, plants with 2 flowers as R2, etc.). When flowers had been eaten by herbivores, they were categorized as RG ("reproductive-grazed").

Density Plots

Density plots were established in the up-slope and below-road subpopulations in 2002 (Appendix A). Although the roadside subpopulation was the most robust and easily accessible, we chose not to establish plots there. The habitat in this subpopulation is very sensitive as it is precariously perched above a steep, eroding road cut and has already been impacted by exclosures and reproduction research by the Oregon Department of Agriculture. In addition, *F. recurva* is intermixed with *F. gentneri* in this subpopulation and we cannot distinguish these two species in vegetative form. The density of the mid-slope subpopulation was too sparse to warrant establishment of monitoring plots.

Both subpopulations, above and below the road, were sketched onto a grid, and out of the 85 potential plots that contained *F. gentneri*, ten were randomly selected from each subpopulation for density monitoring. Plots were distributed so that the number of plots in each area was proportional to the number of plants.

In order to determine the optimal plot size to detect population changes, two different plot sizes were monitored. All density monitoring plots were 3 x 20 meters in size with 2 x 20 meter subplots nested within them. Preliminary analysis using two years of sampling data suggested that both plot sizes were roughly equivalent in their ability to detect overall population change, but the 3-m wide plots were superior to the 2-m wide sampling units in their ability to detect change in flowering size classes (Kaye and Blakeley-Smith 2003). Therefore, we are continuing to use both plot sizes in order to continue the comparison.

Each density plot was marked on both ends by 5-foot metal conduit posts painted red at the top. Each post was labeled with a copper tag indicating the plot number and whether it is the start or end post. A meter tape stretched between the beginning and end posts provides a middle reference line for each plot. (Note: Plot 20 is on an undulating slope across which the meter tape was allowed to sag with the contour.) For the 3 x 20 meter plots, all plants within 1.5 meters of each side of the tape were counted. For the 2 x 20 meter plots, all plants within one meter of each side of the tape were counted. All plants are counted as long as they are rooted within the plot boundaries. Each plant was recorded based on its size class, which approximates life-history stage classes. Vegetative (i.e., non-flowering) plants were classified by the leaf width at the widest point using the following classification groupings: <1 cm, 1-2 cm, 2-4 cm, and >4 cm. For all flowering plants, the number of flowers was recorded using the same protocol used for census data collection (i.e. R1= a plant with one flower, R2= a plant with two flowers, etc.). Grazed flowering plants were designated as "RG." The number of plants within the upper and below-road subpopulations was estimated by multiplying the total mean density of plants in each plot by 85 (the total number of potential plots that include the populations).

Climate Modeling

Climate data [monthly precipitation (in), monthly minimum temperature (°F), and monthly maximum temperature (°F)] from 2001- 2013 were acquired from the PRISM climate group (PRISM 2006). Monthly averages were combined into seasonal means (winter = December-February, spring = March-May, summer = June-August, fall = September-November) and used as predictors for each model tested. We used non-parametric multiplicative regression [NPMR; Hyperniche v. 2.0 (McCune and Mefford 2009)] to determine which climatic factors had the greatest impact on estimated number of total, vegetative, and flowering plants of *F. gentneri* calculated from the density plots. NPMR uses a local multiplicative smoothing function with leave-one-out cross-validation to estimate the response variable. We used a Gaussian weighting function with a local mean estimator in a forward stepwise regression of our response variable against the predictors, then expressed fit as a cross-validated R^2 (or xR^2). The xR^2 differs from the traditional R^2 because each data point is excluded from the basis for the estimate of the response at that point. Consequently, with a weak model, the residual sum of squares can exceed the total sum of squares and thus xR^2 becomes negative. Rather than fitting coefficients in a fixed equation, NPMR fits 'tolerances', the standard deviations used in the Gaussian smoothers. Predictors with narrow tolerances have greater effects on the model than do those with broad tolerances (McCune 2006).

RESULTS AND DISCUSSION

Flowering Plant Census

In 2013 only 68 plants were counted, the second lowest number ever observed in the 12 years of this study (a slight increase from the 46 found in 2012). The largest number of flowering plants observed was 424 plants in 2002 (Table 1). Of the plants observed in the 2013 census, 13% produced one flower, 62% produced two flowers and 12% produced three flowers. The following demographic categories each represented 3% of the flowering individuals: R4, R5, R6 and R-grazed. In 2013 only 0.26% of the total population was flowering (down from a high of 3.14% in 2002, Figure 6, Figure 7).

The number of flowering individuals has dramatically decreased in the four sub-populations (Figure 5, Table 1). The up-slope subpopulation has declined over the twelve years of this study from a maximum of 123 to no flowering individuals in 2012 and only three in 2013. We found no reproductive individuals in the mid-slope subpopulation in 2012 or 2013. The roadside subpopulation which at the initiation of this study was the most vigorous, has declined from185 counted in 2003 to only 8 reproductive individuals in 2013 (Figure 5). The decline of the below road population from a high of 97 in 2003 to 57 in 2013, while not as precipitous as other sub-populations at the site, still represents a significant decrease in reproductive effort at the Pickett Creek site (Table 1).

It is known that flowers of *F. gentneri* in small populations do not produce viable seeds (Amsberry 2006 and personal communication), however it has been shown that large populations, as well as in cross-pollination experiments, have resulted in the production of viable seeds. It may be necessary to augment the population with genetically appropriate plants cultivated individuals to meet the minimum size criterion (Recovery Action 2.43, USFWS 2003).

Table 1. Abundance of flowering *F. gentneri* individuals (determined through census) in the four subpopulations at Pickett Creek, 2002-2013.

Subpopulation	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Up-Slope	122	123	78	123	18	47	10	15	12	0	0	3
Mid-Slope	5	0	0	2	0	0	0	16	2	0	0	0
Roadside	231	185	116	85	36	26	56	22	32	14	6	8
Below Road	66	98	41	40	14	34	87	87	58	86	40	57
Total	424	406	235	250	68	107	153	140	104	100	46	68

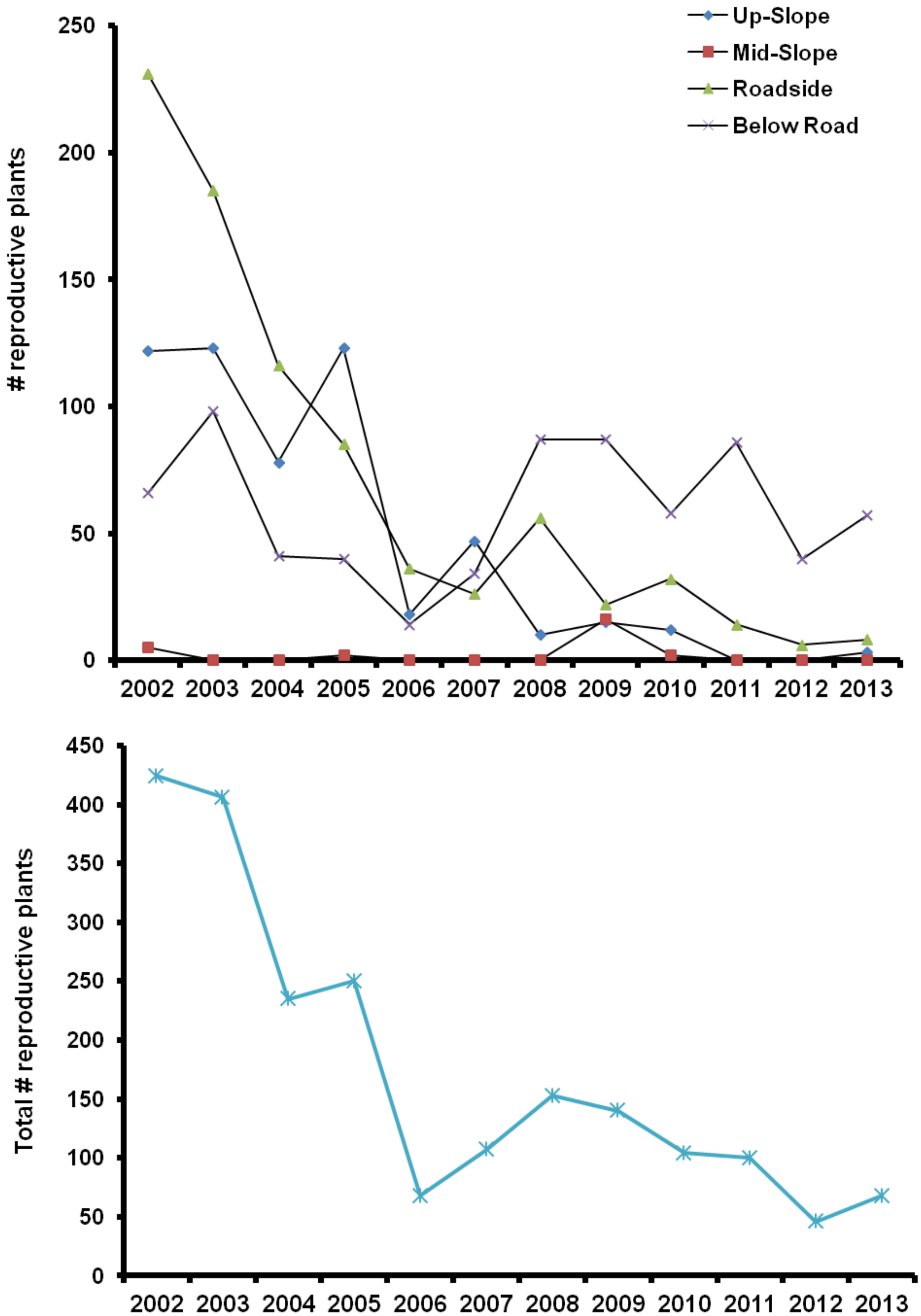


Figure 5. The abundance of flowering *F. gentneri* individuals (determined through census) in the four subpopulations at Pickett Creek from 2002-2013 (top). Total number of flowering individuals observed from 2002-2013 (bottom).

Density Plots

In general, the number of plants counted in the density plots has remained relatively stable throughout the course of this study (Figure 8, Table 2).

The proportion of plants in the smallest vegetative class (<1cm) has been steadily increasing since monitoring began. Conversely, the proportion of plants in the larger vegetative class (>4 cm) has steadily decreased (Table 3). Extrapolating from the density plot sampling data, the total number of *F. gentneri* in the upper and below-road subpopulations in 2013 was 13,783 (95% confidence interval: 10,015 – 17,550, Table 2 , Figure 6).

The percentage of flowering individuals within the density plots has decreased throughout the course of this study from a high of 3.1% in 2002 to only 0.26% in 2013 (Table 3). This decrease is consistent with our census measurements which also show a decrease in the number of flowering individuals observed at Pickett Creek. Currently, flowering plants do not produce seed at this site, thus the decline in the number of flowering plants is not expected to have an effect on the population as a whole. However, if sexual reproduction is restored to the site by crossing or augmenting with bulbs from other populations, then this loss of flowering could limit those positive effects.

Table 2. Estimated population size of *F. Gentneri* at Pickett Creek.

	Estimated Vegetative	Estimated Flowering	Total Estimated Population	95% Confidence Interval	Lower Confidence Limit	Upper Confidence Limit
2002	13,294	272	13,566	6208	7,358	19,774
2003	17,344	340	17,684	5,735	11,950	23,419
2004	13,337	183	13,519	3,412	10,108	19,774
2005	12,682	230	12,912	4,413	8,499	17,324
2006	6,626	89	6,715	1,722	4,993	8,437
2007	10,561	72	10,634	3,576	7,058	14,209
2008	8,772	196	8,968	2,560	6,408	11,527
2009	11,887	162	12,049	4,825	7,224	16,874
2010	14,803	123	14,926	5,425	9,501	20,351
2011	12,737	153	12,890	3,879	9,011	16,769
2012	13,337	64	13,400	3,697	9,703	17,097
2013	13,702	81	13,783	3,767	10,015	17,550

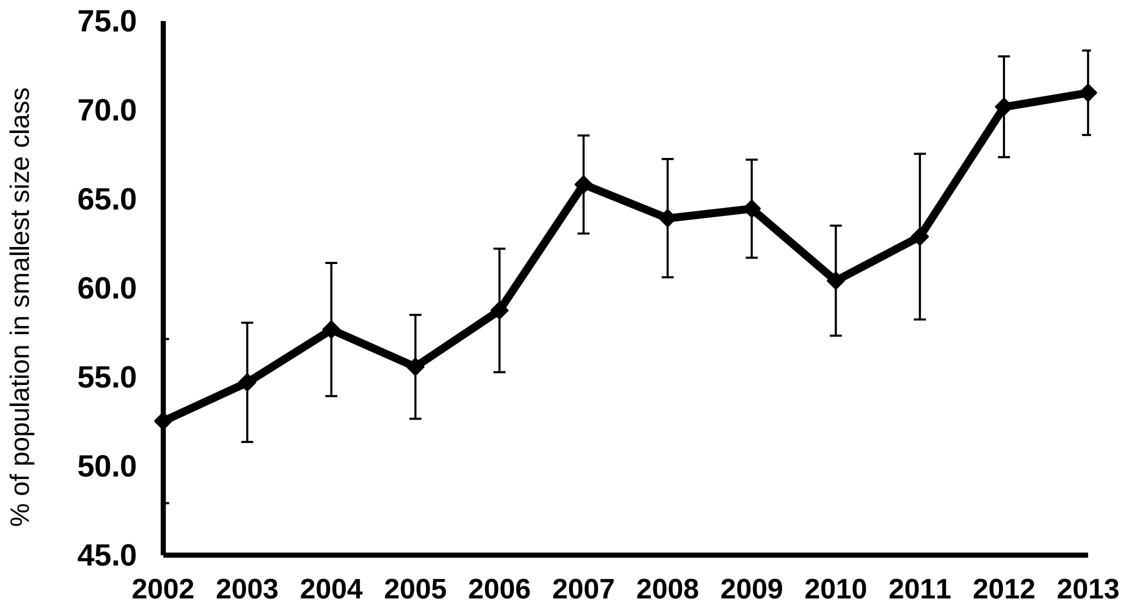


Figure 6. Percentage of individuals in the smallest size class (V1 = 0-1cm), at Pickett Creek. Error bars represent 95% confidence interval. There has been a significant shift in the density plots towards the smallest size classes.

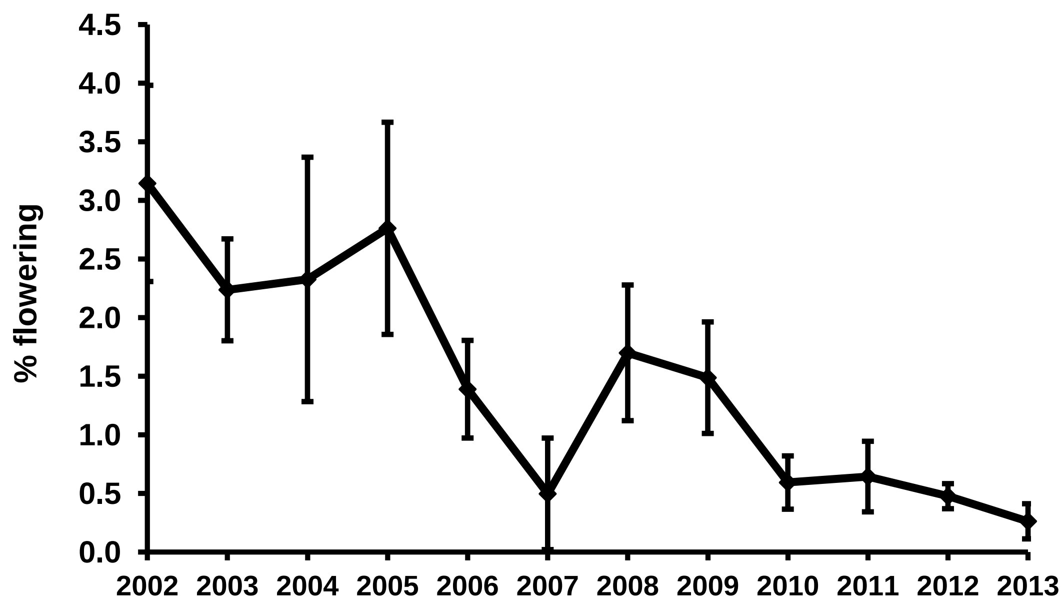
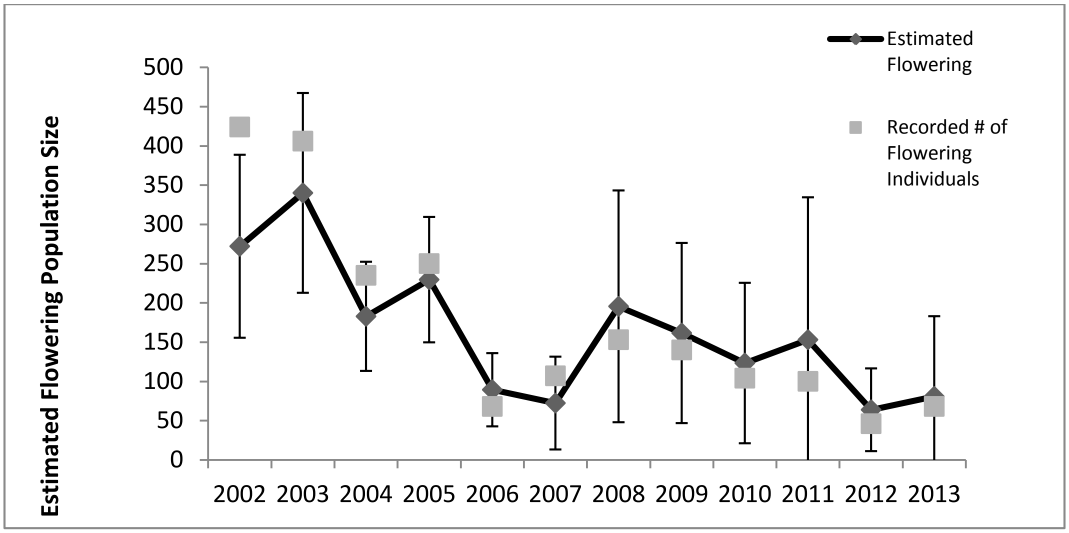


Figure 7. Percentage of flowering individuals at Pickett Creek in the density plots has steadily declined since 2002. Error bars represent 95% confidence interval. There has been a significant decrease in the percentage of the population flowering over the course of the study.

Table 3. Mean number and percent (±SE) of *F. gentneri* individuals per density plot in each stage class at Pickett Creek in 2002-2012.

Stage	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Vegetative plants												
<1 cm	98 ± 28 53 %	119 ± 22 54 %	97 ± 15 58 %	92 ± 20 56 %	48 ± 8 59 %	88 ± 18 66 %	65 ± 9 62 %	96 ± 22 67 %	106 ± 23 60 %	98 ± 18 63 %	111 ± 19 70 %	116 ± 18 71%
1-2 cm	30 ± 10 21 %	49 ± 12 24 %	30 ± 6 19 %	32 ± 7 22 %	16 ± 3 19 %	19 ± 4 17 %	20 ± 5 19 %	28 ± 7 20 %	42 ± 10 24 %	30 ± 6 23 %	31 ± 5 19 %	24 ±3 17%
2-4 cm	23 ± 4 19 %	27 ± 6 14 %	19 ± 3 14 %	19 ± 3 15 %	11 ± 2 16 %	14 ± 3 13 %	15 ± 3 14 %	14 ± 4 10 %	23 ± 6 13 %	18 ± 5 11 %	14 ± 3 9 %	17 ±5 10%
>4 cm	6 ± 1 4 %	9 ± 2 4 %	11 ± 2 8 %	7 ± 1 6 %	4 ± 1 5 %	4 ± 1 4 %	4 ± 1 4 %	3 ± 1 2 %	4 ± 1 3 %	4 ± 2 2 %	2 ± 1 1%	4 ±1 2%
Total Veg.	*156 ± 42* *97 %*	*204 ± 39* *98 %*	*157 ± 23* *98 %*	*149 ± 30* *97 %*	*78 ± 12* *99 %*	*124 ± 24* *100 %*	*103 ± 16* *98 %*	*140 ± 33* *99 %*	*174 ± 37* *99 %*	*149 ± 26* *99 %*	*157 ±25* *99 %*	*161 ±25* *100 %*
Reproductive (flowering) plants (R# indicates # of flowers; RG indicates flowering plants whose flowers were grazed.)												
R1	0.6 ± 0.2 0.70 %	0.8 ± 0.2 0.70 %	0.2 ± 0.1 0.10 %	0.4 ± 0.1 0.40 %	0.1 ± 0.1 0.10 %	0	0.3 ± 0.1 0.30 %	0.4 ± 0.2 0.30 %	0.05 ± 0.05 0.08 %	0.2 ± 0.2 0.03 %	0.3 ± 0.25 0.2 %	0.15 ±0.15 0.3%
R2	1.7 ± 0.5 1.4 %	1.9 ± 0.4 1.1 %	1.3 ± 0.3 1.1 %	1.4 ± 0.3 1.3 %	0.3 ± 0.1 0.3 %	0.7 ± 0.4 0.3 %	1.2 ± 0.8 0.7 %	1.1 ± 0.6 0.7 %	0.9 ± 0.4 0.3 %	1.1 ± 0.7 0.5 %	0.3 ± 0.12 0.2%	0.7 ±0.45 0.21%
R3	0.5 ± 0.3 0.70 %	0.8 ± 0.2 0.20 %	0.3 ± 0.1 0.10 %	0.5 ± 0.2 0.50 %	0.4 ± 0.2 0.50 %	0.1 ± 0.1 0.10 %	0.5 ± 0.3 0.40 %	0.3 ± 0.2 0.21 %	0.4 ± 0.2 0.18 %	0.5 ± 0.4 0.14 %	0.1 ± 0.06 0.06%	0.05 ±0.05 0.01%
R4	0.1 ± 0.1 0.05 %	0.1 ± 0.1 0.01 %	0.1 ± 0.1 0.02 %	0.3 ± 0.2 0.40 %	0.1 ± 0.1 0.40 %	0.1 ± 0.1 0.01 %	0.2 ± 0.1 0.20 %	0.1 ± 0.1 0.10 %	0	0	0	0.05 ±0.05 0.01%
R5	0	0.5 ± 0.1 0.01 %	0	0.1 ± 0.1 0.02 %	0	0	0	0	0	0	0	0
R6	0	0	0	0	0	0	0	0	0	0.5 ± 0.5 0.1 %	0	0
RG	0.3 ± 0.1 0.20 %	0.5 ± 0.2 0.30 %	0.4 ± 0.2 1.0 %	0.2 ± 0.1 0.20 %	0.2 ± 0.1 0.20 %	0.1 ± 0.1 0.10 %	0.2 ± 0.1 0.20 %	0.1 ± 0.1 0.10 %	0.15 ± 0.1 0.02 %	0	0.05 ± 0.05 0.03%	0
Total repro	*3.2 ± 0.8* *3.1 %*	*4.0 ± 0.9* *1.9 %*	*2.2 ± 0.5* *2.3 %*	*2.7 ± 0.5* *2.8 %*	*1.1 ± 0.3* *1.4 %*	*0.9 ± 0.4* *0.5 %*	*2.3 ± 1.0* *1.8 %*	*1.9 ± 0.8* *1.3 %*	*1.5 ± 0.7* *0.6 %*	*1.8 ± 1.2* *0.6 %*	*0.75 ± 0.36* *0.5 %*	0.95 ±0.7 0.26%
Total	160 ± 43	208 ± 39	160 ± 23	152 ± 30	79 ± 12	125 ± 25	106 ± 18	142 ± 33	176 ± 37	152 ± 27	158 ± 25	162 ±26



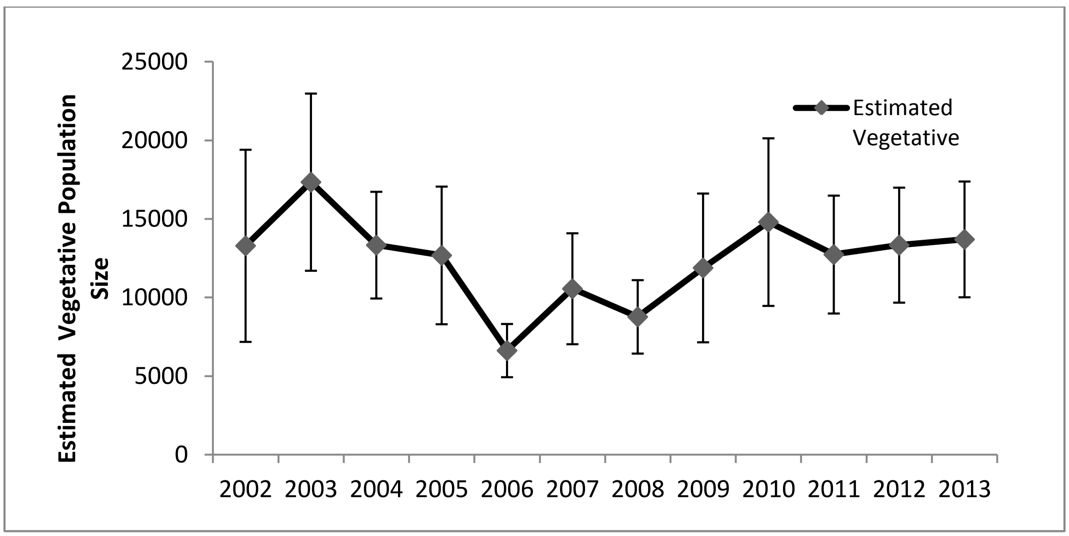


Figure 8. Estimated number of flowering (top) and vegetative (bottom) *F. gentneri* in the upslope and below-road subpopulations at Pickett Creek, based upon the density plot sub-sampling, from 2002-2013. Error bars represent 95% confidence intervals. The number of flowering individuals counted in our census is also reported; note that in all years except 2002 the number of flowering plants counted falls within the 95% confidence intervals.

Climate Modeling

We modeled the response of estimated number of total plants, vegetative plants, and flowering plants from 2002-2013 using climatic predictors in NPMR. Number of vegetative plants was best explained by fall mean maximum temperature (tolerance = 3.69) and winter mean minimum temperature (tolerance = 0.28; $xR^2 = 0.35$). Total number of plants was also best explained by a model of the same predictors; models were extremely similar as the majority of plants were vegetative. For both of these models, the response tended to increase with increased winter minimum temperature, and to increase with warmer fall temperatures (Figure 9). The response surface of these two variables was not linear, the model indicated a dip in number of vegetative plants in relation to winter mean temperatures of around 33°F (Figure 9). Summer mean precipitation and winter mean minimum temperature were the two predictors that best explained the variability in number of flowering plants (tolerances 0.14 and 1.43, respectively; $xR^2 = 0.57$). Though these responses were not strictly linear, number of flowering plants tended to increase with low summer precipitation and increase with winter mean minimum temperature (Figure 10). Thus, a warm fall followed by warm winter temperatures is associated with increased vegetative *F. gentneri*, with flowering promoted by a dry summer, followed by a warm winter. In 2012, the lowest number of flowering plants was documented over the course of this study, with only a slight increase in 2013. This lack of flowering plants likely explains the similar climatic predictors describing both vegetative and flowering plants.

This is the third year conducting climate analysis to predict the factors that may be influential in population dynamics of *F. gentneri* at Pickett Creek. Across all years, we found that a dry and/or warm fall followed by a warm winter was associated with increased number of vegetative plants. Additionally, our models have suggested that winter temperatures around freezing (32°F) can result in a decline of vegetative plants. From 2010-2012, climate in the area of the Pickett Creek population was much cooler than long-term climate normals (1981-2010, PRISM Climate Group; Figure 11), and 2013 was much warmer than previous years. Since climate models suggest that *F. gentneri* does better vegetatively under warmer/drier conditions, the recent decline could be the partial result of recent cool conditions. Likewise, while precipitation has been more variable in the past, in general it has been wetter than long term normal, with 2013 being a particularly dry year compared to climate normals (Figure 11). It will be interesting to see what population trends will hold in 2014, given that models suggest increased vegetative abundance with increased temperature and decreased fall temperatures, which is what has been experienced in 2013.

There has been a significant decline in flowering plants at this population over the course of this study (Figure 5). Across all years, our climate models suggest that for flowering plants, low fall precipitation (approximately 3 inches), along with increased winter temperatures results in more flowers. The relationship between flowering plants and precipitation has varied with regard to the season of precipitation and the amount of rainfall experienced; number of flowers was associated with a wet spring in 2011, a moderate fall in 2012, and a dry summer in 2013. In general, climate in recent years has been wetter than long-term norms (Figure 11), with the exception of 2013 being much drier than past conditions. The current decline in flowering individuals could be in part due to the recent conditions being more cool and wet than long-term normals. The differences in climate between 2013 and climate normals will enable us to see how plants might respond in 2014 to the warmer/drier conditions experienced in 2013 at Pickett Creek.

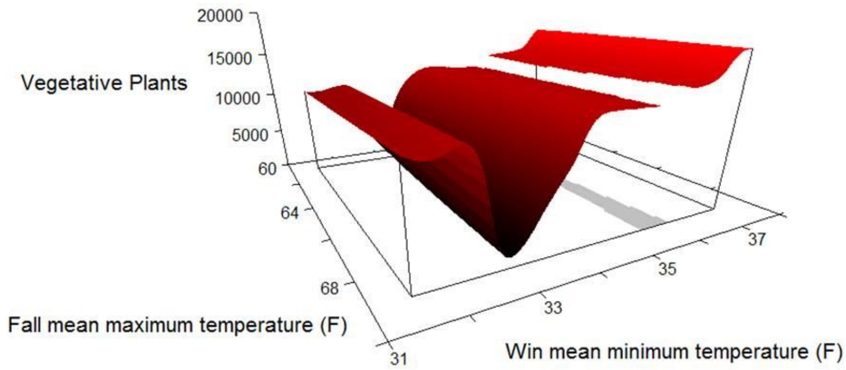


Figure 9. Response surface of a NPMR model for the estimated number of vegetative *F. gentneri* in the density plots (2002-2013). Gaps in the response surface indicate gaps in the data at those predicted conditions.

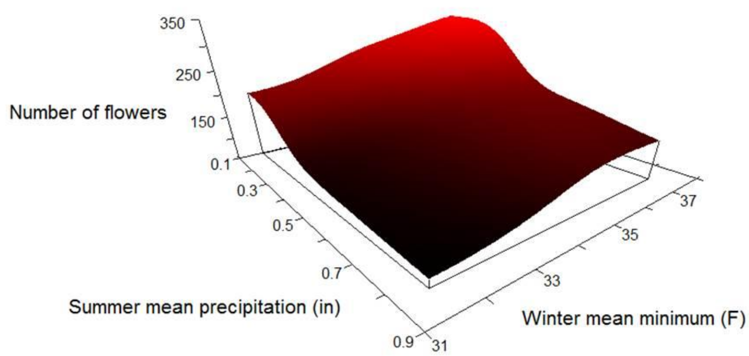


Figure 10. Response surface of a NPMR model for estimated number of flowering *F. gentneri* in the density plots (2002-2013).

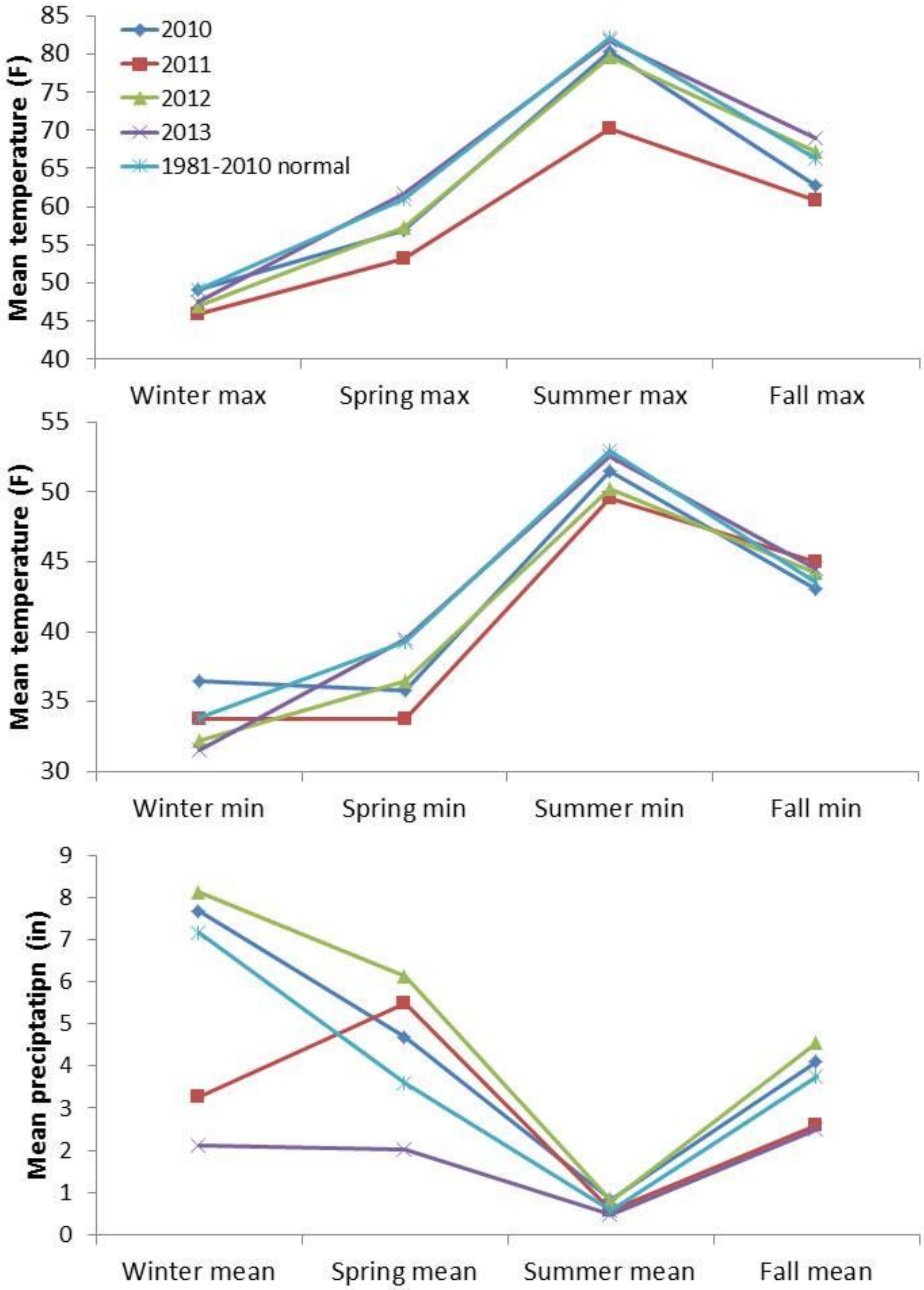


Figure 11. Mean maximum temperature (°F, top), mean minimum temperature (°F, middle), and mean precipitation (in) experienced at the Pickett Creek population from 2010-2013, as compared to long-term normal temperatures (1981-2010).

Our climate analyses suggest that temperature and precipitation can have an effect on the number and life stages of *F. gentneri* found at Pickett Creek. Our climate models indicate that this species prefers warmer and drier conditions such as those experienced in 2013, thus we would expect to see an increase in the number of flowering and vegetative individuals in 2014. For example, 2003 was the highest population size observed during this study. This count was preceded by a year when fall mean precipitation was much lower than the ten year average. The number of flowering plants was predicted to be highest with a fall mean precipitation of approximately 2 inches in our model. Fall precipitation in 2010 and 2011 varied greatly (4 in and 1 in, respectively), with winter temperatures ranging from 45-49 F. While an intermediate level of fall precipitation followed by a warm winter predicts increases in both vegetative and flowering plants, after similar conditions in 2011-2012, flowering plants remained in decline, suggesting that other factors might be influencing life history stages of *F. gentneri* present at Pickett Creek. Understanding the climatic factors related to this species could help us to understand how *F. gentneri* may respond to climate change. Temperature and precipitation may vary across the site and these models are only broad representations of whole-site occurrences. Microclimates may also greatly affect the phenology of this species and may explain different patterns for change in the number of flowering plants in each subpopulation over time.

While climate models suggest that population trends at Pickett Creek are dependent upon climate, there are many additional factors that may affect fluctuations in population size of *F. gentneri* at this site, including dormancy and habitat quality. There may be a cyclical pattern to plant emergence, whereby plants alternate years of emergence (and photosynthate acquisition) with one or more years of dormancy or underground development. It is also possible that the quality of the habitat at this site is declining in a currently undetected manner and the population will continue to decline. Continued monitoring in future years is imperative in order to determine the nature of the population dynamics of *F. gentneri* at Pickett Creek. It is recommended that a habitat assessment for the site be performed and potential management actions including prescribed fire be assessed.

SUMMARY AND RECCOMMENDATIONS

1. The number of flowering *F. gentneri* at Pickett Creek, as determined by census plots and population estimates, has decreased throughout the course of this study. In 2013, the second lowest recorded numbers of flowering individuals were noted (68 flowering individuals). *It is recommended that sexual reproduction be restored to the site by crossing or augmenting with bulbs from other populations.*

2. The estimated total population *size* (both vegetative and flowering plants) based on density plots in the upper and below-road subpopulations has fluctuated throughout the course of the study from a low of 6,715 (± 1,722) in 2006 to a high of 17,684 (±3,411) in 2003. The current population estimate for 2013 is 13,782 (± 3,767) individuals at Pickett Creek.

3. Most *F. gentneri* at Pickett Creek are very small bulblets while plants of larger size classes and flowering stages are much less frequent. In all years, the majority (>97%) of the plants in the population have been vegetative, while fewer than 3% produce flowers. In 2013, only 0.3% of the plants observed in the density plots were flowering. The population at Pickett Creek has shifted towards smaller (presumably younger) size classes since 2002. This shift in size class, could indicate a general decline in the population as fewer plants are reaching or maintaining larger size classes.

4. We found that warmer winter temperature positively affected the number of vegetative and flowering plants at Pickett Creek. In addition, vegetative plants were positively affected by a warmer fall, whereas flowering plants were positively affected by a dry summer. Thus, a warm fall followed by warm winter temperatures is associated with increased vegetative *F. gentneri*, with flowering promoted by a dry summer, followed by a warm winter. Recent decline of this species could be due to recent climate conditions which have been cooler and wetter than historic temperature normals.

5. Continued monitoring of this population is important in order to determine the factors that contribute to the observed variability in population size, particularly the steady decline in flowering individuals. This information will be useful for the management of the *F. gentneri* population at Pickett Creek and for guiding monitoring and management of other *F. gentneri* populations. *It is recommended that habitat manipulation be attempted in a portion of the Pickett Creek population. The 2003 Recovery Plan for the species details potential habitat manipulation including burning and weed removal to encourage expansion of existing populations. Habitat assessments should be performed before and after any management treatments in order to evaluate their effectiveness.*

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Appendix A. Directions to Pickett Creek, locations of study plots and gear list.

From West Pickett Creek to Grants Pass:
Take Riverbanks Road to Grants Pass
At 7.7 miles, right on Lower River Road
Left on Lincoln Road
Quick Right onto Bridge Street
Left onto 7th.

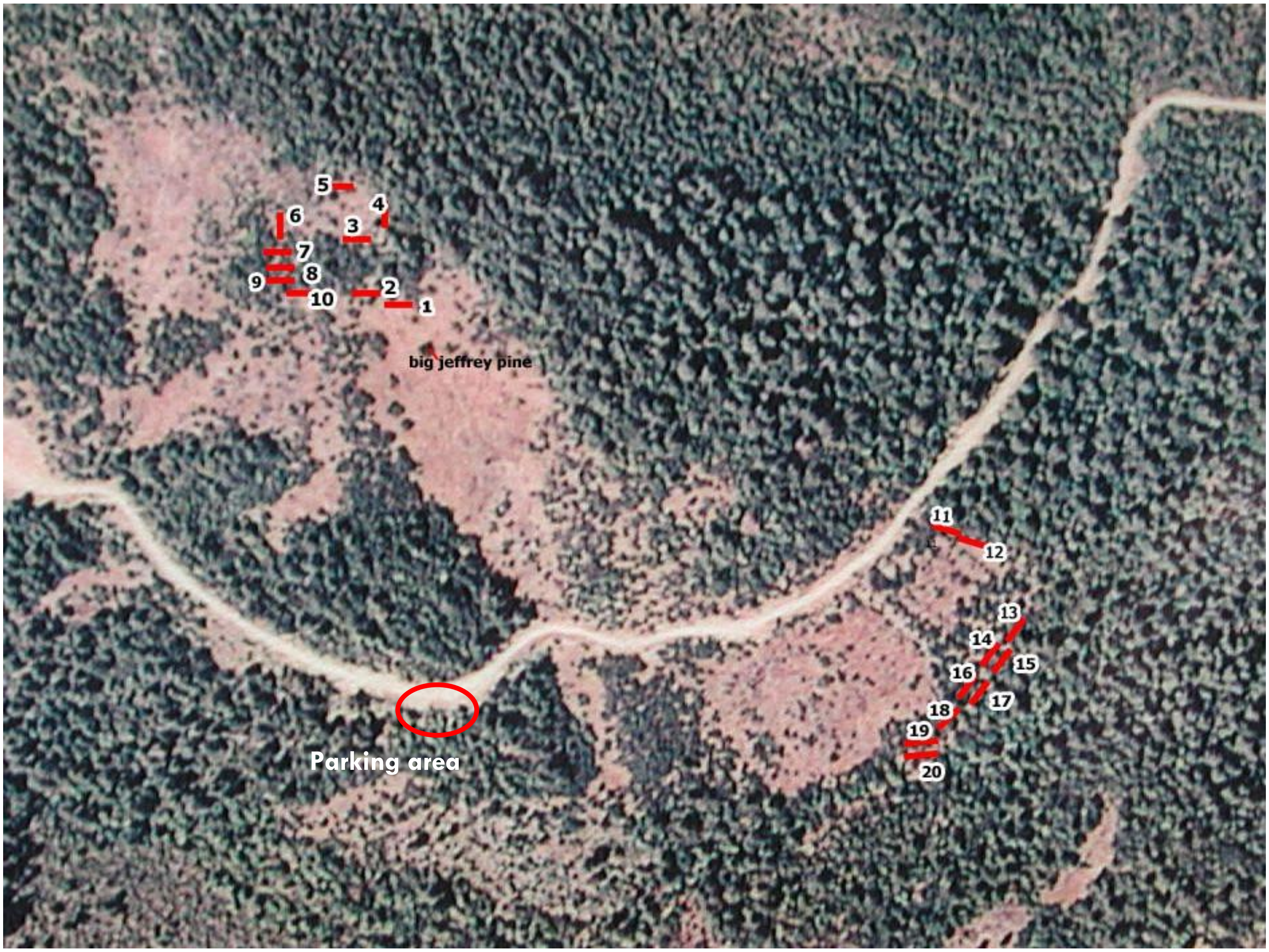
From Merlin to Pickett Creek
From Merlin, head through town, then take a left on Robertson Bridge Road.
Turn right on Lower River Road
Turn left on Pickett Creek Road
West Pickett Creek road to BLM road 35-7-27, then to BLM road 35-7-33.1. Follow this road for 0.6 miles and park along the road.

Parking Spot:
GPS, NAD83, UTM 10N
Easting: 454,009
Northing: 4,703,345

To reach the upper subpopulation, walk up the road from the parking area to the first large, rocky draw. Scramble up the steep roadcut and then continue climbing uphill to the large, distinctive Jeffrey Pine that stands in the open (about a 10-15 minute uphill climb). Density plots are located uphill from this tree. The lower subpopulation is located on the steep, rocky slope extending between the road and the bottom of the Pickett Creek drainage. The least treacherous access route down through this subpopulation is flagged near the road, east of the parking area (near plot 11). Ten density plots each were placed in the upper and lower subpopulations, plots 1-10 and 11-20, respectively.

Gear List

- Extra water
- Last year's data
- 2- Compass
- Copy of previous year report
- Maps
- Jepson field guide
- Walkie-talkies
- 3- 300 ft tapes
- 2- 200 ft tapes
- 6 extra conduit and rebar
- Flagging
- Wire and numbered plot tags
- Mallet
- Rulers 1 per person
- 2 m^2 plot frames + one pole per person if more than 8
- 3 clipboards
- Mechanical pencils
- Data sheets (write in rain paper if needed)
- Health and Safety box (***double check for Tecnu)***

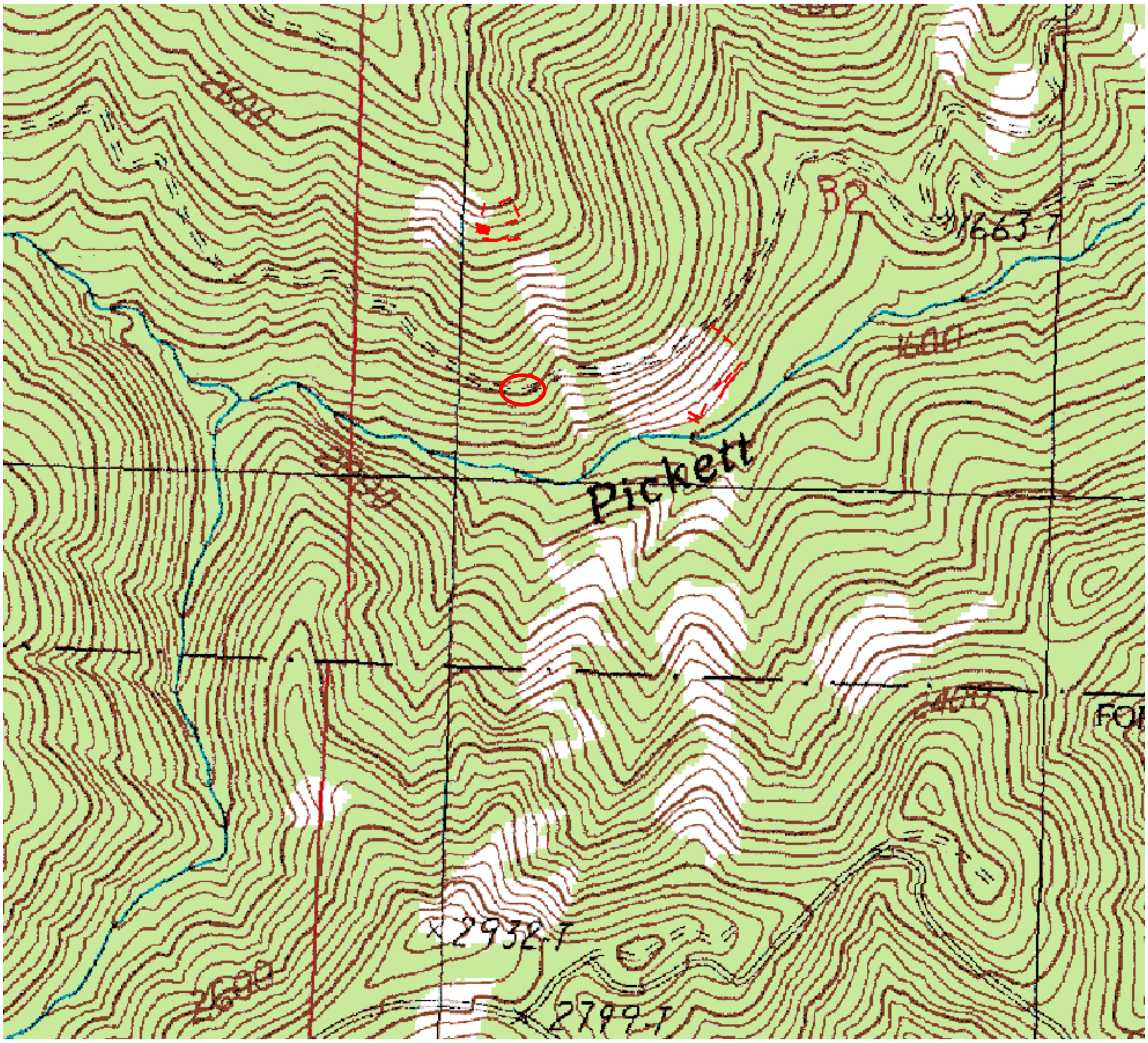


The Pickett Creek *Fritillaria gentneri* population study area, with the locations of the parking area (red oval) and density plots (red lines) indicated.

Map of the Pickett Creek Study Area:

Map Scale: 1:24,000

Transects (red lines) and parking area (red oval).



Topographic Map of the Pickett Creek Study Area:

Map Scale: 1:24,000

Transects (red lines) and parking area (red oval). Contour interval 40 ft.